Musculoskeletal Disorders and Workplace Factors

A Critical Review of Epidemiologic Evidence for Work-Related Musculoskeletal Disorders of the Neck, Upper Extremity, and Low Back

Edited by:
Bruce P. Bernard, M.D., M.P.H.

Contributors:
Vern Putz-Anderson, Ph.D.
Bruce P. Bernard, M.D., M.P.H.
Susan E. Burt
Libby L. Cole, Ph.D.
Cheryl Fairfield-Estill
Lawrence J. Fine, M.D., Dr.P.H.
Katharyn A. Grant, Ph.D.
Christopher Gjessing
Lynn Jenkins
Joseph J. Hurrell Jr., Ph.D.
Nancy Nelson, Ph.D.
Donna Pfirman
Robert Roberts
Diana Stetson, Ph.D.
Marie Haring-Sweeney, Ph.D.
Shiro Tanaka, M.D.

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

July 1997

DISCLAIMER

Mention of any company name or product does not constitute endorsement by the National Institute for Occupational Safety and Health.

This document is in the public domain and may be freely copied or reprinted

Copies of this and other NIOSH documents are available from

National Institute for Occupational Safety and Health
Publications Dissemination
4676 Columbia Parkway
Cincinnati, OH 45226–1998

Telephone number: 1–800–35–NIOSH (1–800–356–4674)
Fax number: (513) 533–8573
E-mail: pubstaft@cdc.gov

To receive other information about occupational safety and health problems, call 1–800–35–NIOSH (1–800–356–4674), or visit the NIOSH Home Page on the World Wide Web at http://www.cdc.gov/niosh

This publication is also available from the National Technical Information Service for $60.00 plus $4.00 handling. Please call (703) 487–4650 and ask for PB97–178628.

DHHS (NIOSH) Publication No. 97B141

FOREWORD

Musculoskeletal disorders (MSDs) were recognized as having occupational etiologic factors as early as the beginning of the 18th century. However, it was not until the 1970s that occupational factors were examined using epidemiologic methods, and the work-relatedness of these conditions began appearing regularly in the international scientific literature. Since then the literature has increased dramatically; more than six thousand scientific articles addressing ergonomics in the workplace have been published. Yet, the relationship between MSDs and work-related factors remains the subject of considerable debate.

Musculoskeletal Disorders and Workplace Factors: A Critical Review of Epidemiologic Evidence for Work-Related Musculoskeletal Disorders of the Neck, Upper Extremity, and Low Back will provide answers to many of the questions that have arisen on this topic over the last decade. This document is the most comprehensive compilation to date of the epidemiologic research on the relation between selected MSDs and exposure to physical factors at work. On the basis of our review of the literature, NIOSH concludes that a large body of credible epidemiologic research exists that shows a consistent relationship between MSDs and certain physical factors, especially at higher exposure levels.

This document, combined with other NIOSH efforts in this area, will assist us in our continued efforts to address these inherently preventable disorders.

Linda Rosenstock, M.D., M.P.H.
Director, National Institute for
Occupational Safety and Health
Centers for Disease Control and Prevention

NOTE TO THE READER

This second printing of *Musculoskeletal Disorders and Workplace Factors: A Critical Review of Epidemiologic Evidence for Work-Related Musculoskeletal Disorders of the Neck, Upper Extremity, and Low Back* incorporates a number of editorial changes, including grammar, formatting, and consistency issues that were identified in the first printing. In addition, the notation of Dr. Lawrence Fine as co-editor was inadvertently omitted in the first printing and has been re-inserted.

The conclusions of the document in terms of decisions regarding the weight of the existing epidemiologic evidence for the relationship between workplace factors and musculoskeletal disorders remain unchanged. The following technical inconsistencies or errors were corrected:

Page 2-14: Text was corrected to reflect that five studies (as opposed to three) examined the relationship between force and musculoskeletal disorders of the neck.

Page 2-28: For Viikari-Juntura [1994], the "NR" entry in the Risk Indicator column was replaced with the value 3.0.

Page 2-34: Bergqvist [1995a] was changed to Bergqvist [1994]. The Risk Indicator entry for this study was changed from 4.4 to 3.7 (both noted as statistically significant), the entry for Physical Examination was changed from "Yes" to "No," and the entry for Basis for Assessing Exposure was changed from "job titles or self-reports" to "observation or measurements."

Page 3-3: Text was corrected to reflect that four studies (as opposed to three) met all four evaluation criteria. A description of Kilbom and Persson [1987] was moved forward in the chapter to this section and includes a clarification that health outcome in their study was based on symptoms and physical findings.

Page 3-32: The confidence interval depicted for Ohlsson [1994] was corrected to show a range from 3.5 to 5.9.

Page 3-69: Schibye et al. [1995] was added to Table 3-5.

Page 4-25: Dimberg [1989] was changed to Dimberg [1987].

Page 5a-3: Text was corrected to reflect that nineteen studies (as opposed to fifteen) reported results on the association between repetition and carpal tunnel syndrome (CTS). Text was also corrected to reflect that five studies (as opposed to four) met the four evaluation criteria for addressing repetitiveness and CTS. A description of Osorio et al. [1994] was moved forward in the chapter to this section.

Page 5a-15: Text was corrected to reflect that eleven studies (as opposed to ten) reported results on the association between force and CTS and that four (as opposed to three) met all four evaluation criteria. Descriptions of Moore and Garg [1994] and Osorio et al. [1994] were moved forward in the chapter to this section.

Page 5a-19 : The discussion (strength of association, temporality, consistency of association, coherence of evidence, and exposure-response relationship) of force and CTS was inadvertently omitted in the first printing and has been re-inserted.

Page 5a-27: The Risk Indicator for Osorio et al. [1994] was changed from 4.6 to 6.7, and for Nathan [1992], the "No association" entry under Risk Indicator was changed to a value of 1.0.

Page 5a-29: Stetson et al. [1993] was moved to the bottom of the table, and entries for Nathan et al. [1992] and McCormack et al. [1990] were added.

Page 5a-31: This table was modified to more accurately reflect the text.

Page 5a-33: For Koskimies et al. [1990], the entry for Basis for Assessing Exposure was changed from "observation or measurements" to "job titles or self-reports."

Page 5b-1: Text was corrected to reflect that seven studies (as opposed to eight) are referenced on Table 5b-1.

Page 5c-4: Text was corrected to reflect that five studies (as opposed to four) met three of the criteria. A brief description of Kivekäs et al. [1994] was added to this section.

A number of references were clarified, and full references for studies that were cited in the text of the first printing but were inadvertently omitted from the reference list were added.

Appendix C was added to the document to provide a concise overview of the studies reviewed relative to the evaluation criteria, risk factors addressed, and other issues.

CONTENTS

EXECUTIVE SUMMARY

The term musculoskeletal disorders (MSDs) refers to conditions that involve the nerves, tendons, muscles, and supporting structures of the body. The purpose of this NIOSH document is to examine the epidemiologic evidence of the relationship between selected MSDs of the upper extremity and the low back and exposure to physical factors at work. Specific attention is given to analyzing the weight of the evidence for the strength of the association between these disorders and work factors.

Because the relationship between exposure to physical work factors and the development and prognosis of a particular disorder may be modified by psychosocial factors, the literature about psychosocial factors and the presence of musculoskeletal symptoms or disorders is also reviewed. Understanding these associations and relating them to the cause of disease is critical for identifying exposures amenable to preventive and therapeutic interventions.

MAGNITUDE OF THE PROBLEM

The only routinely collected national source of information about occupational injuries and illnesses of U.S. workers is the Annual Survey of Occupational Injuries and Illnesses conducted by the Bureau of Labor Statistics (BLS) of the U.S. Department of Labor. The survey, which BLS has conducted for the past 25 years, is a random sample of about 250,000 private sector establishments and provides estimates of workplace injuries and illnesses on the basis of information provided by employers from their OSHA Form 200 log of recordable injuries and illnesses.

For cases involving days away from work, BLS reports that in 1994 (the last year of data available at the time this report was prepared), approximately **705,800** cases (32%) were the result of overexertion or repetitive motion. Specifically, there were

- **367,424** injuries due to overexertion in lifting (65% affected the back); **93,325** injuries due to overexertion in pushing or pulling objects (52% affected the back); **68,992** injuries due to overexertion in holding, carrying, or turning objects (58% affected the back). Totaled across these three categories, **47,861** disorders affected the shoulder.

- **83,483** injuries or illnesses in other and unspecified overexertion events.

- **92,576** injuries or illnesses due to repetitive motion, including typing or key entry, repetitive use of tools, and repetitive placing, grasping, or moving of objects other than tools. Of these injuries or illnesses, 55% affected the wrist, 7% affected the shoulder, and 6% affected the back.

Data for 1992 to 1995 indicate that injuries and illnesses requiring days away from work declined 19% for overexertion and 14% for repetitive motion. The incidence rate of overexertion (in lifting) declined from 52.1 per 10,000 workers in 1992 to 41.1 in 1995; the incidence rate for repetitive motion disorders declined from 11.8 per 10,000 workers in 1992 to 10.1 in 1995. These declines are similar to those seen for cases involving days away from work from all causes of injury and illness.

The reasons for these declines are unclear but may include: a smaller number of disorders could be occurring because of more intensive efforts to prevent them; more effective prevention and treatment programs could be reducing days away from work; employers or employees may be more reluctant to report or record disorders; or the criteria used by health care providers to diagnose these conditions could be changing.

IDENTIFICATION AND SELECTION OF STUDIES

The goal of epidemiologic studies is to identify factors that are associated (positively or negatively) with the development or recurrence of adverse medical conditions. This evaluation and summary of the epidemiologic evidence focuses chiefly on disorders that affect the neck and the upper extremity, including tension neck syndrome, shoulder tendinitis, epicondylitis, carpal tunnel syndrome, and hand-arm vibration syndrome, which have been the most extensively studied in the epidemiologic literature. The document also reviews studies that have dealt with work-related back pain and that address the way work organizational and psychosocial factors influence the relationship between exposure to physical factors and work-related MSDs. The literature about disorders of the lower extremity is outside the scope of the present review.

A search strategy of bibliographic databases identified more than 2,000 studies. Because of the focus on the epidemiology literature, studies that were laboratory-based or that focused on MSDs from a biomechanical standpoint, dealt with clinical treatment of MSDs, or had other nonepidemiologic orientation were eliminated from further consideration for this document. Over 600 studies were included in the detailed review process.

METHODS FOR SYNTHESIZING STUDIES

For the upper extremity studies included in this review, those which used specific diagnostic criteria, including physical examination techniques, were given greater consideration than studies that used less specific methods to define health outcomes. The review focused most strongly on observational studies whose health outcomes were based on recognized symptoms and standard methods of clinical examination. For completeness, those epidemiologic studies that based their health outcomes on reported symptoms alone were also reviewed. For the low-back studies included in this review, those which had objective exposure measurements were given greater consideration than those which used self-reports or other measures. For the psychosocial section, any studies which included measurement or discussion of psychosocial factors and MSDs were included.

No single epidemiologic study will fulfill all criteria to answer the question of causality. However, results from epidemiologic studies can contribute to the evidence of causality in the relationship between workplace risk factors and MSDs. The framework for evaluating evidence for causality in this review included strength of association, consistency, temporality, exposure-response relationship, and coherence of evidence.

Using this framework, the evidence for a relationship between workplace factors and the development of MSDs from epidemiologic studies is classified into one of the following categories:

> **Strong evidence of work-relatedness (+++).** A causal relationship is shown to be very likely between intense or long-duration exposure to the specific risk factor(s) and MSD when the epidemiologic criteria of causality are used. A positive relationship has been observed between exposure to the specific risk factor and MSD in studies in which chance, bias, and confounding factors could be ruled out with reasonable confidence in at least several studies.
>
> **Evidence of work-relatedness (++).** Some convincing epidemiologic evidence shows a causal relationship when the epidemiologic criteria of causality for intense or long-duration exposure to the specific risk factor(s) and MSD are used. A positive relationship has been observed between exposure to the specific risk factor and MSD in studies in which chance, bias, and confounding factors are not the likely explanation.
>
> **Insufficient evidence of work-relatedness (+/0).** The available studies are of insufficient number, quality, consistency, or statistical power to permit a conclusion regarding the presence or absence of a causal association. Some studies suggest a relationship to specific risk factors, but chance, bias, or confounding may explain the association.
>
> **Evidence of no effect of work factors (-).** Adequate studies consistently show that the specific workplace risk factor(s) is not related to development of MSD.

The classification of results in this review by body part and specific risk factor is summarized in Table 1.

Table 1. Evidence for causal relationship between physical work factors and MSDs

Body part *Risk factor*	**Strong evidence (+++)**	**Evidence (++)**	**Insufficient evidence (+/0)**	**Evidence of no effect (-)**
Neck and Neck/shoulder				
Repetition		T		
Force		T		
Posture	T			
Vibration			T	
Shoulder				
Posture		T		
Force			T	
Repetition		T		
Vibration			T	
Elbow				
Repetition			T	
Force		T		
Posture			T	
Combination	T			
Hand/wrist				
Carpal tunnel syndrome				
Repetition		T		
Force		T		
Posture			T	
Vibration		T		
Combination	T			
Tendinitis				
Repetition		T		
Force		T		
Posture		T		
Combination	T			
Hand-arm vibration syndrome				
Vibration	T			
Back				
Lifting/forceful movement	T			
Awkward posture		T		
Heavy physical work		T		
Whole body vibration	T			
Static work posture			T	

CONCLUSIONS

A substantial body of credible epidemiologic research provides strong evidence of an association between MSDs and certain work-related physical factors when there are high levels of exposure and especially in combination with exposure to more than one physical factor (e.g., repetitive lifting of heavy objects in extreme or awkward postures [Table 1]).

The strength of the associations reported in the various studies for specific risk factors after adjustments for other factors varies from modest to strong. The largest increases in risk are generally observed in studies with a wide range of exposure conditions and careful observation or measurement of exposures.

The consistently positive findings from a large number of cross-sectional studies, strengthened by the limited number of prospective studies, provides *strong evidence* (+++) for increased risk of work-related MSDs for some body parts. This evidence can be seen from the strength of the associations, lack of ambiguity in temporal relationships from the prospective studies, the consistency of the results in these studies, and adequate control or adjustment for likely confounders. For some body parts and risk factors, there is some *epidemiologic evidence* (++) for a causal relationship. For still other body parts and risk factors, there is either an insufficient number of studies from which to draw conclusions or the overall conclusion from the studies is equivocal. The absence of existing epidemiologic evidence should not be interpreted to mean there is no association between work factors and MSDs.

In general, there is limited detailed quantitative information about exposure-disorder relationships between risk factors and MSDs. The risk of each exposure depends on a variety of factors such as the frequency, duration, and intensity of physical workplace exposures. Most of the specific exposures associated with the *strong evidence* (+++) involved daily whole-shift exposure to the factors under investigation.

Individual factors may also influence the degree of risk from specific exposures. There is evidence that some individual risk factors influence the occurrence of MSDs (e.g., elevated body mass index and carpal tunnel syndrome or a history of past back pain and current episodes of low-back pain). There is little evidence, however, that these individual factors interact synergistically with physical factors. All of these disorders can also be caused by nonwork exposures. The majority of epidemiologic studies involve health outcomes that range in severity from mild (the workers reporting these disorders continue to perform their routine duties) to more severe disorders (workers are absent from the workplace for varying periods of time). The milder disorders are more common. A limited number of studies investigate the natural history of these disorders and attempt to determine whether continued exposure to physical factors alters their prognosis.

The number of jobs in which workers routinely lift heavy objects, are exposed on a daily basis to whole-body vibration, routinely perform overhead work, work with their necks in chronic flexion position, or perform repetitive forceful tasks is unknown. While these exposures do not occur in most jobs, a large number of workers may indeed work under these conditions. The BLS data indicate that the total employment is over three million in the industries with the highest incidence rates of cases involving days away from work from overexertion in lifting and repetitive motion. Within the highest risk industries, however, it is likely that the range of risk is substantial depending on the specific nature of the physical exposures experienced by workers in various occupations within that industry.

This critical review of the epidemiologic literature identified a number of specific physical exposures strongly associated with specific MSDs when exposures are intense, prolonged, and particularly when workers are exposed to several risk factors simultaneously. This scientific knowledge is being applied in preventive programs in a number of diverse work settings. While this review has summarized an impressive body of epidemiologic research, it is recognized that additional research would be quite valuable. The MSD components of the National Occupational Research Agenda efforts are principally directed toward stimulation of greater research on MSDs and occupational factors, both physical and psychosocial. Research efforts can be guided by the existing literature, reviewed here, as well as by data on the magnitude of various MSDs among U.S. workers.

ACKNOWLEDGMENTS

In addition to the other contributors, the following staff members of the National Institute for Occupational Safety and Health are acknowledged for their support, assistance, and advice in preparing this document:

Penny Arthur
Vanessa Becks
Donna Biagini
Jenise Brassell
Karen Brewer
Carol Burnett
Sue Cairelli
Dick Carlson
Shirley Carr
Dave Case
Sharon Cheesman
Alexander Cohen, Ph.D.
Marian Coleman
Barb Cromer
Judy Curless
David Dankovic
John Diether
Clayton Doak
Karen Dragon
Sue Feldmann
Jerry Flesch
Larry Foster
Sean Gallagher
Lytt Gardner, Ph.D.
Pamela Graydon
Daniel Habes
Rose Hagedorn
William Halperin, M.D., Sc.D.
Anne Hamilton
Denise Hill
Suzanne Hogan
Hongwei Hsiao, Ph.D.
Lore Jackson
Laurel Jones
Susan Kaelin
Sandy Kasper
Aileen Kiel
Diana Kleinwachter
Nina Lalich
Leslie MacDonald
Charlene Maloney
Diane Manning
James McGlothlin, Ph.D.
Patricia McGraw
Alma McLemore
Judy Meese
Matthew Miller
Kathleen Mitchell
Vivian Morgan
Leela Murthy
Rick Niemeier
Andrea Okun
Marty Petersen
Donna Pfirman
Linda Plybon
Faye Rice
Cindy Riddle
Kris Royer
Walt Ruch
Steven Sauter, Ph.D.
Lucy Schoolfield
Mitch Singal, M.D.
Paul Schulte
Becky Spry
Anne Stirnkorb
Naomi Swanson, Ph.D.
Rodger Tatken
Allison Tepper, Ph.D.
Julie Tisdale
Anne Votaw
David Votaw
Thomas Waters, Ph.D.
Jane Weber
Joann Wess
Cindy Wheeler
Kellie Wilson
Ralph Zumwalde

We also thank the following reviewers for their thoughtful comments on an earlier draft of this document:

Gunnar B.J. Andersson, M.D., Ph.D.
Rush-Presbyterian-St. Luke's
Medical Center

Robert Harrison, M.D., M.P.H.
University of California at San Francisco

Mohammed M. Ayoub, Ph.D., P.E., C.P.E.
Texas Tech University

William S. Marras, Ph.D.
The Ohio State University

Sidney J. Blair, M.D., F.A.C.S.
Loyola Chicago University

J. Steven Moore, M.D., M.P.H., C.I.H., C.P.E.
University of Texas Health Center at Tyler

Vance C. Calvez, M.S., C.P.E.
The Joyce Institute

Margareta Nordin, Dr. Med. Sc.
New York University

Don B. Chaffin, Ph.D.
University of Michigan

Donald C. Olsen, Jr., C.S.P., C.P.E.
ERGOSH

Jerome J. Congleton, Ph.D., P.E., C.P.E.
Texas A&M University

Thomas Owens, C.I.H., P.E.
IBM Corporation

Thomas Cook, Ph.D., P.T.
University of Iowa

Malcolm H. Pope, Dr. Med. Sc., Ph.D.
The University of Iowa

Theodore Courtney
Liberty Mutual

Laura Punnett, Sc.D.
University of Massachusetts

Michael Feuerstein, Ph.D.
Uniformed Services University
of the Health Sciences

Robert G. Radwin, Ph.D.
University of Wisconsin-Madison

Eric Frumin
Union of Needle Trades, Industrial,
and Textile Employees (UNITE)

David Rempel, M.D.
University of California, San Francisco

Michael Gauf
CTD News

Suzanne H. Rodgers, Ph.D.
Consultant in Ergonomics

Fred Gerr, M.D.
Emory University

C. Jivan Saran
Central Missouri State University

Lawrence P. Hanrahan, Ph.D., M.S.
Wisconsin Division of Health

Scott Schneider, C.I.H.
The Center to Protect Workers' Rights

Barbara Silverstein, Ph.D., M.P.H., C.P.E.
State of Washington Department of Labor
and Industries

CHAPTER 1
Introduction

PURPOSE

This document examines the epidemiologic evidence that associates selected musculoskeletal disorders (MSDs) of the upper extremity and the low back with exposure to physical factors at work. The authors have paid particular attention to analyzing the strength of the association between MSDs and work factors. Because the development of an MSD may be modified by psychosocial factors, the authors have also reviewed the literature on the relationship of these factors to the presence of musculoskeletal symptoms or disorders. Understanding these associations and relating them to disease etiology is critical to identifying workplace exposures that can be reduced or prevented.

BACKGROUND

The World Health Organization has characterized "work-related" diseases as multifactorial to indicate that a number of risk factors (e.g., physical, work organizational, psychosocial, individual, and sociocultural) contribute to causing these diseases [WHO 1985]. One important reason for the controversy surrounding work-related MSDs is their multifactorial nature. The disagreement centers on the relative importance of multiple and individual factors in the development of disease. The same controversy has been an issue with other medical conditions such as certain cancers and lung disorders—both of which have multiple causal factors (occupational and nonoccupational).

The goal of epidemiologic studies is to identify factors (such as physical, work organizational, psychosocial, individual, and sociocultural factors) that are associated positively or negatively with the development or recurrence of adverse medical conditions. This document addresses and evaluates the literature with regard to these issues for work-related MSDs.

This document reviews the epidemiologic evidence regarding the role of physical factors in the development of MSDs for the following body areas: the neck, shoulder, elbow, hand/wrist, and back. The document also addresses the influence of work organizational and psychosocial factors on the association of physical factors with work-related MSDs. This evaluation and summary of the epidemiologic evidence focuses chiefly on disorders affecting the neck and the upper extremity—including tension neck syndrome, shoulder tendinitis, epicondylitis, carpal tunnel syndrome, and hand-arm vibration syndrome, which have been the most extensively studied in the epidemiologic literature. This document also concentrates on studies that have dealt with the issue of work-related back pain and sciatica. The literature on disorders of the lower extremities is beyond the scope of this review.

SCOPE AND MAGNITUDE OF THE PROBLEM

The only routinely published, national source of information about occupational injuries and illnesses in U.S. workers is the Annual Survey of Occupational Injuries and Illnesses (ASOII) conducted by the Bureau of Labor Statistics (BLS) of the U.S. Department of Labor. This survey is a random sample of about 250,000 private-sector establishments, but it excludes self-employed workers, farms with fewer than 11 employees, private households, and all government agencies. The ASOII provides estimates of workplace injuries and illnesses from information that employers provide to BLS from their OSHA Form 200 log of recordable injuries and illnesses.

BLS has conducted this annual survey since 1972 and has thus provided basic information about cases of occupational injury or illness that required more than first-aid (including medical treatment, restricted work activity, or days away from work). This information includes the total number of cases categorized on the OSHA Form 200 log as either an injury or an illness. The illness data are separated into six subcategories; the category that contains most (but not all) musculoskeletal conditions is *disorders associated with repeated trauma*. This illness category also includes *illnesses associated with noise-induced hearing loss*, but MSDs account for the largest proportion of these cases, especially in recent years. All back disorders or injuries are placed in the single, broad *injury* category, which also includes all other types of injuries such as lacerations, fractures, and burns.

From this part of the ASOII, BLS reports that in 1995, 308,000 (or 62%) of all illness cases were due to disorders associated with repeated trauma (excluding low-back disorders, which are listed as injuries). The number of repeated trauma cases increased dramatically, rising steadily from 23,800 in 1972 to 332,000 in 1994—a 14-fold increase. In 1995, the number of cases decreased by 7% to 308,000 reported cases; but this number still exceeds the number of cases in any year before 1994.

Because these summary data did not adequately describe the nature of occupational injuries and illnesses and the related risk factors, the ASOII was redesigned in 1992 to capture more detailed information about injury and illness cases requiring days away from work. This redesigned survey captures demographic information about injured workers as well as the following characteristics of the injury or illness: (1) the employer's description of the *nature* of the injury or illness, such as sprain or carpal tunnel syndrome; (2) the *part of the body affected* by the specified condition, such as back or wrist; (3) the *source of the injury or illness* that directly produced the disabling condition, such as a crate, heavy box, or a nursing home patient; and (4) the *event or exposure* that describes the manner in which the injury or illness was inflicted, such as overexertion during lifting or repetitive motion. The BLS data are based on information provided by employers from their records of work-related injuries and illnesses and then coded into these categories.

For injury and illness cases involving days away from work, BLS reports that in 1994 (the last year for which the detailed data were complete when this report was prepared), approximately **705,800** cases (32%) resulted from overexertion or repetitive motion. Specifically:

- **367,424** injuries were due to overexertion in lifting; 65% affected the back. Another **93,325** injuries were due to overexertion in pushing or pulling objects; 52% affected the back. In addition, **68,992** injuries were due to overexertion in holding, carrying, or turning objects; 58% affected the back. Totaled across these three categories, **47,861** disorders affected the shoulder. The median time away from work from overexertion injuries was 6 days for lifting, 7 days for pushing/pulling, and 6 days for holding/carrying/turning.

- **83,483** injuries or illnesses occurred in other and unspecified overexertion events.

- **92,576** injuries or illnesses occurred as a result of repetitive motion, including typing or key entry, repetitive use of tools, and repetitive placing, grasping, or moving of objects other than tools. Of these repetitive motion injuries, 55% affected the wrist, 7% affected the shoulder, and 6% affected the back. The median time away from work was 18 days as a result of injury or illness from repetitive motion.

The highest incidence rates (IRs) of work-related injuries and illnesses from over- exertion occur among workers in nursing and personal care facilities, scheduled air transportation, and manufacturing of travel trailers and campers. As Table 1–1 indicates, these industries have rates of overexertion disorders four times higher than the average rate for all private industry. More than 2 million workers are employed in the three highest-risk industries alone. However, rates are not available by occupation within these industries, and not all workers within a high-risk industry will be at equal risk of developing a work-related MSD.

Industries with the highest IRs of work-related injuries and illnesses from repetitive motion include a number of garment manufacturing sectors such as knit underwear mills, men's and boy's work clothes, and hats, caps, and millinery; these industries also include manufacturing sectors such as textile bags, potato chip and similar snacks, motor vehicles, and meat packing plants (Table 1–2). These industries have IRs that are more than eight times the rate for all private industry.

Not all workers in these high-risk industries are exposed to the working conditions associated with these clearly elevated rates of illnesses and injuries from overexertion and repetitive motion; however, smaller proportions of workers in other industries may be similarly exposed. For example, trucking and courier services, an industry employing over 1.6 million people, had IRs for overexertion disorders that were almost three times higher than the average rate for all private industries. Thus, these employment estimates provide a conservative approximation of the number of workers with heavy exposures to high-risk conditions.

The BLS data are surveillance information that might contain misclassifications of both exposure and health outcomes. However, some industries have notably and consistently elevated rates of musculoskeletal injuries and disorders that are not likely to be attributable to data collection or coding. Note that decisions about the event or exposure that resulted in an injury or illness are associations rather than causal inferences. Nevertheless, they provide some perspective on the magnitude of work-related MSDs.

Table 1-1. Private sector industries with the highest incidence rates of injuries and illnesses from overexertion resulting in days away from work, 1994

Industry*	SIC code†	1994 annual average employment‡ (in thousands)	Incidence rate (per 10,000 workers)	95% confidence interval (rate per 10,000)	Number of cases
Nursing and personal care facilities	805	1,648	318.0	(286, 350)	41,884
Air transportation, scheduled	451	607	306.7	(276, 337)	16,309
Travel trailers and campers (manufacturing)	3792	22	303.7	(206, 401)	635
Food products machinery (manufacturing)	3556	24	260.1	(142, 378)	620
Bottled and canned soft drinks (manufacturing)	2086	95	255.6	(224, 287)	2,512
Beer, wine, and distilled beverages (wholesale)	518	150	254.6	(189, 321)	3,750
Coal mining	12	112	235.6	not available	2,609
Mattresses and bedsprings (manufacturing)	2515	31	233.5	(172, 295)	719
Comparison Industries:					
All manufacturing	2, 3	18,319	83.00	(81.4, 84.6)	151,794
All private industry§		94,146	76.00	(75.7, 76.3)	613,251
Finance, insurance, and real estate	6	6,707	17.90	(16.5, 19.3)	11,191

Source: Bureau of Labor Statistics, U.S. Department of Labor, Annual Survey of Occupational Injuries and Illnesses, 1994 Case and Demographic Resource Tables (ftp://stats.bls.gov/pub/special.requests/ocwc/osh/c_d_data).

*High rate industries were those having an incidence rate greater than three times the rate for all private industry, at the most detailed or lowest SIC level at which rates are published. Generally, manufacturing industries are published at the 4-digit code level and the remaining industries at the 3-digit level.

†*Standard Industrial Classification Manual*, 1987 edition.

‡Annual average employment from the BLS Covered Employment and Wages (ES-202) Survey.

§Excludes farms with fewer than 11 employees.

Table 1-2. Private sector industries with the highest incidence rates of injuries and illnesses from repetitive motion resulting in days away from work, 1994

Industry*	SIC code†	1994 annual average employment‡ (in thousands)	Incidence rate (per 10,000 workers)	95% confidence interval (rate per 10,000)	Number of cases
Knit underwear mills (manufacturing)	2254	25	165.6	(145, 187)	370
House slippers (manufacturing)	3142	3	146.3	(92, 201)	48
Men's and boy's work clothes (manufacturing)	2326	42	117.2	(97, 137)	463
Textile bags (manufacturing)	2393	11	115.7	(60, 171)	117
Potato chips and similar snacks (manufacturing)	2096	35	115.2	(95, 135)	406
Motor vehicles and car bodies (manufacturing)	3711	335	113.9	(99, 129)	4,058
Hats, caps, and millinery (manufacturing)	235	21	103.9	(79, 129)	202
Meat packing plants (manufacturing)	2011	138	98.5	(76, 121)	1,402
Bras, girdles, and allied garments (manufacturing)	2342	12	96.2	(73, 119)	111
Wood products, not elsewhere classified (manufacturing)	2499	58	92.8	(69, 117)	515
Men's and boy's suits and coats (manufacturing)	231	40	89.1	(74, 104)	320
Electronic coils and transfers (manufacturing)	3677	17	87.0	(52, 122)	142
Men's footwear (excluding athletic)	3143	28	84.9	(64, 106)	221
Comparison Industries:					
All manufacturing	2, 3	18,319	27.0	(26.4, 27.6)	49,278
All private industry§		94,146	11.5	(11.4, 11.6)	92,576
Finance, insurance, and real estate	6	6,707	8.1	(7.4, 8.8)	5,046

Source: Bureau of Labor Statistics, U.S. Department of Labor, Annual Survey of Occupational Injuries and Illnesses, 1994 Case and Demographic Resource Tables (ftp://stats.bls.gov/pub/special.requests/ocwc/osh/c_d_data).

*High rate industries were those having an incidence rate greater than three times the rate for all manufacturing workers at the most detailed or lowest SIC level at which rates are published. Generally, manufacturing industries are published at the 4-digit code level and the remaining industries at the 3-digit level.

†*Standard Industrial Classification Manual*, 1987 edition.

‡Annual average employment from the BLS Covered Employment and Wages (ES-202) Survey.

§Excludes farms with fewer than 11 employees.

The large number of work-related low-back injuries or illnesses reported in the BLS data is consistent with the results of two representative surveillance studies in the United States and Ontario. In the U.S. study, about 52% of the back pain reports were attributed by the worker to repetitive events at work, and an additional 16% were attributed to discrete, acute events at work; 33% were associated with both types of exposures [Guo et al. 1995].

Although workers often consider MSDs to be work-related, their reports of back pain do not appear to affect the reliability of their self reports about exposure to physical work. In the Ontario study [Liira et al. 1996], 24% of the long-term back disorders were related to bending and lifting, working with vibrating machines, and working in awkward postures. Interestingly, 8% of the population were exposed to at least two of these three factors, and an additional 3% were exposed to all three.

The impact of work-relatedness is demonstrated by the elevated MSD rates for certain industries in workers' compensation data as well as the BLS data. For example, in the State of Washington workers' compensation system, the overall IR of work-related MSDs was 3.87/100 workers in 1992, 3.72 in 1993, and 3.52 in 1994. Work-related MSDs in this study were defined as injuries and illnesses involving sprains/strains, joint inflammation, low-back pain, and nerve-compression syndromes. Four industries had rates at least four times the 1992–94 average rate: wallboard installation (23.6/100 workers per year), temporary help-assembly (23.6), roofing (19.9), and moving companies (18) [Washington State Department of Labor and Industries 1996].

COST

The precise cost of occupational MSDs is not known. Estimates vary depending on the method used. A conservative estimate previously published by NIOSH is $13 billion annually [NIOSH 1996]. Others have estimated the cost at $20 billion annually [AFL-CIO 1997]. Regardless of the estimate used, the problem is large both in health and economic terms.

Work-related MSDs are a major component of the cost of work-related illness in the United States. The California Workers' Compensation Institute (a non-profit research institute) estimates that upper-extremity MSD claims by workers average $21,453 each [CWCI 1993]. Back pain is by far the most prevalent and costly MSD among U.S. industries today. Recent analysis of the 1988 Occupational Health Supplement of the National Health Interview Survey (an ongoing household-based survey) shows that the overall prevalence of self-reported back pain from repeated activities on the most recent job was 4.5%, or 4.75 million U.S. workers [Behrens et al. 1994]. The mean cost per case of compensable low-back pain was reported to be $8,321 in 1989 [Webster and Snook 1994b].

Webster and Snook [1994a] estimated that the mean compensation cost per case of upper-extremity, work-related MSD was $8,070 in 1993; the total U.S. compensable cost for upper extremity, work-related MSDs was $563 million in 1993. For example, the State of Washington averaged 44,648 work-related MSD claims, with an average total cost of $166.8 million/year for the period 1992–94. The State of Washington has a working population that is 2% that of the U.S. workforce. The compensable cost is limited to the medical expenses and indemnity costs (lost wages). When other expenses such as the full lost wages, lost production, cost of recruiting and training replacement workers, cost of rehabilitating the affected workers, etc. are considered, the total cost to the national economy becomes much greater.

DEFINING HEALTH OUTCOMES

Work-related MSDs are defined differently in different studies; thus, it is not surprising that controversy has arisen about the relative importance of various risk factors in the etiology of these disorders. Some investigators restrict themselves to case definitions based on clinical pathology, some to the presence of symptoms, some to "objectively" demonstrable pathological processes, and some to work disability (such as lost work-time status).

The most common health outcome has been the occurrence of pain, which is assumed to be the precursor of more severe disease [Riihimäki 1995] or (as in the case of back pain) the disorder itself. Different MSD health outcomes have been assessed by investigators depending on the particular concern or nature of the study. The specific health outcomes studied vary depending on (a) the purpose of the study, (b) the composition of the study population, (c) the rarity or prevalence of the health outcome in the population, (d) the need to limit specific biases, and (e) the decisions of the investigators.

Different epidemiologic measures and time scales have also been used to quantify MSDs in groups of people (lifetime prevalence, period prevalence, point prevalence, IR, incidence ratio, etc.). Similarly, some studies have included chronic cases, whereas others have studied acute or subacute cases or both. Cross-sectional studies usually employ case definitions that take into account prevalent cases at different stages of the disease process—such as incipient disease or residual signs of a MSD that was once clinically apparent. Because of the multifactorial nature of MSDs, it has been necessary to look at a broad spectrum of outcome measures to assess the effects of these factors.

Certain authors have noted the scarcity of objective measures (including physical examination techniques) to define work-related MSDs, and the lack of standardized criteria for defining MSD cases. Such insufficiencies sometimes make study comparisons difficult [Gerr et al. 1991; Moore 1992; Frank et al. 1995; Riihimäki 1995; Hadler 1997]. It would be useful to have a concise pathophysiological definition and corresponding objective clinical test for each work-related MSD to translate the degree of tissue damage or dysfunction into an estimate of current or future disability and prognosis. Such definitions and tests do not yet exist. Clinically defined work-related MSDs often have no clearly delineated pathophysiological mechanisms for pathological processes. In cases where some criteria exist (such as carpal tunnel syndrome [CTS]), the standard of accuracy is relatively expensive, elaborate, and subject to interpretation. For example, the overlap between symptoms and presence of abnormalities in nerve conduction studies is not great [Stetson et al. 1993]; furthermore, abnormalities in nerve conduction studies cannot be reliably used to predict the future onset of CTS symptoms [Werner et al. 1997]. Thus, in the interest of feasibility, expense, and utility, simpler tests and less specific case definitions may have been used in some studies, thereby introducing some risk of misclassification for specific diagnostic entities.

For upper-extremity studies in this review, those with specific diagnostic criteria (including physical examination techniques) were given greater consideration than studies that used less-specific methods to define health outcomes. The review focused on observational studies whose health outcomes were based on the constellation of recognized symptoms and standard methods of clinical examination. For completeness, those epidemiologic studies that based their health outcomes on reported symptoms alone were also reviewed.

Therefore, this document focuses on the upper-extremity MSDs that have commonly used diagnostic symptoms and physical examination abnormality criteria. Specifically, these MSDs are (1) tension-neck syndrome, (2) rotator cuff tendinitis and impingement syndrome in the shoulder, (3) epicondylitis in the elbow, (4) CTS,
(5) wrist tendinitis, and (6) hand-arm vibration (HAV) syndrome. Generally, the physical examination techniques used to define these MSD cases of the upper extremity have been similar from study to study and involve standard examination techniques recognized by the American Academy of Orthopedic Surgeons, the American College of Physicians, or the International Labor Organization Musculoskeletal Task Force (thus increasing the reliability of comparisons between studies). Although physical examination techniques have not been commonly used in epidemiologic studies of low-back disorders, this document also reviews those epidemiologic studies that address low-back pain.

EXPOSURE MEASUREMENTS

Exposure measurements used in work-related MSD studies range from very crude measures (e.g., occupational title) to complex analytical techniques (e.g., spectral analysis of electrogoniometer measurements of joint motions). Some studies have relied on self-assessment of physical workload by the study subjects.

The accuracy of such self-assessment has been debated (both for under-estimation and over-estimation). Uhl et al. [1987] found that workers reported performing more physical work than observational data could support. Armstrong et al. [1989] found that workers can (on average) distinguish among levels of exposure, but workers' ratings may not correspond with objective measurements. Bernard et al. [1994] found that video display terminal (VDT) operators (those with and those without symptoms of work-related MSDs) reported that the average time they spent typing daily in the last year was twice that noted by independent observers in a single work day (although the 1-day observation period may have been insufficient to capture an average day of typing time). Similarly, Stubbs [1986] found large and significant differences between subjective and observed estimates of time spent working in specified postures. Fransson-Hall et al. [1995], on the other hand, found that workers tended to underestimate their exposures to contact stress of the hand compared with observation. This underestimation may be because workers tend to monitor discomfort from direct contact pressure—not the time spent with direct contact. Katz et al. [1996] found evidence of the validity of self-reported symptoms and functional status, and analysis of their data yielded evidence that variability in self-reports is not influenced by potential secondary gain.

As Riihimäki [1995] pointed out, it is difficult to assess current exposure, but it is even more difficult to assess cumulative past exposure retrospectively. Accurate retrospective data are usually not available; thus the exposure assessment is often based on self-reports, and the assessment may incur information bias.

A few studies have used observational methods to estimate exposures to workplace physical hazards more accurately and reliably. Because studies that directly observe or assess physical exposure factors are less likely to misclassify exposure status, these studies are given greater weight in this review.

Despite the noted limitations, occupations classified as “high-risk” in several studies share a number of workplace exposures associated with work-related MSDs. These workplace exposures occur in various combinations (singly, simultaneously, or sequentially) at different levels for different durations. These exposures have not been routinely broken down into task variables and quantified, with the mechanical or physiological loads defined and measured.

INFORMATION RETRIEVAL

This document examines scientific peer-reviewed epidemiologic journal articles, including recent publications addressing MSD risk factors, conference proceedings, and abstracts dealing with upper-extremity or back MSDs, recent textbooks, internally reviewed government reports or studies conducted by NIOSH, and other documents. Reports of epidemiologic studies were acquired using both CD-ROM and online commercial and governmental databases. Searches were carried out on computer-based bibliographic databases: Grateful Med® (which includes Medline® and Toxline®), NIOSHTIC® (a NIOSH database), and CIS (the International Labour Organization occupational health database). The search strategy included the following key terms: occupation, repetition, force, posture, vibration, cold, psychosocial, psychological, physiological, repetition strain injury, repetitive strain injury, epidemiology, etiology, cumulative trauma disorders, MSDs (neck, tension neck syndrome, shoulder, rotator cuff, elbow, epicondylitis, tendinitis, tenosynovitis, carpal tunnel, de Quervain's, nerve entrapment syndrome, vibration, back pain and sciatica, manual materials handling). Bibliographies of relevant articles were reviewed. Relevant foreign literature citations in English and included in the databases were included in this review along with literature from the personal files of the contributors. This search strategy identified more than 2,000 studies. Because of the focus on the epidemiology literature, a number of these studies that were laboratory-based or focused on MSDs from a biomechanical standpoint that dealt with clinical treatment of MSDs or other non-epidemiologic orientations were eliminated from further consideration for the present document. Over 600 studies were included in the detailed review process.

SELECTION OF STUDIES

The studies that were chosen for more detailed review specifically concerned the work-relatedness of MSDs, musculoskeletal problems of the neck, upper limbs, or back, and/or occupational and nonoccupational risk factors. The following inclusion criteria were used to select studies for the review:

Population: Studies were included if the exposed and referent populations were well defined.

Health outcome: Studies were included if they involved neck, upper-extremity, and low-back MSDs measured by well-defined, explicit criteria determined before the study. Studies whose primary outcomes were clinically relevant diagnostic entities generally had less misclassification and were likely to involve more severe cases. Studies whose primary outcomes were the reporting of symptoms generally had more misclassification of health status and a wider spectrum of severity.

Exposure: Studies were included if they evaluated exposure so that some inference could be drawn regarding repetition, force, extreme joint position, static loading or vibration, and lifting tasks. Studies in which exposure was measured or observed and recorded for the body part of concern were considered superior to studies that used self-reports or occupational/job titles as surrogates for exposure.

Study design: Population-based studies of MSDs, case-control studies, cross-sectional studies, longitudinal cohort studies, and case series were included.

METHODS FOR ANALYZING OR SYNTHESIZING STUDIES

The first step in the analytical process was to classify the epidemiologic studies by the following criteria:

1. The participation rate was ≥70%. This criterion limits the degree of selection bias in the study.

2. The health outcome was defined by symptoms and physical examination. This criterion reflects the preference of most reviewers to have health outcomes that are defined by objective criteria.

3. The investigators were blinded to health or exposure status when assessing health or exposure status. This criterion limits observer bias in classifying exposure or disease.

4. The joint under discussion was subjected to an independent exposure assessment, with characterization of the independent variable of interest (such as repetition or repetitive work). This criterion indicates whether the exposure assessment was conducted on the joint of interest and involved the type of exposure being examined— such as repetitive work, forceful exertion, extreme posture, or vibration. This criterion indicates whether the exposure was measured independently or in combination with other types of exposures. Exposure was also characterized by the method used to measure the level of exposure. Studies that used either direct observation or actual measurements of exposure were considered to have a more accurate exposure classification scheme, whereas studies that exclusively used job titles, interviews, or questionnaire information were assumed to have less accurate exposure information.

During review of the studies, the greatest qualitative weight was given to studies that had objective exposure assessments, high participation rates, physical examinations, and blinded assessment of health and exposure status. The chapters dealing with the different body regions—neck (including neck-shoulder), shoulder, elbow, hand/wrist, and low-back—summarize these characteristics for each study reviewed on the criteria table.

The second step of the analytical process was to divide the studies into those with statistically significant associations between exposures and health outcomes and those without statistically significant associations. The associations were then examined to determine whether they were likely to be substantially influenced by confounding or other selection bias (such as survivor bias or other epidemiologic pitfalls that might have a major influence on the interpretation of the findings). These include the absence of nonrespondent bias and comparability of study and comparison groups. There are also tables that summarize information about confounders and epidemiologic pitfalls for each study reviewed at the end of each body region chapter.

The third step of the analytical process was to review and summarize studies with regard to strength of association, consistency in association, temporal association, and exposure-response relationship. Each of these factors is discussed in greater detail in the next section (Criteria for Causality). Each study examined (those with negative, positive, or equivocal findings) contributed to the pool of data for determining the strength of work-relatedness using causal inference. The exposures examined for the neck and upper extremity were repetition, force, extreme posture, and segmental vibration. The exposures examined for the low back were heavy physical work, lifting, bending/twisting, whole-body vibration, and static postures.

Care should be taken when interpreting some study results regarding individual workplace factors of repetition, force, extreme or static postures, and vibration. As Kilbom [1994] stated, these factors occur simultaneously or during alternating tasks

within the same work, and their effects concur and interact. A single odds ratio (OR) for an individual risk factor may not accurately reflect the actual association, as not all of the studies derived ORs for simultaneously occurring factors. Thus these studies were not only viewed individually (taking into account good epidemiologic principles) but together as a body of evidence for making broader interpretations about epidemiologic causality. Many investigators did not examine each risk factor separately but selected study and comparison groups based on combinations of risk factors (such as workers in jobs involving high force and repetition compared with workers having no exposure to high force and repetition).

CRITERIA FOR CAUSALITY

No single epidemiologic study will fulfill all criteria for causality. However, the results of many epidemiologic studies can contribute to the evidence of causality in the relationship between workplace risk factors and MSDs. Rothman [1986] defined a cause as “an event, condition, or characteristic that plays an essential role in producing an occurrence of the disease.”

This document uses the following framework of criteria to evaluate evidence for causality. The framework was proposed by Hill [1966; 1971] and modified by Susser [1991] and Rothman [1986].

Strength of Association

The ORs and prevalence rate ratios (PRRs) from the reviewed studies were used to examine the strength of the association between exposure to workplace risk factors and MSDs, with the higher values indicating stronger association. The greater the magnitude of the relative risk (RR) or the

OR, the less likely the association is to be spurious [Cornfield et al. 1959; Bross 1966; Schlesselman 1978]. Weaker associations are more likely to be explained by undetected biases.

Debate is ongoing in the epidemiologic literature about studies with small sample sizes that find increased ORs or PRRs but have confidence intervals (CIs) that include 1.0. The question is whether such studies simply show no significant association or can be seen as useful estimates of associated risk. Nonetheless, it is useful to identify trends across such studies and consider whether they have valuable information after taking into account other epidemiologic principles. If the studies with and without significant findings both have similarly elevated ORs or PRRs, this information is useful in estimating the overall level of risk associated with exposure.

Consistency

Consistency refers to the repeated observation of an association in independent studies. Multiple studies yielding similar associations support the plausibility of a causal interpretation. Finding the same association with different and valid ways of measuring exposure and disease may show that the association is not dependent on measurement tools. Similar studies that yield diverse results weaken a causal interpretation.

Specificity of Effect or Association

This criterion refers to the association of a single risk factor with a specific health effect. We have not emphasized this criterion because of the different views of its utility in determining causality. If this criterion is interpreted to mean that a single stressor can be related to a specific outcome (e.g., that forceful exertion alone can be related to hand/wrist tendinitis) it becomes an important criterion for MSDs. However, this criterion can be interpreted and applied too simplistically. Schlesselman [1982] noted that the concept of specificity is that is generally too simplistic and that multiple causes and effects were more often the rule than the exception. Rothman [1986] referred to specificity of effect as "useless and misleading" as a criterion for causality.

Temporality

Temporality refers to documentation that the cause precedes the effect in time. Prospectively designed studies ensure that this criterion is strictly adhered to—that is, that exposure precedes adverse health outcome. But cross-sectional studies are not designed to allow strict adherence to this criterion because both exposure information and adverse health outcome are obtained at the same point in time.

Even though the cross-sectional study design precludes strict establishment of cause and effect, additional information can be used to make reasonable assumptions that exposure preceded the health effect—particularly when the relationship between physical exposures is measured by observation or direct measurement and by MSD-related health outcomes. If the exposure was directly measured or observed, it is also unlikely that the measurement was influenced by the presence or absence of the MSD in the employee. Rothman [1986] stated that it is important to realize that cause and effect in an epidemiologic study or epidemiologic data cannot be evaluated without making some assumptions (explicit or implicit) about the timing between exposure and disease. For example, from a cross-sectional study of hand/wrist tendinitis and highly forceful, repetitive jobs, a researcher can determine when exposure began from recorded work histories or from interviews. The researcher can also reasonably determine the time of tendinitis onset by interviews. Kleinbaum et al. [1982] said that in cross-sectional studies, risk factors and prognostic factors cannot be distinguished empirically *without additional information*.

With additional information (e.g., laboratory experiments or biomechanical findings), an investigator can deduce that the adverse health outcome followed exposure. For example, taking other confounders into account, it is unreasonable to deduce that persons with hand/wrist tendinitis are likely to seek employment in jobs that require highly forceful, repetitive exertion of the hand/wrist area.

Exposure-Response Relationship

The exposure-response relationship relates disease occurrence with the intensity, frequency, or duration of an exposure (or a combination of these factors). For example, if long-duration, forceful, repetitive work using the hands and wrists is associated with an increased prevalence of hand/wrist tendinitis, this association would tend to support a causal interpretation. Some have challenged the importance of physical factors as causal agents, but prospective studies have shown that reduced exposures result in a decreased disease [Bigos et al. 1991b]. In occupational health, important and effective preventive actions have been initiated without prospective demonstration that reduced exposure decreases the incidence of disease.

Coherence of Evidence

Coherence of evidence means that an association is consistent with the natural history and biology of disease. For example, an observed association between repetitive wrist motion and CTS (defined by nerve conduction criteria) must be supported by biological plausibility: repeated wrist movement can cause swelling of tissue in the carpal tunnel, resulting in injury to nerves. It is important to remember, however, that epidemiologic studies can identify new associations for further study.

CATEGORIES USED TO CLASSIFY THE EVIDENCE OF WORK-RELATEDNESS

After assessing the quality of individual epidemiologic studies, NIOSH investigators judged whether the evidence was strong enough to relate the risk factor to the MSD. In making this judgement, the investigators considered the criteria for causality. Studies which met all four evaluation criteria were given more weight than those which met at least one of the criteria.

The evidence of work-relatedness from epidemiologic studies is classified into one of the following categories: strong evidence of work-relatedness (+++), evidence of work-relatedness (++), inadequate evidence of work-relatedness (+/0), and evidence of no effect of work factors (-).

Strong Evidence of Work-Relatedness (+++)

A causal relationship is very likely between intense and/or long duration exposure to a specific risk factor(s) and an MSD when using the epidemiologic criteria of causality. A positive relationship has been observed between exposure to the risk factor and the MSD in at least several studies in which chance, bias, and confounding could be ruled out with reasonable confidence.

Evidence of Work-Relatedness (++)

Some convincing epidemiolgic evidence exists for a causal relationship using the epidemiologic criteria of causality for intense and/or long-duration exposure to a specific risk factor(s) and an MSD. A positive relationship has been observed between exposure to the risk factor and the MSD in studies in which chance, bias, and confounding are not the likely explanation.

Insufficient Evidence of Work-Relatedness (+/0)

The available studies are of insufficient quality, consistency, or statistical power to permit a conclusion regarding the presence or absence of a causal association. Some studies suggest a relationship to specific risk factors but chance, bias, or confounding may explain the association.

Evidence of No Effect of Work Factors (-)

Adequate studies consistently and strongly show that the specific risk factor is not related to MSDs.

SUMMARY

This document critically reviews the evidence regarding work-related risk factors and their relationship to MSDs of the neck, shoulder, elbow, hand/wrist, and low back. The document represents a first step in assessing the work-relatedness of MSDs. This step involves examination of relevant epidemiologic information to assess the strength of the available evidence that, under certain conditions of exposure, specific risk factors could increase the risk of MSDs or increase the likelihood of impairment or disability from MSDs. The second step would involve quantitative risk estimates that are beyond the purpose and scope of this document. This review of the epidemiologic literature may assist national and international authorities, academics, and policy makers in assessing risk and formulating decisions about future research or necessary preventive measures.

This document does not necessarily cite all of the literature on a particular MSD. Included are articles considered relevant by NIOSH investigators and internal and external reviewers of the draft document. Only reports that have been published or accepted for publication in the openly available scientific literature have been reviewed by the authors. In certain instances, they have included government agency reports that have undergone peer review and are widely available.

DESCRIPTION OF TABLES, FIGURES, AND APPENDICES

In each chapter on neck, shoulder, elbow, hand/wrist, and low back disorders, there are tables summarizing the risk indicators and epidemiologic criteria used in examining studies relevant to each body part. For each of these criteria tables there are corresponding figures which depict ORs, PRRs, or IRs, along with their associated CIs, if available.

In a separate table for each chapter, more extensive descriptions of studies, whether or not they contributed to decisions regarding causal inference, are provided for each body part. These tables include information from each study about their design, population, outcome, and exposure measures, as well as reported MSD prevalence. Some studies are included in the tables that may not be mentioned in the text. These additional studies are for information purposes only.

Appendix A, *Epidemiologic Review*, is a brief primer on occupational epidemiologic methods. Appendix B, *Individual Factors Associated with Work-Related Mus-culoskeletal Disorders (MSDs)*, discusses individual factors (age, gender, etc.) and their association with work-related MSDs. Appendix C, *Summary Tables*, provides a concise overview of the studies reviewed relative to the evaluation criteria, risk factors addressed, and other issues.

CHAPTER 2
Neck Musculoskeletal Disorders: Evidence for Work-Relatedness

SUMMARY

Over 40 epidemiologic studies have examined physical workplace factors and their relationship to neck and neck/shoulder musculoskeletal disorders (MSDs). Among these studies are those which fulfill rigorous epidemiologic criteria and appropriately address important issues so that causal inferences can be made. The majority of studies involved working groups with a combination of interacting work factors, but certain studies assessed specific work factors. Each of the studies we examined (those with negative, positive, or equivocal findings) contributed to the overall pool of data for us to use in assessing the strength of the work-relatedness using causal inference.

There is **evidence** for a causal relationship between highly repetitive work and neck and neck/shoulder MSDs. Most of the epidemiologic studies reviewed defined “repetitive work” for the neck as work activities which involve continuous arm or hand movements which affect the neck/shoulder musculature and generate loads on the neck/shoulder area; fewer studies examined relationships based on actual repetitive neck movements. The two studies which measured repetitive neck movements by measuring head position (using frequency and duration of movements) fulfilled the most stringent epidemiologic criteria, showing strong associations with neck/shoulder MSDs. In those studies defining repetitive work involving continuous arm or hand movements affecting the neck/shoulder, nine studies were statistically significant and had odds ratios (ORs) greater than 3.0.; eight studies fulfilled all the epidemiologic criteria except the exposure criteria, and measured repetition for the hand/wrist and not for the neck. Of these, three were statistically significant and had ORs greater than 3, five had nonsignificant ORs, all under 2.0.

There is also **evidence** for forceful exertion and the occurrence of neck MSDs in the epidemiologic literature. Most of the epidemiologic studies reviewed defined “forceful work” for the neck/shoulder as work activities which involve forceful arm or hand movements, which generate loads to the neck/shoulder area; no study examined a relationship based on actual forceful neck movements. Of the 17 studies addressing force as one of the exposure factors, five studies found statistically significant associations, but did not derive ORs; two studies found ORs greater than 3.0, seven studies from 1 to 3.0, and two studies with ORs less than 1.0. Many of the studies relating measured force (as workload, etc.) to MSDs are in the biomechanical and ergonomic literature.

There is **strong evidence** that working groups with high levels of static contraction, prolonged static loads, or extreme working postures involving the neck/shoulder muscles are at increased risk for neck/shoulder MSDs. Consistently high ORs were found (twelve statistically significant studies with ORs over 3.0) providing evidence linking tension-neck syndrome with static postures or static loads.

The epidemiologic data were **insufficient** to provide support for the relationship of vibration to neck disorders. At this time, further studies must be done before a decision regarding causal inference is made. The few prospective studies which have included interventions to decrease workplace exposures that include decreasing repetitive work and less extreme working postures showed a decrease in the incidence of neck MSDs and an improvement in symptoms among affected workers. The data on intervention provide additional evidence that these disorders are related to workplace risk factors.

INTRODUCTION

Studies from the United States have generally classified neck disorders separately from shoulder disorders when evaluating work-related risk factors. Scandinavian studies examining work-related factors, on the other hand, have often combined neck and shoulder MSDs into one health outcome variable. This was based on the concept that several muscles act on both the shoulder girdle and the upper spine together. We have divided our reviews of the neck and shoulder MSDs into two chapters: Chapter 2 addresses neck and neck/shoulder MSDs and Chapter 3 addresses shoulder MSDs.

Our discussion of the evidence for work-relatedness of the neck will include criteria Tables 2-1 through 2-6 and Figures 2-1 through 2-6. Shoulder MSDs will be discussed in the next chapter.

Epidemiologic studies have defined neck MSDs in one of two ways: (a) by symptoms occurring in the neck (usually with regard to a specific duration, frequency, or intensity), or (b) by using both symptoms and physical examination findings.

The prevalence of reported MSDs is generally lower when they are defined using both symptoms and physical examination results than when defined using symptoms alone. For example, the prevalence rate of tension neck syndrome (TNS) among male industrial workers in the United States was reported to be 4.9% from interview data and 1.4% when case definitions included physical exam findings [Hagberg and Wegman 1987]. The percent of work-related MSD cases defined by physical examination findings to those defined solely by symptoms has ranged from approximately 50% (Silverstein et al. [1987]; Blåder et al. [1991]; Bernard et al. [1993]; Hales et al. 1994]) to about 85% (Andersen and Gaardboe [1993b]). Forty-seven of the listed studies referenced included physical examination findings in their health outcome assessment criteria.

Many of the neck and neck/shoulder MSD studies referenced in the tables were part of larger studies that inquired about musculoskeletal symptoms and physical findings in multiple body sites. In most of these studies, there were no separate ergonomic exposure observations or measurements made that pertained to the neck region (e.g., there were no neck posture observations, neck angle measurements, neck work-load assessment, trapezius electromyographic testing, etc.). In these studies, the primary interest and measurement strategies focused on the hand and wrist region (e.g., Kuorinka and Koskinen [1979]; Ohlsson et al. [1989]; Hales et al. [1989]; Kiken et al. [1990]; Baron et al. [1991]). In the studies, workers were categorized only by hand/wrist exposures. Hand/wrist categorization will not reflect exposures of the neck region (or other musculoskeletal sites). For example, workers who may have frequent and rapid awkward postures of the neck but less frequent or extreme postures of the hand and wrist region may be misclassified as low risk if classification depends only on hand/wrist exposure. In general, we have given these studies less weight because of a significant potential for misclassification.

The text of this section on neck and neck/shoulder MSDs is organized by work-

related exposure factor. The discussion within each factor is organized according to the criteria for evaluating evidence for work-relatedness in epidemiologic studies using the strength of association, the consistency of association, temporal relationships, exposure-response relationship, and coherence of evidence. Conclusions are presented with respect to neck and neck/shoulder MSDs as a single disorder for each exposure factor. Summary information relevant to the criteria used to evaluate study quality is presented in Tables 2-1 through
2-6. A more extensive summary, which includes information on health outcome, covariates, and exposure measures, is presented at the end of this chapter.

Studies Included in Neck MSDs Tables

Forty-six epidemiologic studies dealing with neck MSDs and 23 dealing with neck/shoulder MSDs appear in the summary tables. Of the studies, 38 were cross-sectional, 2 were case-control studies, and 6 were prospective studies. Among all the studies pertaining to the neck or neck/shoulder area, 35 had participation rates of over 70%, 3 had less than 70%, and 8 did not report their participation rates.

REPETITION

Definition of Repetition for Neck and Neck/Shoulder MSDs

For our review of the neck or neck/shoulder region, we chose those epidemiologic studies that examined repetition or repetitive work activities and MSDs. Studies generally address repetition as cyclical work activities that involved either: (1) repetitive neck movements (e.g., the frequency of different head positions during a cycle), or

(2) repeated arm or shoulder motions that generate loads to the neck/shoulder area (e.g., trapezius muscle). Most of the studies that examined repetition or repetitive work as a potential risk factor for neck or neck/shoulder MSDs had several concurrent or interacting physical workplace factors that were being evaluated. Therefore, repetitive work was not necessarily considered the primary exposure factor but was considered along with the other work factors.

Studies Reporting on the Association of Repetition as a Work Factor for Neck and Neck/Shoulder MSDs

Either the risk factor “repetition” or “repetitive work” was included in 26 studies as a factor for selection of the study population in their examination of neck and neck/shoulder MSDs in the workplace. However, only a handful of these studies examined repetitive movements of the neck. Few of these studies observed or measured: (a) the frequency or duration of tasks pertaining to the neck, (b) the ratio of work-time-to-recovery time for neck or neck/shoulder involvement, or (c) the percentage of the workday spent on repetitive activities involving the neck. Instead, studies tended to compare and contrast the prevalences of neck symptoms and/or physical findings in workers in occupations requiring a combination of forceful, repetitive movements and extreme postures of the upper extremities (mainly of the hand/wrist) to workers in occupations without those requirements.

Twenty studies that mentioned repetitive work or repetitive movements found a statistically significant positive association between repetition and neck or neck/shoulder MSDs; 6 others had non-significant findings (Tables 2-1 and 2-2, Figures 2-1 and 2-2). In terms of magnitude of the association, 11 studies had ORs greater than 3.0, 11 had ORs between 1.0 and 3.0, and none had an OR less than 1.0. Four studies did not report their results in terms of ORs or Prevalence Rate Ratio (PRRs), although all of these found significant associations ($p<0.05$).

Studies Meeting the Four Evaluation Criteria

Of the 27 investigations (see Tables 2-1 and 2-2), 2 fulfilled all four evaluation criteria outlined earlier in the introduction section [Ohlsson et al. 1995; Jonsson et al. 1988]. Only the Ohlsson study reported ORs. The investigations assessed repetitive work as an independent variable in terms of frequency and duration of neck movements.

In the cross-sectional study by Ohlsson et al. [1995], female industrial assembly-line workers exposed to repetitive tasks with short (<30 seconds) cycles were compared to 2 referent groups: 68 former assembly workers and 64 other workers with no repetitive exposure at their current jobs. Industrial workers had to perform tasks with a posture requiring an intermittently flexed neck and elevated arms, which were abducted intermittently. Workers and referents reported neck/shoulder symptom(s) and had physical exams performed by a single examiner. The examiner was blinded to exposure status but not completely to group status. Ergonomic exposure assessment was extensive. It included videotaping, observation, and analysis of postures, including measurements of critical angles (15E and 30E) of flexion of the neck. Two independent readers determined frequency, duration, and critical angles of movement for each variable by taking the average of the two readings. Weekly working time, work rotation, patterns of breaks, and individual performance rate (piece rate) were recorded and used in the analysis. The study controlled for age, gender (only females were included), and psychosocial variables ("tendency for stress" and "worry").

The other study that fulfilled the four criteria concerned a 3-year prospective study written up in a series of articles by Kilbom et al. [1986], Kilbom and Persson [1987], and Jonsson et al. 1988]. Female electronic workers in highly repetitive tasks with static postural loads to the neck and shoulder areas were followed over a 3-year period. In the second year, some of the employees had workplace interventions that decreased the number of repetitive tasks involving extreme neck and shoulder postures, while others continued to work at unaltered tasks. Three separate physical exams were carried out at yearly intervals, the first one initially assessing tenderness on palpation and pain or restriction with active and passive movements. Ergonomic assessments occurred at the outset of the study and included video analysis of postures and movements of the head, shoulder, and upper arm. The evaluation recorded work-cycle time and number of cycles per hour; time at rest for the arm, shoulder, and head; total number of rest periods; and average and total duration per work cycle and hour. (The method was designed to study short-cycle repetitive work under visual control.) The mean number of

neck forward flexions
>20E per hour was 728 (standard deviation [s.d.] 365) in the initial 96 workers. The participation rate of the study was 72% after 3 years; the investigators analyzed several variables separately for dropouts and found no significant differences with regards to medical status, physiologic capacity, working technique, or work history. The investigators performed step-wise logistic regression with deterioration of disorders or remaining healthy in the different locations (neck and neck/shoulder) as the two dependent variables. Age, muscle strength, job satisfaction, and high productivity were included in the logistic regression analyses of these studies. Video analysis and observation were used to assess repetitive exposure on all subjects, using work cycle time, number of cycles per hour, as well as number of neck flexions per hour as criteria. Work cycle time varied between 4.6 and 9.1 min, with a mean value of 6.6 min.

Strength of Association for Repetition

In the Ohlsson et al. [1995] study, the OR for the association between repetitive work related to the neck and any neck/shoulder diagnoses was 4.6; for a diagnosis of tension neck syndrome, it was 3.6.

For the cohort study carried out by Kilbom et al. [1986], at the 2-year followup, the number of neck flexions per hour appeared as a strong predictor for deterioration to severe disorders of the neck. Improvement to a "healthy status" classification from
Year I to Year II was seen with reallocating workers to more varied work tasks (which required a reorganization of monotonous and repetitive work tasks). The new tasks were characterized as more dynamic and varied and included only occasional sitting tasks, caretaking work, surveillance of machinery, or assembling of bigger and heavier equipment. The article documenting the last phase of the cohort study by Jonsson et al. [1988] did not specifically address the neck but broadened the health outcome definition to include the neck/shoulder area and the rest of the upper extremity using "cervicobrachial region" as the health outcome of interest. A significant association between deterioration of health status of the cervicobrachial region between Year II and Year III of the study and "work cycle, total time" at the $p<0.05$ level was found (ORs were not given).

Studies Meeting at Least One of the Four Criteria—Strength of Association

Of the studies that found significant ORs over 3.0 but did not mention or fulfill all of the criteria, almost all focused on working groups with a combination of repetitive and forceful work and compared them to either population referents or groups in occupations with lower exposure. Almost all were cross-sectional surveys. These studies used health outcomes from symptom surveys and self-reported workplace exposure (no direct observations) and either compared symptomatic workers (neck MSD cases) to asymptomatic workers in the same workforce (e.g., Yu and Wong [1996]; Bergqvist et al. [1995a]; Schibye et al. [1995]; Hünting et al. [1981]) or in other occupations (e.g., Liss et al. [1995]; Andersen and Gaardboe [1993b]; Milerad and Ekenvall [1990]; Onishi et al. [1976]). Onishi et al. [1976] found significant differences in neck/shoulder MSDs (OR 3.8) between groups involved in repetitive upper limb operations and office workers. They found workers involved in repetitive activity had 10% to 30% maximum voluntary contraction (MVC) of the trapezius muscle. They concluded that habitual neck or shoulder muscle fatigue is caused by repetitive tasks that result in localized tenderness and may be a precursor to chronic MSDs.

Andersen and Gaardboe [1993a] used a cross-sectional design to compare sewing machine operators with a random sample of women from the general population of the same region. A neck case required a strict predetermined symptom and physical examination definition. Exposure was assessed through observation and categorization of jobs, based on the authors' experience and judgements. However, the main interest for exposure assessment was duration of exposure as a sewing machine operator. Statistical modeling controlled for age, having children, not doing leisure exercise, smoking, and socioeconomic status found a significant trend for "neck/shoulder syndrome" in relation to years of exposure as a sewing machine operator, with ORs from 3.2 to 36.74. The OR for the lowest exposure category, 0-7 years, was not statistically significant, although the higher exposure levels were. For this study, the exposure classification scheme does not allow separation of the effects of repetition from those of force, and there was no precise measure of repetitiveness.

Baron et al. [1991] studied neck MSDs in 124 grocery store checkers and 157 other grocery store workers who were not checkers. The neck MSD case definition met predetermined symptom and physical exam criteria. Physical examinations had higher participation rates among the checkers (85%) than among the referents (55%). Telephone interviews to non-checkers resulted in questionnaire completion by 85% of the non-checkers. The OR for neck disorders among checkers was 2.0 (95% confidence interval [CI] 0.6–6.7), in a model that included age, hobbies, second jobs, systemic disease, and obesity.

Bergqvist et al. [1995a] carried out a study comparing office workers using video display terminals (VDTs) to those who did not. A physiotherapist's diagnosis of tension-neck syndrome was used to define a case. Exposure assessment was based on both self-reports and the investigators' observation of work postures, movements, and measurements of heights of work-station equipment in conjunction with the user. Statistical modeling included several individual factors, organizational factors, and ergonomic factors. For "tension neck" syndrome, no factor related to repetitive work was found to be significantly related.

Blåder et al. [1991] surveyed 199 sewing machine operators from 4 plants. Of the 155 who reported shoulder or neck pain, 131 were examined. Exposure assessment was by questionnaire and addressed employment duration and hours per week. Authors stated that the study involved a control group and took into account psychosocial factors, but the results were not included in the article. Both employment duration and working more than 30 hours per week were found to be statistically significant at the $p<0.05$ levels. For this study, the exposure as duration of work (per week and per years) does not allow separation of the effects of repetition from those of force. There was no direct measure of repetitiveness.

Ekberg et al. [1994] carried out a case-control study involving cases from a semi-rural community in southern Sweden who had consulted a community physician for MSDs of the neck, shoulder, arm, or upper thorax.

Cases had to have been ill immediately prior to physician visit and

have been on sick leave less than 4 weeks. Cases were excluded for trauma, infectious causes, accident, malignancy, rheumatic disease, abuse, or pregnancy. Controls were randomly selected from the Swedish insurance registry. Exposure was obtained by questionnaire. The analysis showed that for neck disorders with precise repetitive movements the OR was 3.8 for medium exposure and 15.6 for high exposure comparing jobs with low force and low repetition. Gender, immigrant status, work pace, and current smoking were also analyzed in the logistic model.

Ekberg et al. [1995] surveyed 637 Swedish residents for the presence of neck symptoms in the past six months. Exposure was based on questionnaire responses. Twenty questionnaire items on physical work conditions were factor analyzed. Age, smoking, exercise habits, and family situation with preschool children were not significantly associated with symptoms. Repetitive movements demanding precision was found to have an OR of 1.2 for neck pain.

Hales and Fine [1989] compared 89 female workers in 7 high exposure jobs to 25 female poultry workers in low exposure jobs employed in poultry processing. Neck case definition required symptoms and physical examination findings that met predetermined criteria. Exposure assessment was based on hand/wrist assessment of forceful and repetitive jobs. No assessment of neck repetition was performed. Twelve percent of workers in high risk jobs versus none in low risk jobs were found to have neck MSDS.

In a study of VDT users in a range of jobs (data entry to “conversational” VDT use), Hünting et al. [1981] used a case definition requiring symptoms and physical exams and an extensive exposure assessment using questionnaire, observation, and measurements of workstations, and body posture measurements using a prescribed method. Data entry terminal users, whose tasks required more extensive repetitive work than traditional office workers, found an OR of 9.9 with the comparison. There were no adjustments for confounders in this analysis.

Kamwendo et al. [1991] compared 420 medical secretaries with frequent, significant neck pain to those with few episodes based on questionnaire responses. Exposure was also questionnaire based. The analysis was controlled for age and length of employment. A surrogate for repetitive work consisted of hours sitting or working with office machines with high exposure equal to 5 hrs or more/day.

Kiken et al. [1990] also studied poultry workers at two plants with exposure to highly forceful, highly repetitive jobs and compared them to other poultry workers with less exposure. Neck case definition required symptoms and physical examination findings that met predetermined criteria. Exposure assessment was based on hand/wrist assessment of forceful and repetitive jobs. No assessment of neck repetition was performed. Job turnover was around 50% at plant 1 and 70% at plant 2 making survivor bias a strong possibility.

Kuorinka and Koskinen [1979] studied occupational rheumatic diseases and upper limb strain among 93 scissor makers and compared them to the same group of department store assistants (n=143) that Luopajärvi et al. [1979] used as a comparison group. Temporary workers and

those with recent trauma were excluded from the scissor makers group. Exposure assessment included videotape analysis of scissor maker tasks, however exposure assessed for the hand and wrist region and not the neck. No formal exposure assessment was conducted on the shop assistants. Health assessment involved an interview and physical examination by a physiotherapist following a standard protocol. Diagnoses of tension neck syndrome were determined using predetermined criteria [Waris et al. 1979]. In problem cases, orthopedic and physiatric teams determined case status. It is unclear whether cashiers were excluded from the comparison group in this study as they were in the Luopajärvi et al. [1979] study. The study group was 99% female.

Luopajärvi et al. [1979] compared the prevalence of neck/shoulder disorders among 152 female assembly line packers in a food production factory to 133 female shop assistants in a department store. Exposure to repetitive work, awkward hand/arm postures, and static work was assessed by observation and videotape analysis of factory workers. No formal exposure assessment was conducted on the department store workers; their job tasks were described as variable. Cashiers were excluded, presumably because their work was repetitive. No formal assessment occurred for neck/shoulder repetition. The health assessment consisted of interviews and physical examinations conducted by a physiotherapist, and diagnoses of tension neck syndrome were later determined by medical specialists using these findings and predetermined criteria (95% CI 2.63–6.49). Age, hobbies, and housework were considered in the analysis.

Milerad and Ekenvall [1990] compared the self-reported neck and neck/shoulder symptoms between dentists and pharmacists. Dentists had been considered the high risk group because of awkward postures and repetitive use of small handtools. Exposure was based on self-reports. The authors examined several covariates and stratified by gender for their analysis. No difference between groups in leisure time, smoking, systemic disease, and exposure to vibration.

Ohlsson et al. [1989] studied 148 electrical equipment and automobile assemblers, 76 former female assembly workers who quit within 4 years and compared these two groups to 60 randomly sampled females from the general population. A case was determined by questionnaire; exposure was based on job categorization and questionnaire responses. Repetitive exposure was based upon the number of items completed per hour. The work pace was divided into four classes: (1) Slow: <100 items/hr; (2) Medium: 100 to 199 items/hr; (3) Fast: 200 to 700 items/hr; (4) Very Fast: >700 items/hour. The OR increased with increasing work pace, except at very high paces, where there was a decrease. This was attributed to “selective quitting of subjects with complaints, only the healthiest being left in the assembly work.”

Onishi et al. [1976] compared several groups of workers with varying exposure to repetitive tasks. Health outcome was based on symptoms of shoulder stiffness, dullness, pain, numbness; pressure measured by strain transducer at which a subject felt pain; and a physical exam. Observation and measurements of some job tasks, including some measures of repetition, were performed then job categorization was done. Based on job categorization and job analysis, and taking into account shift length, activities, number of breaks, repetitive movements of the hands, arm manipulations, and length of employment, there was not a difference between workers with tenderness threshold above 1.5 kg/cm² and those below with respect to age, height, weight, skinfold thickness, grip strength, upper arm abduction strength, and back muscle strength.

Punnett et al. [1985] compared neck/shoulder MSDs based on symptom reporting alone in 162 women garment workers and 76 women hospital workers such as nurses, laboratory technicians, and laundry workers. There was a low participation rate among the hospital workers. Eighty-six percent of the garment workers were sewing machine operators and finishers (sewing and trimming by hand). The sewing machine operators were described as using highly repetitive, low force wrist and finger motions, while the finishers had shoulder and elbow motions as well. The exposed garment workers likely had more repetitive jobs than most of the hospital workers. The neck/shoulder cases were found to lift both the "typical" and "heaviest" loads with greater frequency than non-cases.

Sakakibara et al. [1995] found among orchard workers that neck shoulder MSDs based on symptom and physical findings were significantly higher when performing pear bagging than when apple bagging. Exposure was based on measurements of specific angles of the neck and shoulder and job tasks in a representative worker. ORs were not derived in this study. Confounders were not checked for in this study.

Sakakibara et al. [1987] did not include physical exam findings in the case definition of neck and neck/shoulder MSDs when comparing workers bagging pears versus apples. Exposure was again based on measurements of job tasks by a representative worker.

Schibye et al. [1995] followed up 303 sewing machine operators at nine factories representing different technology levels who completed a questionnaire in 1985. In April 1991, 241 of 279 traced workers responded to the same 1985 questionnaire. Operators still working were compared to those who moved to other employment in 1991. Exposure was assessed through a questionnaire asking type of machine operated, work organization factors, workplace design factors, units produced per day, the payment system, and the duration of employment as a sewing machine operator. Although the authors state that the analysis did not show that neck symptoms among workers who had worked as a sewing machine operator to be significantly related to exposure, exposure time, or age, there was a significant drop-out rate of those above 35 years.

Rossignol et al. [1987] chose 38 random sites from Massachusetts workers with more than 50 employees, and selected 191 workers from computer and data processing services, and public utilities and the Commonwealth Government. Subjects were selected after the observation of the worksite. A self-administered questionnaire case definition was used for neck MSD. Exposure was also based upon self-reports of number of hours worked each day with a keyboard machine with a VDT. Analysis controlled for the following confounding factors: age, cigarette smoking, industry, and educational VDT training.

Yu and Wong [1996] chose to compare 90 data entry, data processing, and computer programmers from an International Bank in Hong Kong and 61 infrequent users of VDTs. Both neck MSD case definition and exposure assessment were based on symptom data. Analysis controlled for "age and gender, and other covariates" (as stated in the paper). For frequent VDT use an OR of 28.9 was found.

Kuorinka and Koskinen [1979] found a significant difference in neck MSDs between scissor makers (an occupation chosen for study because of its assembly-line repetitive hand tasks) and shop assistants (non-stereotypic, non-repetitive jobs) with an OR of 4.1. In the same study, comparing the different stereotypic, repetitive jobs in scissor-making, those in short-cycled tasks (2–9.5 sec) had no significantly different prevalence of neck disorders than workers in longer-cycled tasks (7.3–26 sec) (OR 1.6, 95% CI 0.7– 3.8). It is important to note that both the longer-cycled tasks and short-cycled tasks in Kuorinka's study would have been classified as "highly repetitive" in most other ergonomic studies [Silverstein et al. 1987; Chiang et al. 1993; Viikari-Juntura et al. 1991a; Kurppa et al. 1991]. When comparing two groups in which the level of repetitive exposure may not differ by much (in this case, where both groups have highly repetitive tasks), it is unlikely that one will find a significant difference because there is not enough variance between the exposures.

Three studies [Ekberg et al. 1994, 1995; Milerad and Ekenvall 1990] used health outcomes and exposure assessments based on self-reports and found significant associations between symptoms and repetitive work. The Ekberg studies specifically asked about "precise repetitive movements" in their questionnaire and controlled for confounders and effect modifiers (age, gender, having pre-school children) in their analyses. Milerad and Ekenvall [1990] compared dentists and pharmacists, stratified by gender, and found no association between neck or neck/shoulder MSDs with metabolic disease, smoking, leisure time, exposure, or vibration. Significant ORs of 2.0 to 2.6. for neck MSDs were reported for dentists compared to pharmacists.

Of those studies reporting no significant association between repetition and neck or neck/shoulder MSDs, none included exposure assessment or observations of the neck or neck/shoulder area that were both objective and independent of the hand/wrist. Several of these studies [Baron et al. 1991; Kiken et al. 1990; Hales et al. 1989; Ohlsson et al. 1989; Luopajärvi et al. 1979] categorized workers into high and low exposure groups based strictly on hand/wrist exposure and not arm, shoulder, or neck exposure. All of these studies reported ORs below 2.0.

In the study of VDT users by Bergqvist et al. [1995a], exposure was based on self-reports of "the presence of repeated work movements" for all work tasks and not specifically focused on the neck or neck/shoulder area. They found no significant association with neck/shoulder MSDs when the variable "repeated work movements" was analyzed in the logistic model alone, but found a significant relationship with a combination of variables: (1) workers wearing glasses, (2) who reported VDT use, and (3) VDT use for more than 20 hours/week. In this case, it was the combination of variables at higher levels of exposure (VDT use more than

20 hours per week) that was found to be statistically significant.

Temporal Relationship—Repetition and Neck/Shoulder MSDs

Of the prospective studies of neck MSDs that can be used to establish a temporal relationship between exposure to repetitive work and neck or neck/shoulder disorders, the study by Jonsson et al. [1988] fulfills all the four study criteria. Jonsson's study was a followup of the cohort studied by Kilbom et al. [1986], electronic workers who entered the study without MSDs. Exposure assessment pertaining specifically to the neck/shoulder area was completed three times over 3 years.

In the longitudinal study by Ohara et al. [1976], the authors attributed the increase in neck symptoms in cash register operators to the introduction of new electronic cash registers placed at unsuitable heights. They noted an increase in repetitiveness and an increase in awkward and static postures by cash register operators using the new registers. The authors reported a relationship between static loading and MSDs and found that a subsequent reduction in exposure to static loading resulted in less worker disability (sick leave).

Although temporality cannot be obtained from cross-sectional studies, several studies attempted to insure that disorders developed following the exposure being studied. In certain studies [Baron et al. 1991; Kiken et al. 1990; Hales et al. 1994; Hoekstra et al. 1994], the health outcome definition excluded persons reporting symptoms prior to the job or reporting acute injury thought to be unrelated to work, insuring that exposure preceded MSD occurrence. Other studies excluded participants with less than 6 months (or even longer) of job experience, thereby omitting from their study workers who may have developed their MSDs prior to working at the job of interest, or who had experienced discomfort or fatigue due to new activities or a "break-in period" at work. It is reasonable to assume that in those studies, given the exclusions required by the case definitions, the onset of exposure was prior to the onset of neck/shoulder MSDs in the majority of participants.

Consistency in Association for Repetition and Neck/Shoulder MSDs

In the studies fulfilling the four criteria [Ohlsson et al. 1995; Jonsson et al. 1988; Kilbom et al. 1986], significantly positive associations between neck MSDs and repetitive work were found. Many more studies involved workers in repetitive work from a range of industries (VDT workers, dentists, electronic assembly, sewing machine operators, etc.), comparing symptom prevalences to those in less repetitive jobs. There was also significant association between neck and neck/shoulder MSDs and jobs with repetitive tasks, with ORs between 1.6 and 5.9 [Onishi et al. 1976; Kuorinka and Koskinen 1979; Rossignol et al. 1987; Vihma et al. 1982; Kamwendo et al. 1991; Andersen and Gaardboe et al. 1993b; Ekberg et al. 1994, 1995; Schibye et al. 1995] indicating that workers exposed to higher levels of work risk factors have greater rates of neck and neck/shoulder symptoms. None of the studies that failed to find significant associations carried out exposure assessment of the neck or neck/shoulder.

Coherence of Evidence for Repetition

Studies outside the epidemiologic literature give supportive evidence that repetitive work is related to neck/shoulder disorders. Stevens et al. [1966] found that the neck injuries among fork-lift truck drivers were from repetitive, extreme head rotations needed for the operation of fork lift trucks and introduced the sideways-sitting driver forklift. Eklund et al. [1994] reported following up on a "sideways-sitting" forklift (in an unpublished study); these drivers experienced neck pain three times as often as other drivers on traditional forklifts—indicating that moderate head rotations during long periods of time can be more risky than short term and extensive head rotations. Nicholas [1990] reported in his discussion on pathophysiologic mechanisms of sports injuries that a low-load force with high repetition results in a gradual deterioration of tissue strength from strain to fatigue to deformation, with prefailure symptoms, such as pain on use, a common clinical sign of early inflammation from overuse.

Exposure-Response Relationship for Repetition

There were no studies reviewed that showed a clear dose-response relationship between repetition and neck and neck/shoulder MSDs.

Conclusions Regarding Repetition

The association between neck or neck/shoulder MSDs and repetitive work

was found to be statistically significant in 19 studies using different epidemiologic approaches and under different circumstances of exposure. Twenty-seven studies found ORs above one; of these, 13 were above 3.0. Almost all the studies (6 of 8) with non-significant associations used hand/wrist exposure assessments for their analyses and did not conduct specific neck, shoulder, or upper extremity (apart from hand/wrist) exposure assessment. (Only one of the studies finding significant associations did so using hand/wrist exposure assessment.) The possibility of misclassification affecting the results must be a consideration.

FORCE

Definition of Force for Neck and Neck/Shoulder MSDs

For our review, we included studies that examined force or forceful work or heavy loads to the neck and neck/shoulder, or described exposure as strenuous work involving the upper extremity that generates loads to the trapezius muscles. Most of the studies that examined force or forceful work as a risk factor for neck/shoulder had several concurrent or interacting physical work load factors.

Force has generally been defined as: (1) either externally as a load or internally as a force on a body structure, or (2) a force magnitude expressed in newtons or pounds or as a proportion of an individual's strength capacity, that is, of a person's MVC, usually measured by EMG. Most studies that have dealt with force loading of the neck or stress generated on the neck structures are from biomechanical studies performed in the laboratory. These studies are not included in this document. In the epidemiologic studies reviewed, force is usually estimated by either questionnaire, biomechanical models, in terms of weight lifted, electromyographic activity, or the variable, " heavy physical workload."

Seventeen studies reported results on the association between force or forceful work (in combination with repetition) and neck and neck/shoulder MSDs. Of the 17 studies of force and neck MSDs, 11 found a statistically significant positive association between force and neck or neck/shoulder MSDs; six others had non-significant findings. In terms of magnitude of the association, two studies had ORs greater than 3.0, seven were between 1.0 and 3.0, and two were less than 1.0. Six studies did not report their results in terms of ORs or prevalence rate ratios (PRRs) but reported that the findings were statistically significant at the $p<0.05$ level.

Studies Meeting the Four Criteria for Force and Neck/Shoulder MSDs

There were no studies that met the four epidemiologic evaluation criteria for forceful exertion of the neck.

Studies Not Meeting the Four Criteria for Force and Neck/Shoulder MSDs

Åaras [1994] carried out a cohort study of four groups, 15 female assembly workers making telephone exchanges, 27 female VDT users, 25 female data entry operators, and 29 male VDT users. Case definition for neck MSD was based on self-reports. However, musculoskeletal sick leave per man-labor years was also used as an endpoint. For force estimate the load on the

trapezius was measured by electromyography (EMG).

Quantification of the muscle load was done by ranking the interval estimate (0.1 s) to produce an amplitude probability distribution function. Both the total duration and number of periods per minute when muscle activity was below 1% maximum voluntary contraction (MVC) were calculated. Post-intervention (which involved changes to the workstation, tools, and organization of work)—see Table 2-4 at the end of the chapter for further explanation, the mean static trapezius load in assemblers was reduced from 4.3% MVC to 1.4%, the mean static trapezius load in VDT users reduced from 2.7% MVC to 1.6% MVC (post-intervention). Sick leave also decreased considerably. Because so many interventions were involved in this study, it is not clear to what intervention changes the decrease in sick-leave per man-labor years might be attributed.

Bjelle et al. [1981] compared 13 workers of an industrial plant consecutively seen at a health clinic with acute, nontraumatic shoulder-neck pain not due to causative disease or malformation compared to 26 controls, matched on age, gender and place of work.

In another cohort study, Veiersted and Westgaard [1994] followed 30 female chocolate manufacturing workers, 17 of whom contracted trapezius myalgia within 6 to 51 weeks compared to those workers who did not. Diagnosis was based on both symptoms and physical exam. There were prospective interviews every 10 weeks to detect symptoms of muscle pain. Daily “pain diaries” were also kept by subjects.

Exposure assessment consisted of measured static muscle tension recorded by EMG. Interviews concerning exposure at work were also conducted prospectively every 10 weeks for 1 year. Only 55% of the subjects were retained during the full study; however, the ‘drop-outs’ were follow-up subjects and had no significant differences in static muscle tension compared to the participants.

Viikari-Juntura et al. [1994] , the third longitudinal study discussed under force and neck and neck/shoulder MSDs, used questionnaire to assess neck symptoms and based exposure on job category, comparing 688 machine operators, 553 carpenters, and 591 office workers. For the initial evaluation, observation of work sites were performed. In multivariate analysis occupation, age, and current smoking were significant predictors in change from no neck trouble to severe neck trouble (ORs were not given for logistic model.)

Wells et al. [1983] evaluated letter carriers with an increased load on the shoulder from a mailbag. Letter carriers were compared to gas meter readers (without heavy loads) and postal clerks. A telephone survey was used to obtain both symptoms and exposure. This analysis was adjusted for age, number of years on the job, quetelet (body mass) ratio and previous work experience.

Of the studies in the tables, five (that did not fulfill all the inclusion criteria) examined the risk factor, force, either as trapezius muscle load (using EMG), or as forceful work in combination with other risk factors [Aåras 1994; Wells et al. 1983; Onishi et al. 1976; Andersen and Gaardboe 1993a; Punnett 1991]. Wells et al. [1983] found a significant difference ($p<0.05$) in reported neck pain between letter carriers and postal clerks and attributed it to weight from carrying heavy mail bags on shoulder straps. In the Wells study, confounding due to age, number of years on the job, previous work experience, or quetelet ratios was ruled out. As noted above, Onishi et al. [1976] reported that the operations studied required continuous contraction of the trapezius muscle to sustain the arms, estimated to be about 10 to 30% of the maximum contraction of the trapezius. This level, 10 to 30% of the maximum contraction, was found by Tanii et al. [1972] to induce static fatigue significant enough to produce electromyographic changes. Hales et al. [1989] and Kuorinka and Koskinen [1979] reported statistically significant ORs (1.6 and 4.1, respectively) for the association between neck MSDs and high levels of force combined with high levels of repetition estimated for the hand/wrist areas. There were no separate force measurements for the neck area. Both studies controlled for age, gender, and length of employment in the current job. Two of the four studies that used estimated hand and wrist exposure measurement combinations of force and repetition (but carried out no neck, shoulder, or upper extremity exposure measurements) found non-significant associations between neck MSDs and force/repetition exposure [Baron et al. 1991; Kiken et al. 1990].

Temporal Relationship—Force and Neck/Shoulder MSDs

See temporal relationship above in Repetition and Neck/Shoulder MSDs.

Consistency in Association for Force and Neck/Shoulder MSDs

Both Kilbom et al. [1986] in their cross-sectional study and Jonsson et al. [1988] in their follow-up cohort studies found that "time spent in physically heavy work before the present employment" appeared as a strong risk factor for deterioration of health of the neck/shoulder area (specifically, the health outcome was for the cervicobrachial region in the Jonsson study). Jonsson et al. [1988] noted that the physical demands of the previous jobs had only been assessed at the initial interview and constituted a subjective estimate. However, the relationship was strengthened by the consistency of findings in the prospective and cross-sectional studies.

Coherence of Evidence for Force

There is coherence with the biological mechanisms proposed by Hagberg [1984] for occupational muscle-related disorders, such as tension neck syndrome. The first mechanism concerns stress on the trapezius and surrounding muscles of the neck from heavy physical exertion that causes rupture of the muscle's z-discs, and an outflow of metabolites from the muscle fibers, and activation of pain receptors through edema or other mechanisms. This temporary high, local stress involving eccentric contractions in the shoulders improves with time through a re-orientation of collagen in the muscles. This mechanism is offered as an explanation for MSDs in workers unaccustomed to the work. The second mechanism is from local decreased blood flow (ischemia), as seen in assembly workers whose tasks involved dynamic, frequent contractions above 10 to 20% of the MVC and few rest breaks. Reduced blood flow was found to be correlated with myalgia (muscle pain) and ragged red fibers in 17 patients with chronic myalgia thought to be associated with static load during repetitive assembly work [Larsson et al. 1990]. The third pathophysiologic mechanism for muscle pain deals with energy metabolism disturbance, caused by long-term static contractions of the muscles. Supporting this theory was a study finding a correlation between muscle tension and plasma myoglobin among patients with regional muscle tenderness and pain [Dammeskiold-Samsøe et al. 1982].

Other laboratory studies have examined muscle damage that may arise during static muscle contractions used to maintain static postures. Hägg et al. [1990] proposed that while maintaining static postures (that have low force levels), the same low-threshold motor units are contracted repeatedly for prolonged periods, during which time they work close to their maximal capacity. This may lead to injury of these units, despite the fact that the total workload is low. This hypothesis was recently supported by a longitudinal study by Veiersted et al. [1993] who investigated the number of rest-pauses during muscle fiber activity using EMG recording from neck and shoulder muscles. Among subjects performing machine-paced repetitive packing work, those with symptoms had fewer rest-pauses (0.9 versus 8.4 per minute) and a tendency toward shorter total duration of rest-pauses in the muscle fiber activity of their trapezius muscle when compared with those without symptoms. These mechanisms of decreased blood flow, increased metabolite concentration, and prolonged activation of certain small units at near maximum capacity may explain the chronic myofascial shoulder pain seen in workers performing repetitive assembly work with static loading of the trapezius muscles [Hagberg and Kvarnström 1984; Larsson et al. 1988].

Exposure-Response Relationship for Force

Åaras [1994] reported that by reducing static muscle loading (an indication of force measurement) through equipment changes among VDT users, as well as improving workplace organization, he was able to decrease the prevalence of neck pain, decrease the number of sick days taken, and cause a significant reduction in trapezius load measured by EMG in VDT operators.

Conclusions Regarding Force

There is **evidence** for forceful exertion and neck MSDs in the epidemiologic literature. Most of the epidemiologic studies reviewed defined "forceful work" for the neck/shoulder as work activities that involve forceful arm or hand movements that, in turn, generate the loads to the neck/shoulder area; no study examined a relationship based on actual forceful neck movements. Of the 17 studies addressing force as one of the exposure factors, 5 found statistically significant associations but did not derive ORs; 2 found ORs greater than 3.0, 7 found ORs from 1 to 3.0, and 2 studies showed ORs less than 1.0. Many of the studies regarding measured force (as workload, etc.) and MSDs are in the biomechanical and ergonomic literature.

POSTURE

Definition of Posture for Neck and Neck/Shoulder MSDs

We included those articles that mentioned neck or head postures, adverse or extreme head or neck postures, or static postures of the head and/or neck.

Studies Reporting on Posture as a Work Factor for Neck and Neck/Shoulder Musculoskeletal Disorders

We included 31 studies of the association between extreme or static posture and neck and neck/shoulder MSDs, including TNS. Studies usually focused on the different prevalences of neck symptoms and/or physical findings in workers in occupations or tasks requiring some combination of forceful, repetitive movements, and extreme or static postures of the upper extremity, and compared them to workers in occupations without those requirements.

Twenty-seven studies that considered extreme or static posture found a statistically significant positive association between posture and neck or neck/shoulder MSDs; three had non-significant findings (Table 2-1. Overall, in terms of magnitude of the association, looking at both significant and non-significant findings, 13 studies had estimations of risk (ORs or PRRs) greater than 3.0, 9 had risk estimates between 1 and 3, and none had an estimate less than 1.0. Eleven studies did not report their results in terms of ORs or PRRs; of these, all but one found a significant relationship.

Studies Meeting the Four Evaluation Criteria

Of the 31 studies evaluating neck postures and neck MSDs, the four investigations mentioned above [Ohlsson et al. 1995; Jonsson et al. 1988; Kilbom and Persson 1987; Kilbom et al. 1986] fulfilled the four evaluation criteria. Three of these studies [Jonsson et al. 1988; Kilbom et al. 1986; Kilbom and Persson 1987], dealt with the same cohort; female electronics workers followed for 3 successive years. These studies found significant association between posture variables and neck MSDs; however, none used methods that reported ORs.

Studies Not Meeting the Four Criteria for Posture and Neck/Shoulder MSDs

Bernard et al. [1993] carried out a cross-sectional study of 894 newspaper employees using a questionnaire survey for case definition based on frequency, duration, and intensity of symptoms in the neck. Exposure was based upon both questionnaire and job analysis. Time spent on the telephone was associated with an increased prevalence of neck MSDs, with a slightly elevated OR of 1.4. Analysis was controlled for age, gender, height, psychosocial factors, and medical conditions.

Kukkonen et al. [1983] compared 104 data entry operators with 57 female workers in varying office tasks. Neck MSD was based on pre-determined symptom and physical exam. Exposure was based on observation of posture, movements and working techniques, assessment of equipment, interview with workers and supervisors. An intervention consisting of adjustment of office furniture and equipment was carried out. The study group was given a short course of basic training on pertinent aspects of ergonomics. Four lessons on relaxation was given by means of exercises. There was no controlling of confounders. There was a significant decrease in tension neck syndrome among the cases involved in the intervention compared to those workers who had no change.

Linton and Kamwendo [1989] surveyed 22,180 employees undergoing screening examinations at their occupational health care service in Sweden. Neck cases defined from questionnaire responses as those persons reporting "yes" to having seen a health care professional for neck pain in the last year. Cases were compared to "non-cases" defined by outcome (neck pain). Exposure was based on questionnaire responses regarding heavy lifting, monotonous or assembly line work, sitting, uncomfortable work postures (bending and twisting), and vibration. The psychosocial work environment was also studied; the analysis was stratified for age and gender.

As part of a longitudinal study, Viikari-Juntura et al. [1994] studied 154 subjects from Helsinki, Finland that originally entered the study in 1955, and had repeated cross-sectional exams from 1961 to 1963. During that time, 1084 subjects underwent cross-sectional examination. In 1985, a questionnaire was sent to all subjects; 801 (74%) responded. Of the respondents, 180 lived in the Helsinki area. It was from this group that 162 responded. Eight were excluded due to illnesses. Outcome was based on questionnaire data for this study — because of small number of abnormal physical findings, the physical exam was eliminated from analysis. Exposure was also based on survey, asking the amount of work with hands overhead, work in forward bent position, and work in twisted or bent position. This analysis was controlled for physical and creative hobbies, with no interactions seen.

In a cross-sectional study of machine operators, carpenters were compared to office workers by Tola et al. [1988], who used a postal questionnaire to obtain both health outcome and exposure information. Analysis used "occupation" to examine relationships. Pain Drawing Diagrams were used to distinguish body areas. For the logistic regression model a 12 month prevalence of neck and shoulder symptoms on 8 days or more was used. The logistic regression models were adjusted for years working in an occupation and age.

Welch et al. [1995] examined 39 electricians at a screening convention using surveys to collect information on symptoms and exposures. The questionnaire included questions concerning the frequency of tasks performed, including the percent of time spent hanging duct work. The analysis did not control for confounders except for length of employment.

Strength of Association for Posture

Ohlsson et al.'s [1995] study, discussed previously, compared female industrial workers performing repetitive tasks to referents without such exposure and found significant associations (p<0.05) between (1) neck and neck/shoulder diagnoses with time spent in neck flexion, with critical angles greater than 15E; and (2) neck/shoulder diagnoses and time spent with upper arm abduction greater than 60E.

Kilbom et al. [1986], in the initial paper concerning the electronic workers, reported two findings: (1) that the more dynamic the working technique, the fewer neck symptoms experienced by electronic workers; and (2) that the greater the average time per work cycle spent in neck flexion, the greater the association with symptoms in the neck and neck/shoulder angle. A statistically significant association (p<0.05) was also obtained from the job analysis variables describing neck forward flexion and upper arm elevation and neck and neck/shoulder disorders. Jonsson et al. [1988], in the follow-up study, performed an analysis that grouped the different parts of the neck and upper extremity into a health outcome labeled “cervicobrachial disorder” (unlike the cross-sectional study by Kilbom et al. [1986] that used “neck” and shoulder”). They found that the relationships between MSDs and neck forward flexion, upper arm elevation, and cervicobrachial disorders weakened (compared with the results that Kilbom et al. [1986] had found), but that the results still remained statistically significant in some of the multifactorial analyses (no numerical results were reported). The most important finding, according to the authors, was that reallocation to more varied work tasks was a strong predictor of improvement over the second year. This change would have decreased static loading and increased the dynamic pattern of movements of the workers.

Of those studies not fulfilling the four criteria, results regarding extreme or static posture were similar to those of the studies which did fulfill them. Sakakibara et al. [1995] found a significant difference in the prevalence of neck MSDs when they examined orchard workers who picked and bagged pears and two months later picked and bagged apples. Exposure was assessed by job analysis and posture measurements of two representative workers. Arm and neck elevation was significantly greater for bagging pears (more than 90E for 75% of the time) than for bagging apples (less than 40% of the time). The same authors found similar results in 1987 when only the symptoms of orchard workers were studied. They found significant a positive association between posture and neck MSDs, reporting histograms (not ORs) in their article.

Although they did not mention the participation rates in their methods, Aåras [1994], Veiersted and Westgaard [1994], and Bjelle et al. [1981] found significant relationships between postures and neck MSDs (they fulfilled the other three criteria). Veiersted and Westgaard [1994] found an association between “perceived strenuous postures" and neck MSDs (OR 7.2), but found that these perceived postures were not reflected in any of the conventional EMG parameters (static, median or peak loads) measured in the participants. One explanation for these results may be information bias, if the data concerning perceived strenuous posture are from questionnaires. Another explanation may be that EMG testing results reflect parameters for a single day, whereas symptoms were asked about concerning the entire previous year.

Several studies that carried out no independent assessment of ergonomic factors, but relied on self-reported exposure found significant relationships between posture variables and neck disorders. Ekberg et al. [1994] found an OR of 4.8 for the variable "work with lifted arms," and an OR of 3.6 for "uncomfortable sitting position" and neck MSDs. Hales et al. [1994] found that "use of bifocals" (OR 3.8) in VDT users was significantly associated with neck MSDs; this variable was interpreted to be a surrogate for neck posture, as bifocals require either neck flexion or extension for eye accommodation when viewing a VDT screen. Bernard et al. [1994] reported that as workers' time spent on the telephone increased, so did the ORs for neck symptoms, and interpreted this variable as a surrogate for static posture requiring neck deviation to cradle the telephone receiver. Holmström et al. [1992] found that the odds of workers with neck MSDs reporting working with hands above their shoulders for greater than 4 hrs/day compared with those reporting less than 1 hr/day was 2.0, a statistically significant finding. Bergqvist et al. [1995a] reported an OR of 4.4 for workers using highly placed keyboards in their logistic modeling of neck MSDs. Kuorinka and Koskinen [1979] found an increased OR (4.1) of neck MSDs for scissor makers (chosen for their stereotypic, repetitive work using extreme postures) compared to shop assistants, although no quantitative measurements or observations of neck posture were reported. One study by Hünting et al. [1981] showed a fairly strong association (OR 4.9) with constrained postures and neck MSDs in those workers having neck flexion of more than 56E and an OR of 9.9 from the comparison of groups. Several articles with significant posture and neck MSD associations dealt with comparisons of workers in occupations chosen for higher observed combinations of exposure factors and compared them to workers with fewer observed exposure stressors: Viikari-Juntura et al. [1994], OR 3.9 to 4.2; Milerad and Ekenvall [1990], OR 2.6; and Wells et al. [1983], OR 2.57.

For those studies that did not find a significant relationship, 2 out of the 3 did not carry out observation or measurement (ergonomic assessment) of the neck or upper extremity postures. Ferguson [1976] stated that seven body dimensions were measured in the telephonists studied, but that neither discomfort nor aching were linked with any of these body postures. The article does not mention the body postures that were measured. Ferguson's conclusion, that "physical complaints in telephonists are probably due to static load on joints and muscles occasioned by the fixed forward bent position determined by visual, auditory and manipulative tasks." Ferguson's data are contrary to the conclusions presented. These conclusions may then only be speculative.

Temporality for Extreme or Static Postures

The prospective study by Veiersted and Westgaard [1994] followed the development of trapezius myalgia among 30 female chocolate manufacturing workers. Seventeen workers developed the MSD within 6 to 51 weeks of starting work. Perceived strenuous postures on the assembly line were found to contribute to the disorders. Although retention of subjects was low (55%), the authors found that the "drop-outs" did not differ in exposure estimates and symptom reporting from those retained in the study. The prospective study of Viikari-Juntura et al. [1994] used self-reported symptoms and exposure defined by occupational status to find a temporal relationship between the development of severe and persistent severe neck pain and jobs involving dynamic work, static posture, and whole body vibration, as compared to office work.

Consistency in Association for Extreme or Static Postures and Neck/Shoulder MSDs

Of the 31 studies we reviewed reporting results on the association between specific or static posture and neck and neck/shoulder MSDs, 27 found statistically significant associations. There were many different studies reporting ORs of greater than 3.0 with CIs above 1, indicating that the effects were not explained by chance. Consistent associations were also found in those studies dealing with specific postures and neck MSDs across many industries, from fish workers [Ohlsson et al. 1995] to fruit pickers [Sakakibara et al. 1995], to assembly line workers [Jonsson et al. 1988], to garment workers [Vihma et al. 1982; Andersen and Gaardboe 1993a,b].

Coherence of Evidence for Extreme Or Static Postures

See section above under Coherence of Evidence for Force.

Exposure-Response Relationship for Specific or Static Postures

The study by Ohara et al. [1976], mentioned earlier, not only portrayed the multifactorial nature of neck and shoulder MSDs, but documented that an increase in specific and static postures by cash register operators using new registers placed on unsuitable counter heights increased symptoms in neck MSDs.

Several studies have suggested an exposure-response effect between increased level or duration of exposure and an increase in number of cases of neck MSDs. Burt et al. [1990], in their investigation at a major urban newspaper, found that an increase in the self-reported percentage of time spent typing at VDT keyboards was associated with a moderate increase in neck symptoms. (Job analysis found a significant relationship between independent observation of time spent typing and self-reported time) Keyboard time was considered by the authors to be a surrogate for time spent with the neck held in static postures with arms unsupported. Rossignol et al. [1987] found that the prevalence of neck symptoms among 1,545 clerical workers increased with the number of hours per day using VDTs. Knave et al. [1985] found that, among VDT operators, total daily working hours and time spent at the VDT screen were significant risk factors for neck pain. Andersen and Gaardboe [1993a,b] found an exposure-response relationship between persistent neck pain and years of being a sewing machine operator, controlling for age.

Conclusions Regarding Extreme or Static Postures

Overall, the strength of the association (OR ranging from about 1.6 [Vihma et al. 1982] to 7 [Veiersted and Westgaard 1994], dropping the outliers) between specific postures and neck MSDs was similar between studies using the most restrictive criteria and carrying out a prospective design and those that used symptom-based health outcome or self-reported exposures to static or specific postures and cross-sectional methods. We conclude that there is **strong evidence** for support of an association between static or specific postures and neck and neck/ shoulder MSDs based on strength of association criteria. A positive relationship has been observed between exposure to this risk factor and neck or neck/shoulder MSDs in studies where chance, bias, and confounding can be ruled out with reasonable confidence.

VIBRATION

No study of neck MSDs met the four criteria to address strength of association between vibration and neck MSDs and only one of the reviewed studies in the tables mentioned neck MSDs and vibration. Viikari-Juntura et al. [1994] selected study groups for their longitudinal study based on different work exposures. Machine operators exposed to static work and whole-body vibration were compared to carpenters exposed to dynamic physical work and presumably no vibration to see whether occupational status was related to neck MSDs. Results found that the OR for progressing from no neck pain to moderate to severe neck trouble was from 3.9 to 4.2; for operators compared to carpenters; a significant difference. No vibration measurements were performed in this study, and vibration was likely to be confounded by neck twisting and static loads.

Conclusions—Vibration and Neck or Neck/Shoulder MSDs

We conclude that there is **insufficient evidence** to support an association between vibration and neck or neck/shoulder MSDs based on strength-of-association criteria. Too few studies of neck or neck/shoulder MSDs have examined the relationship between exposure to vibration and to draw any conclusions about their relationship.

NECK OR NECK/SHOULDER MSDs AND THE ROLE OF CONFOUNDERS

As in many MSDs, prevalence of neck and neck/shoulder disorders tends to increase with age. Therefore, it is important that studies take into account when examining the strength of occupational versus non-occupational factors. Age and gender were the primary potential confounders that investigators addressed in many of the studies on neck and neck/shoulder MSDs (The tables at the end of the chapter list summaries of each of the articles and include which particular covariates or confounders were considered.) These were either dealt with by logistic regression modeling, as in the case of age (e.g., Andersen and Gaardboe [1993a]; Rossignol et al. [1987]; Tola et al. [1988]; Ohlsson et al. [1989]; Baron et al. [1991]), through matching of case subjects and referents (e.g., Vihma et al. [1982]), or through study of a single gender (e.g., Luopajärvi et al. [1979]; Hünting et al. [1994]), or stratifying by gender [Sakakibara et al. 1995]. Most studies performed univariate analysis prior to logistic regression to consider factors which needed to be introduced into the logistic models as confounders or covariates.

Almost all the studies we reviewed accounted for the confounders of age and gender. Many of the studies controlled for leisure exercises [Andersen and Gaardboe [1993a,b] smoking (Linton [1990]; Milerad and Ekenwall [1990]; Bergqvist et al. [1995a,b]; Viikari-Juntura et al. [1994]), medical conditions [Bernard et al. [1994]; Hales et al. [1994]). Reviewing the methods and results of these studies, the confounding factors do not account for the consistent relationship that is found with the work-related factors.

CONCLUSIONS

Interpreting association for individual workplace factors is difficult, as most epidemiologic studies of MSDs used populations selected because of multiple factors (such as forceful exertion and repetitive tasks). Unlike laboratory experiments, one cannot isolate exposure factors, nor alter some factors while keeping others constant to insure accuracy in examining, recording, and interpreting results. However, one can examine the body of epidemiologic evidence and infer relationships. There have been over 40 epidemiologic studies which have examined work factors and their relationship to neck and neck/shoulder MSDs. Many studies identified individuals in heavier industrial occupations and compared them to workers in light industry or office environments. Other studies identified a symptomatic group of workers, or those with symptoms and physical exam abnormalities, and compared them to asymptomatic workers at the same worksite, or to population referents, and looked for differences in exposure. These approaches, although quite different, by and large have chosen to focus on similar workplace risk factors. These include repetition, forceful exertions, and constrained or static postures, usually found in combination.

There is also reasonable **evidence** for a causal relationship between highly repetitive work and neck and neck/shoulder MSDs. Most of the epidemiologic studies reviewed defined "repetitive work" for the neck as work activities which involve continuous arm or hand movements which affect the neck/shoulder musculature and generate loads to the neck/shoulder area; fewer studies examined relationships based on actual repetitive neck movements. The two studies which measured repetitive neck movements by head position (using frequency and duration of movements), and fulfilled the four criteria, found strong associations with neck/shoulder MSDs. In those studies defining repetitive work as continuous arm or hand movements affecting the neck/shoulder, nine studies found statistically significant ORs greater than 3.0. Eight studies fulfilled all the criteria except for objective exposure assessment and measured repetition for the hand/wrist, not the neck. Of these, three had statistically significant ORs greater than 3, and five had non-significant ORs, all under 2.0.

There is reasonable **evidence** for forceful exertion and neck MSD found in the epidemiologic literature. Most of the epidemiologic studies reviewed defined "forceful work" for the neck/shoulder as work activities which involve forceful arm or hand movements which generate the loads to the neck/shoulder area; no study examined a relationships based on actual forceful neck movements. Of the 17 studies

addressing force as one of the exposure factors, five studies found statistically significant associations but did not derive ORs; two studies found ORs greater than 3.0, seven studies from 1 to 3.0, and 2 studies with ORs less than 1.0.

There is **strong evidence** that working groups with high levels of static contraction, prolonged static loads, or extreme working postures involving the neck/shoulder muscles are at increased risk for neck/shoulder MSDs. Consistently high ORs (12 studies found statistically significant ORs over 3.0) for tension neck syndrome associated with static postures or static loads have been found.

The epidemiologic data are **insufficient** to document relationship of vibration and neck disorders. The few prospective studies which have included interventions to decrease workplace risk factor exposures, including decreasing repetitive work and less extreme working postures, have shown a decrease in incidence of neck MSDs, and an improvement in symptoms among affected workers. These data provide additional evidence that these disorders are related to work factors.

However, cumulative exposure-response data is lacking, although VDT studies using surrogate exposure variables suggests a relationship.

Table 2-1. Epidemiologic criteria used to examine studies of neck MSDs associated with repetition

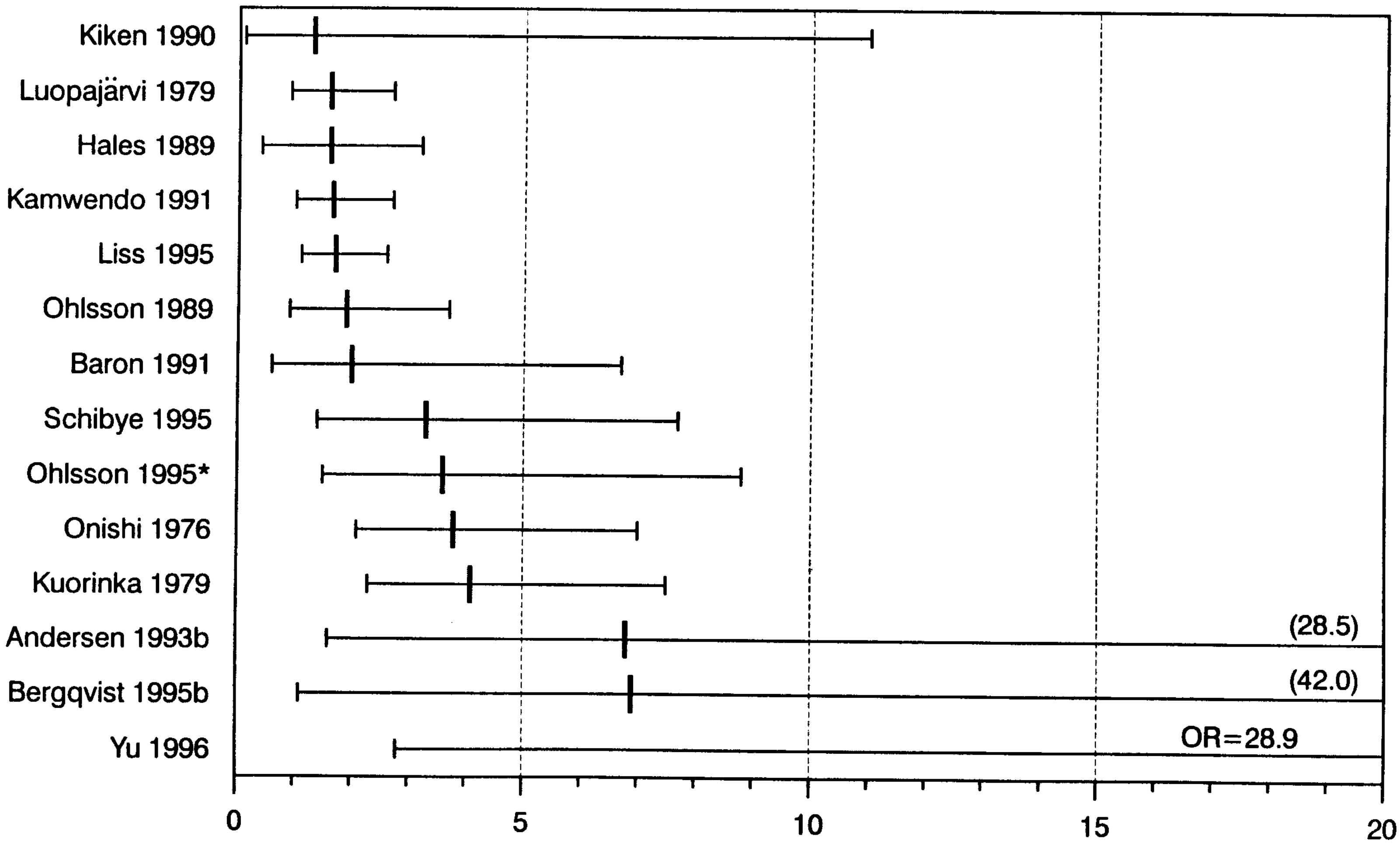
Study (first author and year)	Risk indicator (OR, PRR, IR or *p*-value)*,†	Participation rate $70%	Physical examination	Investigator blinded to case and/or exposure status	Basis for assessing neck exposure to repetition
Met all four criteria:					
Ohlsson 1995	3.6†	Yes	Yes	Yes	Observation or measurements
Met at least one criterion:					
Andersen 1993b	6.8†	Yes	Yes	Yes	Job titles or self-reports
Baron 1991	2.0	No	Yes	Yes	Job titles or self-reports
Bergqvist 1995b	6.9†	Yes	Yes	Yes	Job titles or self-reports
Hales 1989	1.6	Yes	Yes	Yes	Job titles or self-reports
Kamwendo 1991	1.65†	Yes	No	NR‡	Job titles or self-reports
Kiken 1990	1.3	Yes	Yes	Yes	Job titles or self-reports
Knave 1985	NR†	Yes	No	NR	Job titles or self-reports
Kuorinka 1979	4.1†	Yes	Yes	NR	Job titles or self-reports
Luopajärvi 1979	1.6	Yes	Yes	Yes	Job titles or self-reports
Onishi 1976	3.8†	NR	Yes	NR	Observation or measurements
Sakakibara 1987	NR†	Yes	No	NR	Job titles or self-reports
Schibye 1995	3.3†	Yes	No	NR	Job titles or self-reports
Yu 1996	28.9†	Yes	No	NR	Job titles or self-reports
Met none of the criteria:					
Liss 1995	1.7†	No	No	No	Job titles or self-reports
Ohlsson 1989	1.9	NR	No	NR	Job titles or self-reports

*Some risk indicators are based on a combination of risk factors—not on repetition alone (i.e., repetition plus force, posture, or vibration). Odds ratio (OR), prevalence rate ratio (PRR), or incidence ratio (IR).

†Indicates statistical significance. If combined with NR, a significant association was reported without a numerical value.

‡Not reported.

Figure 2-1. **Risk Indicator for "Repetition" and Neck Musculoskeletal Disorders**
(Odds Ratios and Confidence Intervals)



* Studies which met all four criteria.
Note: Two studies indicated statistically significant associations without reporting odds ratios. See Table 2-1.

Table 2-2. Epidemiologic criteria used to examine studies of neck/shoulder MSDs associated with repetition

Study (first author and year)	Risk indicator (OR, PRR, IR or *p*-value)*,†	Participation rate ≥70%	Physical examination	Investigator blinded to case and/or exposure status	Basis for assessing neck/shoulder exposure to repetition
Met all four criteria:					
Jonsson 1988	NR[†,‡]	Yes	Yes	Yes	Observation or measurements
Ohlsson 1995	4.6[†]	Yes	Yes	Yes	Observation or measurements
Met at least one criterion:					
Andersen 1993a	4.6[†]	Yes	No	Yes	Job titles or self-reports
Bergqvist 1995a	3.6	Yes	No	Yes	Observation or measurements
Blåder 1991	NR[†]	Yes	Yes	No	Job titles or self-reports
Ekberg 1994	15.6[†]	Yes	No	NR	Job titles or self-reports
Ekberg 1995	1.2[†]	Yes	No	NR	Job titles or self-reports
Hünting 1981	9.9[†]	NR	Yes	NR	Observation or measurements
Milerad 1990	2.1[†]	Yes	No	NR	Job titles or self-reports
Punnett 1991	1.8	Yes	No	NR	Observation or measurements
Rossignol 1987	1.8–4.6[†]	Yes	No	NR	Job titles or self-reports
Vihma 1982	1.6[†]	NR	No	NR	Observation or measurements

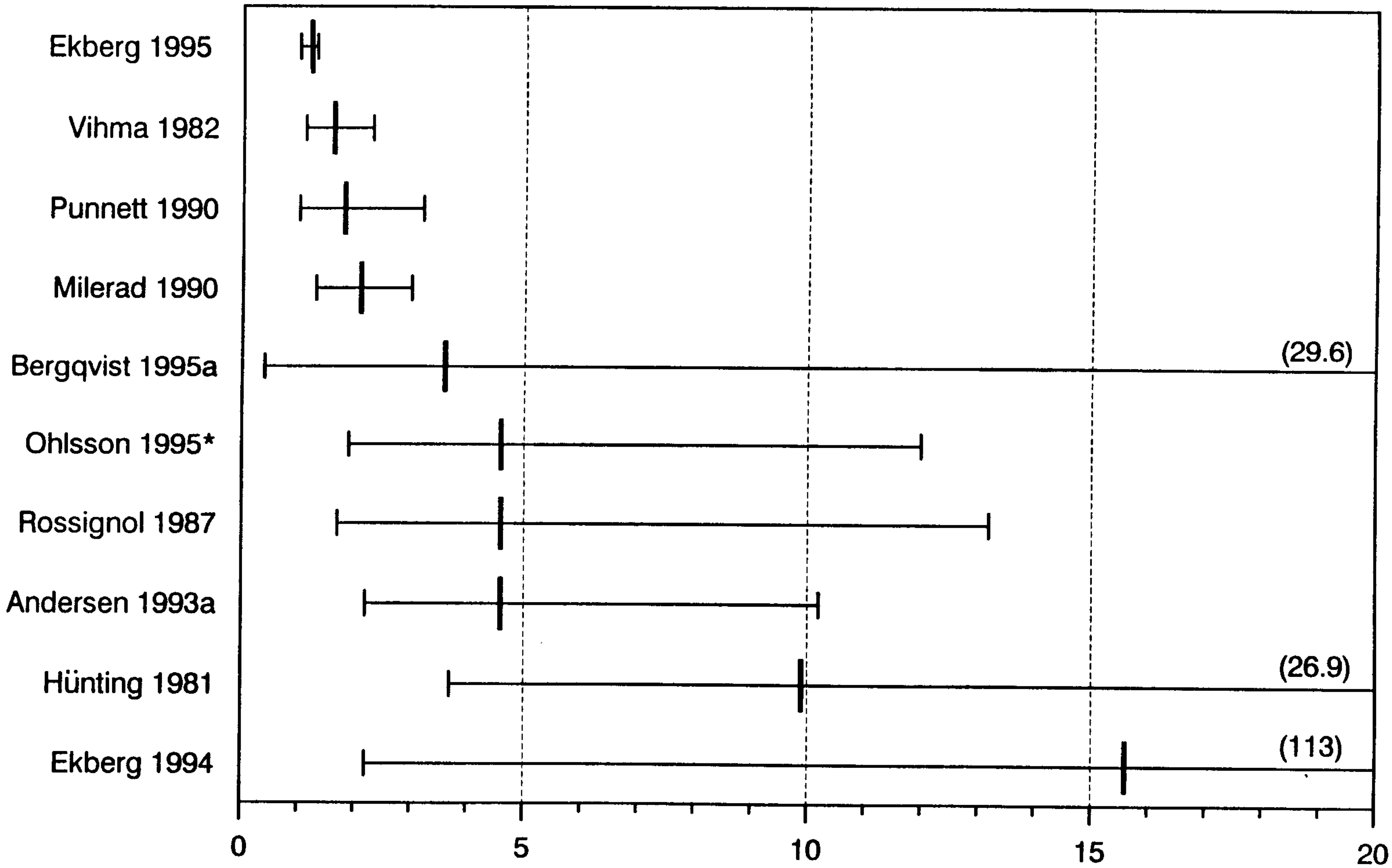
*Some risk indicators are based on a combination of risk factors—not on repetition alone (i.e., repetition plus force, posture, or vibration). Odds ratio (OR), prevalence rate ratio (PRR), or incidence ratio (IR).

†Indicates statistical significance. If combined with NR, a significant association was reported without a numerical value.

‡Not reported.

Figure 2-2. **Risk Indicator for "Repetition" and Neck/Shoulder Musculoskeletal Disorders**

(Odds Ratios and Confidence Intervals)



* Studies which met all four criteria.

Note: Two studies indicated statistically significant associations without reporting odds ratios. See Table 2-2.

Table 2-3. Epidemiologic criteria used to examine studies of neck MSDs associated with force

Study (first author and year)	Risk indicator (OR, PRR, IR or *p*-value)*,†	Participatio n rate $70%	Physical examinatio n	Investigator blinded to case and/or exposure status	Basis for assessing neck exposure to force
Met at least one criterion:					
Baron 1991	2.0	No	Yes	Yes	Job titles or self-reports
Hales 1989	1.6	Yes	Yes	Yes	Job titles or self-reports
Kiken 1990	1.3	Yes	Yes	Yes	Job titles or self-reports
Kuorinka 1979	4.1†	Yes	Yes	NR‡	Job titles or self-reports
Luopajärvi 1979	1.6	Yes	Yes	Yes	Job titles or self-reports
Veiersted 1994	6.7†	No	Yes	NR	Observation or measurements
Viikari-Juntura 1994	3.0†	Yes	No	Yes	Job titles or self-reports
Wells 1983	2.57†	Yes	No	NR	Job titles or self-reports
Met none of the criteria:					
Liss 1995	1.7†	No	No	No	Job titles or self-reports

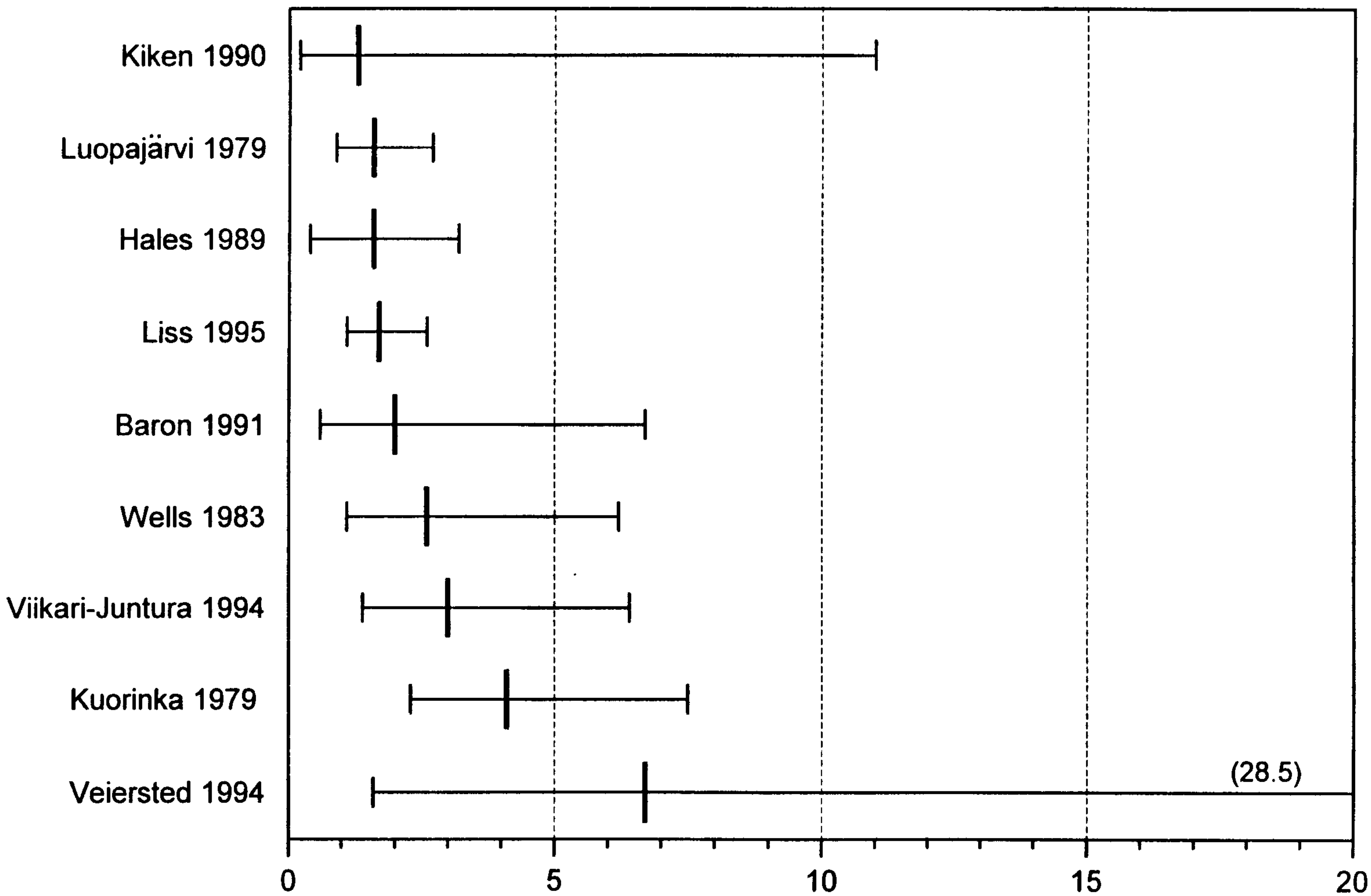
*Some risk indicators are based on a combination of risk factors—not on force alone (i.e., force plus repetition, posture, or vibration). Odds ratio (OR), prevalence rate ratio (PRR), or incidence ratio (IR).

†Indicates statistical significance.

‡Not reported.

Figure 2-3. **Risk Indicator for "Force" and Neck Musculoskeletal Disorders**

(Odds Ratios and Confidence Intervals)



Note: One study indicated a statistically significant association without reporting odds ratios. See Table 2-3.

Table 2-4. Epidemiologic criteria used to examine studies of neck/shoulder MSDs associated with force

Study (first author and year)	Risk indicator (OR, PRR, IR or *p*-value)*,†	Participation rate ≥70%	Physical examination	Investigator blinded to case and/or exposure status	Basis for assessing neck/shoulder exposure to force
Met at least one criterion:					
Åaras 1994	NR[†,‡]	NR	No	NR	Observation or measurements
Andersen 1993a	3.2	Yes	No	Yes	Job titles or self-reports
Bjelle 1981	NR[†]	NR	Yes	Yes	Observation or measurements
Jonsson 1988	NR[†]	Yes	Yes	Yes	Job titles or self-reports
Punnett 1991	0.9 (females) 1.8 (males)	Yes	No	NR	Observation or measurements

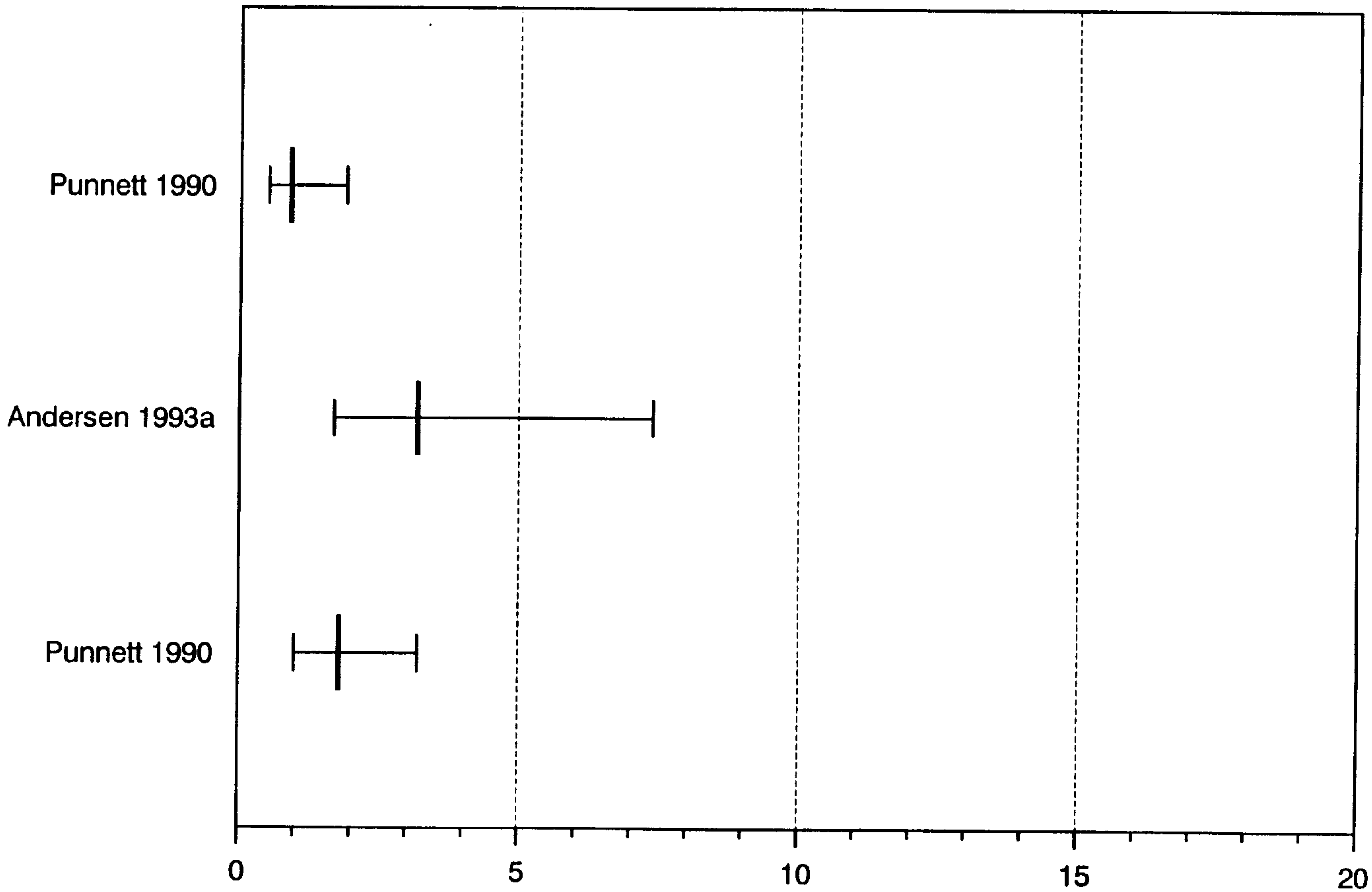
[*]Some risk indicators are based on a combination of risk factors—not on force alone (i.e., force plus repetition, posture, or vibration). Odds ratio (OR), prevalence rate ratio (PRR), or incidence ratio (IR).

[†]Indicates statistical significance. If combined with NR, a significant association was reported without a numerical value.

[‡]Not reported.

Figure 2-4. **Risk Indicator for "Force" and Neck/Shoulder Musculoskeletal Disorders**

(Odds Ratios and Confidence Intervals)



Note: Three studies indicated statistically significant associations without reporting odds ratios. See Table 2-4.

Table 2-5. Epidemiologic criteria used to examine studies of neck MSDs associated with posture

Study (first author and year)	Risk indicator (OR, PRR, IR or *p*-value)*,†	Participation rate ≥70%	Physical examination	Investigator blinded to case and/or exposure status	Basis for assessing neck exposure to posture
Met at least one criterion:					
Bernard 1994	1.4[†]	Yes	No	Yes	Job titles or self-reports
Ferguson 1976	NR[‡]	Yes	No	No	Observation or measurements
Hales 1994	3.8[†]	Yes	Yes	Yes	Job titles or self-reports
Kamwendo 1991	1.65[†]	Yes	No	NR	Job titles or self-reports
Kukkonen 1983	3.6[†]	NR	Yes	Yes	Job titles or self-reports
Kuorinka 1979	4.1[†]	Yes	Yes	NR	Job titles or self-reports
Linton 1990	3.5[†]	Yes	No	NR	Job titles or self-reports
Onishi 1976	3.8[†]	NR	Yes	NR	Observation or measurements
Sakakibara 1987	NR[†]	Yes	No	NR	Observation or measurements
Sakakibara 1995	1.5	Yes	Yes	NR	Observation or measurements
Veiersted 1994	7.2[†]	No	Yes	NR	Observation or measurements
Viikari-Juntura 1994	3.9–4.2[†]	Yes	No[§]	Yes	Job titles or self-reports
Welch 1995	7.5	Yes	No	No	Job titles or self-reports
Wells 1983	2.57[†]	Yes	No	NR	Job titles or self-reports
Yu 1996	784.4[†]	Yes	No	NR	Job titles or self-reports

*Some risk indicators are based on a combination of risk factors—not on posture alone (i.e., posture plus force, repetition, or vibration). Odds ratio (OR), prevalence rate ratio (PRR), or incidence ratio (IR).

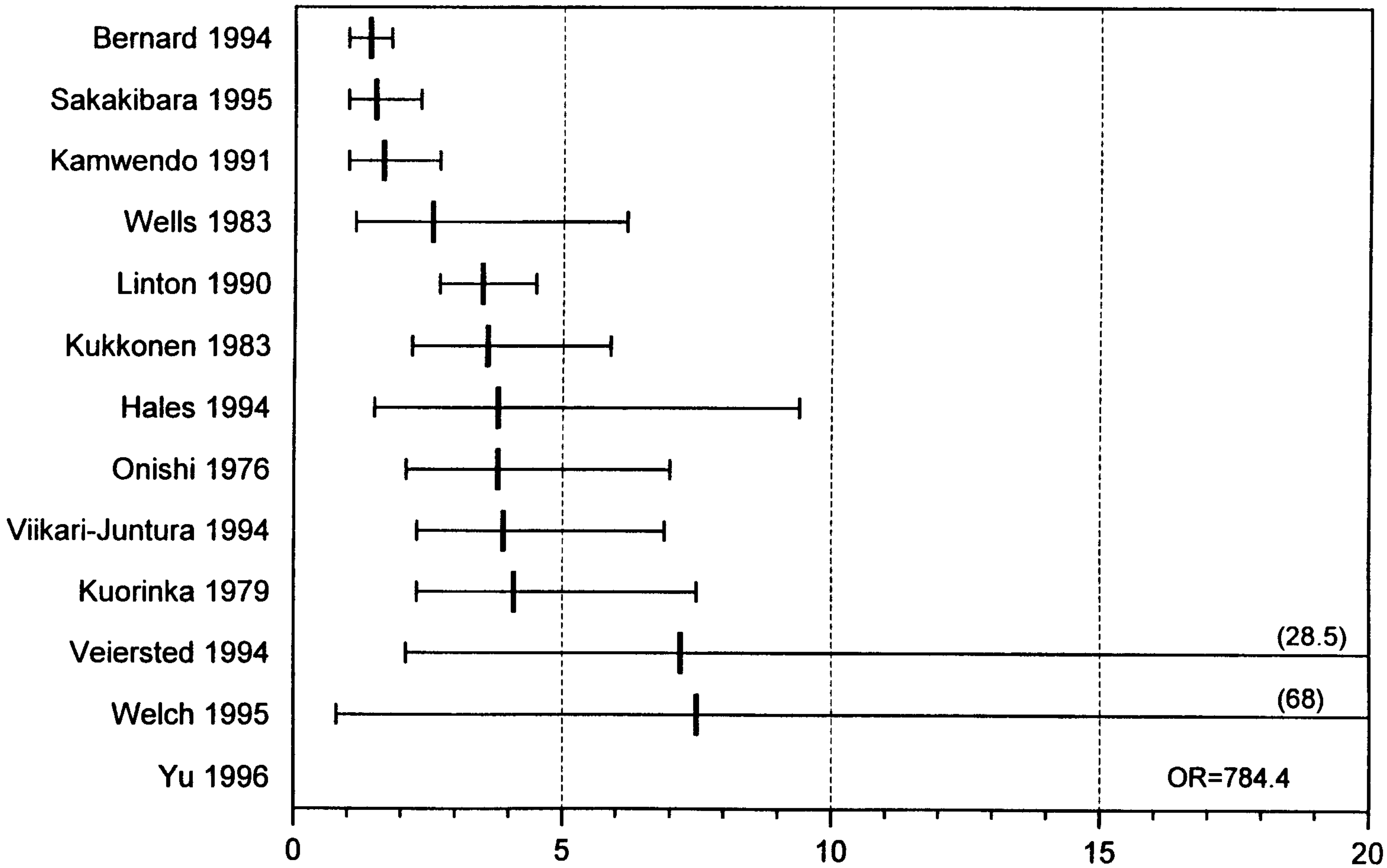
†Indicates statistical significance. If combined with NR, a significant association was reported without a numerical value.

‡Not reported.

§Physical examinations were not analyzed because there were too few cases.

Figure 2-5. **Risk Indicator for "Posture" and Neck Musculoskeletal Disorders**

(Odds Ratios and Confidence Intervals)



Note: Two studies indicated statistically significant associations without reporting odds ratios. See Table 2-5.

Table 2-6. Epidemiologic criteria used to examine studies of neck/shoulder MSDs associated with posture

Study (first author and year)	Risk indicator (OR, PRR, IR or *p*-value)*,†	Participation rate $70%	Physical examination	Investigator blinded to case and/or exposure status	Basis for assessing neck/shoulder exposure to posture
Met all four criteria:					
Jonsson 1988	NR†,‡	Yes	Yes	Yes	Observation or measurements
Kilbom 1986	NR†	Yes	Yes	Yes	Observation or measurements
Ohlsson 1995	NR†	Yes	Yes	Yes	Observation or measurements
Met at least one criterion:					
Åaras 1994	NR†	NR	No	NR	Observation or measurements
Bergqvist 1995a	4.4†	Yes	No	Yes	Observation or measurements
Bjelle 1981	NR†	NR	Yes	Yes	Observation or measurements
Blåder 1991	NR†	Yes	Yes	No	Job titles or self-reports
Ekberg 1994	4.8†, 3.6†	Yes	No	NR	Job titles or self-reports
Holmström 1992	2.0†	Yes	No	Yes	Job titles or self-reports
Hünting 1981	9.9†	NR	Yes	NR	Observation or measurements
Milerad 1990	2.6†	Yes	No	NR	Job titles or self-reports
Rossignol 1987	1.8, 4.0†, 4.6†	Yes	No	NR	Job titles or self-reports
Ryan 1988	NR†	Yes	No	Yes	Observation or measurements
Tola 1988	1.8†	Yes	No	NR	Job titles or self-reports
Vihma 1982	1.6†	NR	No	NR	Observation or measurements
Viikari-Juntura 1991a	1.5	Yes	Yes§	NR	Job titles or self-reports

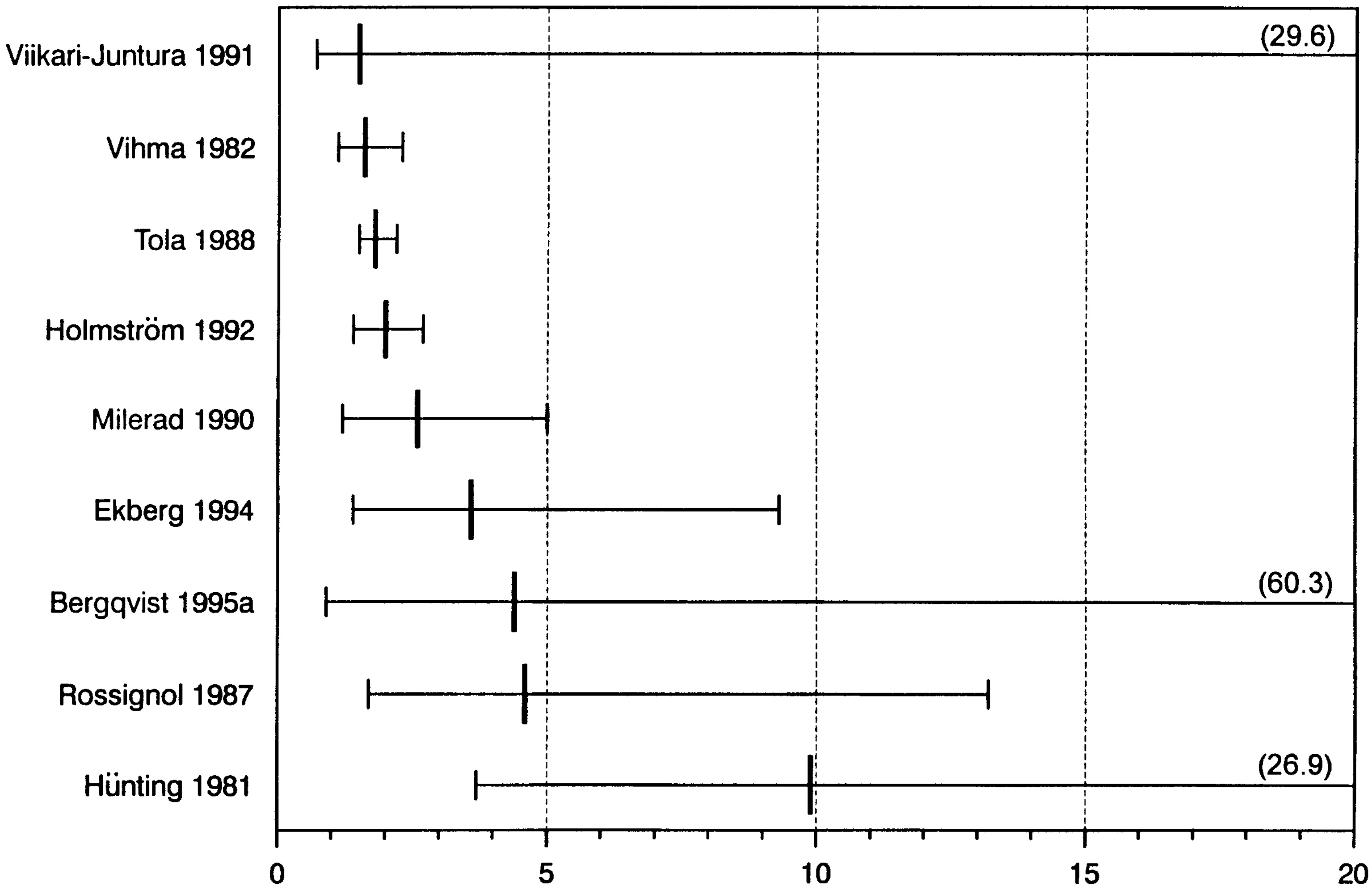
*Some risk indicators are based on a combination of risk factors—not on posture alone (i.e., posture plus force, repetition, or vibration). Odds ratio (OR), prevalence rate ratio (PRR), or incidence ratio (IR).

†Indicates statistical significance. If combined with NR, a significant association was reported without a numerical value.

‡Not reported.

Figure 2-6. **Risk Indicator for "Posture" and Neck/Shoulder Musculoskeletal Disorders**

(Odds Ratios and Confidence Intervals)



Note: Seven studies indicated statistically significant associations without reporting odds ratios. See Table 2-6.

Table 2–7. Epidemiologic studies evaluating work-related neck musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD Prevalence: Exposed workers	MSD Prevalence: Referent group	MSD Prevalence: RR, OR, or PRR	MSD Prevalence: 95% CI	Comments
Andersen and Gaardboe 1993a	Cross-sectional	701 female sewing machine operators (SMO), compared to 781 females from the general population of the region and internal referent group of 89 females from the garment industry.	Outcome: Case of chronic pain was defined as continuous pain lasting for a month or more after beginning work and pain for $30 days within the past year. Exposure: Job categorization based on "authors' experiences as occupational health physicians" and involved crude assessment of exposure level and exposure repetitveness. Jobs involving high repetitiveness (several times/min) and low or high force, and jobs with medium repetitiveness (many times/hr) combined with high force were classified as high exposed jobs; jobs with medium repetitiveness and low force and jobs with more variation and high force were classified as medium exposed. Job titles such as teachers, self-employed, trained nurses, and the academic professions were "low exposed."	26.2%	General population: 9.9% Internal referent group: 6.7%	SMO compared to: (1) General population: OR=3.2 (2) Internal referent group: OR=4.9 Logistic Model: Years as SMO: 0 to 7 years: 1.9 8 to 15 years: 3.8 >15 years: 5.0 Age $ 40 years: 1.5 Children (>0): 1.3 Exercise: 0.9 Socioeconomic status: 1.29 Smoking: 1.39 Current Exposure: 1.3	2.3-4.5 2.0-12.8 1.3-2.9 2.3-6.4 2.9-8.7 1.1-2.2 0.8-2.0 0.6-1.3 0.7-2.3 0.99-1.9 0.9-1.9	Participation rate: 78.2%. Examiners blinded to control/subject status. Controlled for age, having children, not doing leisure exercise, smoking socioeconomic status. Age-matched exposure groups and controls. Logistic regression limited to a combined neck/shoulder case definition. No difference in education, marital status, number of children. Poor correlation between degenerative X-ray neck changes and cervical syndrome. Most frequent diagnosis among study group was "cervicobrachial fibromyalgia" significant for test of trend with exposure time in years. Chronic neck pain and palpatory findings: Sensitivity: 0.85; Specificity: 0.93.

(Continued)

Table 2–7 (Continued). Epidemiologic studies evaluating work-related neck musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Andersen and Gaardboe 1993b	Cross-sectional	From a historical cohort of 424 sewing machine operators, 120 were randomly selected and 82 exposed workers were categorized by number of years of employment: 0-7 years, 8-15 years and greater than 15 years. These were compared to a referent group of 25 auxiliary nurses and home helpers. A total of 107 subjects participated.	Outcome: Measured by health interview and exam of the neck, shoulder and arm. Case of chronic pain was defined as continuous pain lasting for a month or more after beginning work and pain for at least 30 days within the past year. Physical examination: Restricted movements in the cervical spine and either palpatory tenderness in cervical segments or irradiating pain or tingling at maximum movements or positive foraminal test. Exposure: Exposure categorization broken down according to current occupational status by job title. Classification into exposure groups based on author's experiences as occupational health physicians and involved crude assessment of exposure level and exposure repetitiveness. High exposure jobs: Involved high repetition/high force or high repetition/low force or medium repetition/high force. Medium exposure jobs involved medium repetition/low force and low repetition and high force. Low exposure jobs were low repetition/low force.		Referents: OR=1	0 to 7 years: 2.3 8 to 15 years: 6.8 >15 years: 16.7 Age at least 40 years: 1.9 Children >0 years: 0.5 Exercise: 1.4 Smoking: 1.5 Current high exposure: 1.6	0.5-11 1.6-28.5 4.1-67.5 O.9-4.1 0.1-1.7 0.6-2.96 0.7-3.3 0.7-3.6	Participation rate: 78.2%; logistic regression limited to a combined neck/shoulder case definition. Age-matched exposure groups and controls. Examiners blinded to control/subject status. Controlled for age, having children, not doing leisure exercise, smoking, socioeconomic status. Poor correlation between degenerative X-ray neck changes and cervical syndrome. Most frequent diagnosis among study group was "cervicobrachial fibromyalgia" significant for test of trend with exposure time in years. Chronic neck pain vs. palpatory findings: Sensitivity: 0.85; Specificity: 0.93.

(Continued)

Table 2–7 (Continued). Epidemiologic studies evaluating work-related neck musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Baron et al. 1991	Cross-sectional	124 grocery checkers using laser scanners (119 females, 5 males) compared to 157 grocery non-checkers (56 females, 101 males); excluded 18 workers in meat, fish, and deli departments, workers under 18 and pregnant workers.	Outcome: Based on symptom questionnaire and physical exam. Case defined as having positive symptoms and a positive physical exam. Symptoms must have begun after employment at supermarket of employment and in current job; lasted one week or occurred once a month during the past year; no history of acute injury to part of body in question. Exposure: Based on job categorization. Estimates of repetition and average and peak forces of hand and wrist based on observed and videotaped postures, weight of scanned items, and subjective assessment of exertion. Specific neck assessment was not done.	16%	5%	Odds of neck pain, checkers vs. non-checkers: OR=2	0.6-6.7	Participation rate: 85% checkers; 55% non-checkers in field study. Following telephone survey 91% checkers and 85% non-checkers. Examiners blinded to worker's job and health status. Adjusted for duration of work, age, hobbies, systemic disease obesity. Total repetitions/hr ranged from 1,432 to 1,782 for right hand and 882 to 1,260 for left hand. Average forces for cashiers were low and peak forces medium. Force was not analyzed in the models. Multiple awkward postures of all upper extremities recorded but not analyzed in models. Statistically significant increase in neck MSD with increase in years "checking."

(Continued)

Table 2–7 (Continued). Epidemiologic studies evaluating work-related neck musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Bergqvist et al. 1995a	Cross-sectional	Office workers using VDTs, (n=260), 198 females; symptomatic cases compared to non-cases.	Outcome: Neck discomfort— any discomfort over the last 12 months; intense neck discomfort— as above, if occurred in last 7 days and interfered with work. Outcome: Physiotherapist's diagnosis of: (1) tension neck syndrome (TNS): ache/pain in the neck; feeling of tiredness and stiffness in neck; possible headache; pain during movements; muscular tenderness; (2) cervical diagnoses—ache/pain in neck and arm; headache; decreased mobility due to cervical pain during isometric contraction; often root symptoms such as numbness or parathesias. Exposure: Based on observation— static work posture, nonuse of lower arm support, hand in non-neutral position, insufficient leg space at table, repeated movements with risk of tiredness, specular glare present on VDT. Measured: Height difference of VDT keyboard-elbow, high visual angle to VDT.	Neck: 61.5% Female: 63% Male: 57% TNS: 22% Female: 25% Male: 13% Cervical diagnosis: 23% Female: 25% Male: 20%	Asympto-matic workers	Tension neck syndrome: Females no children: OR= 2.0 Females with children: OR=6.4 Limited rest break: OR=7.4 Too highly place keyboard: OR=4.4 Cervical Diagnoses: Age >40 OR=2.7 Spectacles: OR=4.0 Static Posture: OR=5.1 Spectral glare: OR=1.9 Stomach reactions: OR=3.9 Tiredness: 1.9	0.7-5.6 1.9-21.5 3.1-17.4 1.1-17.6 1.0-7.2 1.3-12.5 0.6-42.5 0.9-4.2 2.0-7.7 1.0-3.5	Participation rate: 92% of 353 office workers. Adjusted for age and gender. Factors included in analysis: Age, gender, smoking, children at home, negative affectivity, tiredness-related stress reaction, stomach-related stress reaction, use of spectacles, peer contacts, rest breaks, work task flexibility, overtime, static work position, non-use of lower arm support, hand in non-neutral posture, repeated movements with risk of tiredness, height differences keyboard/elbow, high visual angle to VDT, glare on VDT. Found that “frequent overtime” protective for cervical diagnoses OR=0.48 (0.23, 0.99). Examiner and workplace investigators blinded to case and exposure status. There are problems with interpreting results because of multiple comparisons and multiple models. Not all significant findings presented in paper.

(Continued)

Table 2–7 (Continued). Epidemiologic studies evaluating work-related neck musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Bergqvist et al. 1995b	Cross-sectional	322 office workers; VDT users compared to non-VDT users. 52% interactive, 29% data entry, 19% non-VDT users.	Outcome: Neck discomfort—any discomfort over the last 12 months; intense neck/shoulder discomfort—as above, if occurred in last 7 days and interfered with work. Outcome: Physiotherapist's diagnosis of tension neck syndrome (TNS)—ache/pain in the neck; feeling of tiredness and stiffness in neck; possible headache; pain during movements; muscular tenderness. Exposure: Based on self-reporting of VDT use. VDT users categorized into data entry or interactive VDT users.	Neck discomfort: 60% Intense neck discomfort: 7.4% Tension neck syndrome: 21%		Current VDT work: OR=1.4 Intense neck discomfort: OR=0.5 Tension neck syndrome: OR=1.0 TNS Diagnosis: <20 hr/week VDT: 1.2 >20 hr/week VDT: 0.7 TNS diagnosis with bifocal or progressive glasses at VDT work and $20 hr/week VDT work duration: OR=6.9	0.8-2.4 0.2-1.8 0.5-1.9 0.4-3.7 0.3-1.5 1.1-42.1	Participation rate: 76%. Adjusted for age and gender. Intensive neck discomfort associated with VDT work over 20 hr and having stomach reactions often and repetitive movements: OR=3.9 (1.1, 13.8). Originally 535 workers queried in 1981. Of those, 182 had left the workplace (quit, retired, etc.). Possible bias from "healthy worker effect." Covariates considered: Children at home, smoking, negative affectivity, stomach-related stress reactions, tiredness-related stress reactions. Organizational factors considered: limited or excessive peer contacts, limited rest break opportunity, limited work task flexibility, frequent overtime. For cervical diagnoses: Excess OR suggested for combined occurrence of VDT work of >20 hr/week and specular glare on the VDT screen.

(Continued)

Table 2–7 (Continued). Epidemiologic studies evaluating work-related neck musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Bernard et al. 1994	Cross-sectional	Of a total population of 3,000 workers in the editorial, circulation classified advertising and accounting departments, 1,050 were randomly selected for study and 973 participated. Those fulfilling case definition compared to those workers not fulfilling definition.	Outcome: Health data and psychosocial information were collected using a self-administered questionnaire. Definition: Presence of pain, numbness, tingling, aching, stiffness or burning in the neck occurring $ once a month or 7 days continuously within the past year, reported as moderately severe. The symptom must have begun during the current job. Workers with previous nonoccupational injuries to the relevant area were excluded. Exposure: Based on observation of work activity involving keyboard work, work pace, posture, during a typical day of a sample of 40 workers with and 40 workers without symptoms. Exposure to work organization and psychosocial factors based on questionnaire responses.	26% (case) Cases with daily neck pain: 22%	Õ Õ	Females: OR=2.1 Number of hr spent on deadline/week (30 to 39 hr vs. 0 to 10 hr) OR=1.7 Work variance (continually changing work load; occasionally vs. often) OR=1.7 Time spent on the telephone (4 to 6 hr vs. 0 to 2 hr): OR=1.4 Perceived lack of importance for ergonomic issues by management: OR=1.9	1.4-2.4 1.4-3.0 1.2-2.5 1.0-1.8 1.4-2.4	Participation rate: 93%. Examiners blinded to case and exposure status. Analysis controlled for confounders, age, gender, height, psychosocial factors, medical conditions. Psychosocial scales analyzed by splitting the responses into quartiles, then comparing the 75% response score to the 25% response score for deriving the ORs in each scale. In sub-analysis of jobs having comparable number of males and females. Only number of hr spent on deadline/week and perceived lack of importance for ergonomic issues by management were significant.

(Continued)

Table 2–7 (Continued). Epidemiologic studies evaluating work-related neck musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Ferguson 1976	Cross-sectional	418 telephonists interviewed	Outcome: Symptoms by questionnaire. Neck ache categorized on 3-point discomfort scale: (1) very comfortable, (2) barely comfortable, and (3) uncomfortable, very uncomfortable. Exposure: Personal and social attributes and attitudes to aspects of the work and the equipment were obtained by questionnaire. Seven body dimensions were measured, and standing posture was categorized by observation against a grid according to predetermined criteria.	Telephonists: Uncomfortable or very uncomfortable neck ache =26%		Chi sq=11.01 (df=2), $p<0.005$		Participation rate: 95%. Although author states the following: "Discomfort, aching, and other symptoms are common, important but usually neglected problems in telephonists which could be ameliorated by ergonomic job and equipment," the results of his study did not support his conclusion. Neither discomfort nor aching was linked to any of the body postures observed. Height and weight were not related to discomfort or aching. Multiple correlations not helpful in identifying combinations of personal, equipment, environmental or other variables predictive of aching and discomfort.

(Continued)

Table 2–7 (Continued). Epidemiologic studies evaluating work-related neck musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	95% CI	Comments
Hales and Fine 1989	Cross-sectional	Of 96 female workers employed in 7 high exposure jobs in poultry processing: 89 were compared to 23 of 25 female workers in low exposure jobs.	Outcome: Period prevalence—symptoms in last 12 months by questionnaire. Case defined as: Pain, aching, stiffness, numbness, tingling or burning in the neck and symptoms began after employment at the plant; were not due to a previous injury or trauma to the joint; lasted >8 hr; and occurred 4 or more times in the past year. Point prevalence: Determined by physical exam of the neck using standard diagnostic. Tension neck syndrome: Palpable muscle tightness, hardening or pain $ 3 (on 8 point scale) on passive or resisted neck flexion or rotation. Cervical root syndrome: Pain $ (on 8 point scale) radiating from neck to one or both arms with numbness in the hand criteria. Case must also fulfill symptom definition. Exposure: Observation and walk-throughs; jobs categorized as high exposure and low exposure based on estimates of force and repetition of hand maneuvers.	Period prevalence: 21% Point prevalence: 12%	Period prevalence: 13% Point prevalence: 0%	Outcome: Neck symptoms: RR=1.64 Outcome: Neck symptoms and physical: OR indeterminate because of "0" cell Estimated OR by adding 1 to each cell in crude 2 X 2 table: 3.69	0.4-3.19 0.4-164	Participation rate: 93%. Adjustment for age and duration of employment. Examiner blinded to case and exposure status. Exposure based on repetitive and forceful hand/wrist motions and not neck exposure assessment. 80% of workers involved in job rotation program. No information collected on non-work related risk factors.

(Continued)

Table 2–7 (Continued). Epidemiologic studies evaluating work-related neck musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Hales et al. 1994	Cross-sectional	Telecommunication workers (n=518, 416 females, 117 males) in 3 offices, employed > 6 months. "Cases" fulfilling neck work-related MSD definition compared to non-cases.	Outcome: Self-administered questionnaire and standardized physical exam (PE). Case defined as: Pain, aching, stiffness, burning, numbness or tingling lasting >1 week or >12 times a year; no previous traumatic injury to neck; occurring after employment on current job within the last year and positive PE—moderate to worst pain experienced with tension neck or cervical root syndrome. Exposure: Assessed by questionnaire and observation; number of keystrokes/day; no exposure questions were specifically aimed at the neck region. Physical workstation and postural measurements were taken but not analyzed in models.	9%	Õ Õ	Lack of decision making opportunities: OR=4.2 Use of bifocals: OR=3.8 Lack of a productivity standard: OR=3.5 Fear of being replaced by computers: OR=3.0 High information processing demands: OR=3.0 Job requiring a variety of tasks: OR=2.9 Increasing work procedure: OR=2.4	2.1-8.6 1.5-9.4 1.5-8.3 1.5-6.1 1.4-6.2 1.5-5.8 1.1-5.5	Participation rate: 93%. Physician examiner blinded to worker case status. Logistic analysis adjusted for demographics, work practices, work organization, individual factors; electronic performance monitoring; DAO keystrokes; Denver DAO keystrokes/day. ORs for psychosocial variables represent risk at scores one standard deviation above mean score compared to risk at scores one SD below mean. Because of readjustments and changes of workstations during study period, measurements of VDT workstations considered unreliable and excluded from analyses. Number of hr spent in hobbies and recreational activities not significant. Although keystrokes/day found not significant, data available was for workers typing an average of 8 words/min over 8-hr period. 97% of participants used VDT $6 hr so not enough variance to evaluate hr of typing. Over 70 variables analyzed in models may have multiple comparison problem.

(Continued)

Table 2–7 (Continued). Epidemiologic studies evaluating work-related neck musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Hunting et al. 1994	Cross-sectional	308 of 400 apprentice and journeymen, electricians from one labor union participated.	Outcome: Three-symptom definitions used; most restrictive includes neck symptoms occurring $once/month or lasting >1 week during past year, and no previous traumatic injury to site. Exposure: Questionnaire dealing with lifting activities, working overhead, working with hand tools.	16% 3% with medical visits, missed work, or light duty	õ õ	õ õ 1 to 3 years worked: OR=1 4 to 5 years worked: OR=1.3 6 to 10 years worked: OR=1.6 >10 years worked: OR=1.3	õ õ	Participation rate: 75%. 98% of participants were male. Stratified by most experienced vs. least experienced electrician, by years worked, by age group, current work as an electrician. Analysis of specific work factors (repetition, force, extreme posture, vibration, or combinations of risk factors) not analyzed in this paper which dealt with prevalence of symptoms among electricians.

(Continued)

Table 2–7 (Continued). Epidemiologic studies evaluating work-related neck musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Kamwendo et al. 1991	Cross-sectional	420 medical secretaries; compared those frequently having neck pain to those less frequently having pain.	Outcome: Questionnaire using 6 point scale ranging from "very often" to "almost never" and Nordic Questionnaire. Definition of neck MSD: Discomfort, ache, or pain during previous year; whether they had pain in last 7 days, whether pain prevented them from doing daily duties. 10 questions on psychosocial work environment included. Exposure: Based on questionnaire. Low exposure was regarded as 1 to 4 hr sitting or working with office machines, high exposure was regarded as 5 to 8 hr.	63% period prevalence. 33% point prevalence. 15% with constant neck pain.	õ õ	OR for work with office machines 5 hr or more/day: 1.65 Working >5 years: OR=1.6 Sitting 5 or more hr/day: OR=1.9	1.02-2.67 0.9-2.8 0.86-2.6	Participation rate: 96%. Neck symptoms associated with a "poorly experienced psychosocial work environment." Age, length of employment significantly related to neck pain. Questionnaire included psychosocial scales, length of employment, part-time or full-time work, average hr sitting working with machines. Ability to influence work, a friendly spirit of cooperation between co-workers, being given too much to do significantly positively associated with neck pain.

(Continued)

Table 2–7 (Continued). Epidemiologic studies evaluating work-related neck musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	RR, OR, or PRR	95% CI	Comments
Kiken et al. 1990	Cross-sectional	294 poultry processors. Plant #1 (n=174) Plant #2 (n=120)	Outcome: Period prevalence—based on questionnaire. Case—pain, aching, stiffness, burning, numbness or tingling in the neck, began after employment at the plant; not due to previous accident or injury outside work; lasted >8 hr and occurred 4 or more times in the past year.	Plant #1: (High exposure) Any symptoms: 34%	Plant #1: (Low exposure) Any symptoms: 16%	OR= 2.2	0.9-5.0	Participation rate: 98%. Analysis stratified by gender and age.
				Period prevalence: 9%	Period prevalence: 3%	2.9	0.4-21.4	Higher exposure jobs (HE) were located in the receiving, evisceration, whole bird grading, cut up and deboning departments. Lower exposure jobs (LE) were located in the maintenance, sanitation, quality assurance and clerical departments.
			Point prevalence: Based on symptom and physical exam using standard diagnostic criteria. Case must fulfill symptom definition listed above.	Point prevalence: 4%	Point prevalence: 3%	1.3	0.2-11	Examiners blinded to case and exposure status.
			Exposure: Observation and walkthrough; jobs categorized as high exposure and low exposure based on observed force and repetition of hand maneuvers.	Plant #2: (High exposure) Any symptoms: 42%	Plant #2: (Low exposure) Any symptoms: 11%	OR= 3.9	1.5-10.2	30% of workers in job rotation program may influence associations.
				Period prevalence: 5%	Period prevalence: 3%	1.8	0.2-15.2	Annual turnover rate -50% at plant 1 and 70% at plant 2; making survivor bias a strong possibility.
				Point prevalence: 1%	Point prevalence: 0%	õ õ	õ õ	

(Continued)

Table 2–7 (Continued). Epidemiologic studies evaluating work-related neck musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Knave et al. 1985	Cross-sectional	400 VDT operators from 4 industries using VDTs >4 hr/day; compared to 157 office employees without VDT work at the same industries.	Outcome: Questionnaire—symptom questionnaire based on frequency and intensity scores: negligible=1, slight=2, pronounced=3. Exposure: Based on self-assessment "hrs of typing." A special gaze direction instrument recorded time spent looking at VDT screen. Observation was conducted but not included in analysis.	Results estimated from histogram: Rt. side of neck: 5% Lt. side of neck: 20%	Results estimated from histogram: Rt. side of neck: 5% Lt. side of neck: 0%	Õ Õ Typing hr significantly related to neck symptoms. Dose-response relationship found between registered work duration and musculo-skeletal complaints.	Õ Õ	Participation rate: Initially exposed 97%; referent 100%; Phase IV exposed 84% referents 84%. Cases and referents matched on age and gender. Musculoskeletal complaints grouped in analysis; because of large number of comparisons, some without *a prior* hypotheses, reliable conclusions limited to *p*<0.001. Significant difference between females and males in reported neck symptoms. No statistical difference between cases and referents in discomfort scores, but "tendency towards higher discomfort scores for shoulder, neck, and back among the exposed group." No difference in cases and referents in whether work was "interesting" or they had a "positive attitude" towards work. Age, smoking, educational status, and drinking did not correlate with symptoms. Females reported more symptoms than males in both referent and case groups. 'Registered' total work hr associated with musculoskeletal symptoms *p*<0.05.

(Continued)

Table 2–7 (Continued). Epidemiologic studies evaluating work-related neck musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Kukkonen et al. 1983	Cross-sectional/ Inter-vention	104 female data entry workers. 60 data entry operators (noted as "study group") were grouped with 44 data entry operators who worked at another bank and were compared with 57 female workers in varying office tasks.	Outcome: Questionnaire—stiffness and pain in the neck and shoulder region, frequency of symptoms and localization. Physical exam (PE): A clinical functional examination performed by a physiotherapist. Exposure: Observation of posture, movements and working techniques, assessment of characteristics of desk, chair, equipment, interview with foremen and workers to get determination of physical, mental, and social environment at workplace. Foremen and workers were interviewed so that the organization of work and the physical, mental, and social environment at the workplace could be determined.	Data entry groups: 47% Tension neck syndrome in study group pre-interven-tion: 54% Tension neck syndrome in study group post-interven-tion: 16%	28% Tension neck syndrome in data entry comparison group pre-interven-tion: 43% Tension neck syndrome in data entry comparison group post-interven-tion: 45%	2.3	1.1-4.6	Participation rate: Not reported. Examiners blinded to case status. No adjustment for confounders. Examiner blinded to case status. Average duration of employment 3.5 years. Intervention consisted of: Adjustment of desk, chairs, data processing equipment individually to suit each worker, who was instructed to carry out adjustments herself. Document holders were added. The study group was given a short course of basic training on pertinent aspects of ergonomics. Four lessons on relaxation was given by means of exercises. Physiotherapy was given to workers for whom the doctor prescribed—17 from the study group and none from the first reference group had treatments.

(Continued)

Table 2–7 (Continued). Epidemiologic studies evaluating work-related neck musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Kuorinka and Koskinen 1979	Cross-sectional	93 scissor makers, (n=90 females, 3 males) compared with 113 female department store shop assistants from Luopäjarvi's 1979 study. Excluded those with seropositive rheumatic affections as well as cashiers.	Outcome: Symptoms and physical examination—two tender spots symptoms of neck stiffness and fatigue/ weakness and/or palpable hardenings + muscle tenderness in neck movements. Physiotherapist examined workers, diagnoses were from predetermined criteria [Waris 1979]. In problem cases orthopedic and physiatric teams handled cases. Exposure: Based on job analysis from work history of previous year from production and salary forms. Conducted record review of hr worked/task, production statistics, absences: used only cases where 80% of hr cross-checked (n=76). Work methods for each type of station analyzed. Stations classified according to dominance of inspection or manipulation of scissors, and length of cycle using observation and video-taping. Observations made looking at hand/wrist force, repetition and hand grasp. Calculated index for wrist deviation. —Work methods for each work station analyzed: Cycle time. —Total workload during investigation/year recorded individually as pieces handled.	61%	28%	Scissor makers vs. referents: OR=4.1 Short cycle tasks vs. long-cycle tasks and tension neck syndrome: OR=1.64	2.3-7.5 0.7-3.8	Participation rate: 81%. 99% female study group, no significant age difference. Used Waris [1979] criteria for examination which called for blinding of examiners, otherwise it was not mentioned. No association between tension neck syndrome and: (1) age, (2) duration of employment, and (3) weight/height^2. Total workload for the number of pieces handled in one year significantly associated with tension neck syndrome Although authors state no relationship between short cycled and longer cycled tasks; both groups of tasks would be classified as highly repetitive using Kilbom, Silverstein's and other criteria. Lack of variance in comparison groups. Authors noted: "earlier unpublished questionnaire pertaining to activities outside factory — extra work, hobbies, did not indicate correlations with work..." Found that "diseases" seem to accumulate in same individuals. Physical workload was low. A slight trend towards tension neck being more common in manipulation tasks than in inspection but not statistically significant.

(Continued)

Table 2–7 (Continued). Epidemiologic studies evaluating work-related neck musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Linton 1990	Cross-sectional	22,180 employees undergoing screening examinations at their occupational health care service in Sweden. 85% of the Swedish workforce is covered by health care services. Cases compared to "non-cases" defined by outcome. Groups selected *a priori* which would represent exposure as well as little or no exposure for psychosocial variables.	Outcome: Cases defined from questionnaire responses as those persons reporting "yes" to having seen a health care professional for neck pain in the last year. Exposure: Based on questionnaire responses—questions asked regarding heavy lifting, monotonous or assembly line work, sitting, uncomfortable work postures (bending or twisting), vibration. Psychosocial work environment: Work content, workload, social support.	18% had seen health care profes-sional for neck pain 31% had experi-enced neck pain	õ õ	Monotonous work and poor psychosocial environment: OR = 3.6 Lifting and poor psychosocial environment: OR=2.7 Uncomfortable posture and poor psychosocial environment: OR=3.5	2.8-4.6 2.0-3.6 2.7-4.5	Participation rate: Authors had access to all workers' records; 85% of working population has occupational health care services. Analysis stratified for age, gender. Lifestyle factors asked: Exercise, eating, smoking, alcohol consumption. On univariate analysis, heavy lifting, monotonous work, uncomfortable posture, and vibration had elevated ORs. Sitting did not. On univariate analysis, eating regularly and smoking had elevated ORs. Alcohol and exercise did not. Authors caution direct comparison of ergonomic and psychosocial variable's ORs. The scales were not consistent for the different factors measured.

(Continued)

Table 2–7 (Continued). Epidemiologic studies evaluating work-related neck musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	Referent group	RR, OR, or PRR	95% CI	Comments
Liss et al. 1995	Cross-sectional	1,066 of 2,142 dental hygienists from Ontario Canada Dental Hygienists Association compared to referent group, 154 of 305 dental assistants who do not scale teeth.	Outcome: Mailed survey, case definitions based on Nordic Questionnaire, percent reporting neck symptoms >7 days in past 12 months. Exposure: Based on mailed survey and self-reported answers—length of practice, days/week worked, patients/day, patients with heavy calculus, percent of time trunk in rotated position relative to lower body, instruments used, hr of typing/week, type of practice.	43%	30%	1.7 Had to modify their work or were unable to work at some point, (hygienists compared to dental assistants): OR=2.4	1.1-2.6 1.1-5.4	Participation rate: 50% from both groups. Study population >99% female. No association with duration of employment. Not controlled for confounders. Very low response rate, confounders not considered, study has methodologic problems which influence interpretation of results.

(Continued)

Table 2–7 (Continued). Epidemiologic studies evaluating work-related neck musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Luopäjarvi et al. 1979	Cross-sectional	Assembly line workers (n=152 females) compared to shop assistants in a department store (n=133 females). Cashiers excluded from comparison group.	Outcome: Tension neck syndrome (TNS): Neck stiffness and fatigue/weakness and two tender spots and/or palpable hardenings + muscle tenderness in neck movements. Exposure: Observation, video analysis, and interviews used to assess exposure to repetitive arm work, static muscle work affecting neck/shoulder area.	37%	28%	TNS: OR=1.56 Had seen a doctor for neck symptoms: OR=4.38	0.9-2.7 2.1-9.24	Participation rate: 84%. Workers excluded from participation for previous trauma, arthritis and other pathology. No difference in mean ages between exposed and referents. Examined only females. Factory opened only short time so no association between duration of employment and MSDs possible. Social background, hobbies, amount of housework not significant.

(Continued)

Table 2–7 (Continued). Epidemiologic studies evaluating work-related neck musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Milerad and Ekenvall 1990	Cross-sectional	99 dentists randomly selected from Stockholm dentist registry who practiced $ 10 years compared to 100 pharmacists selected from all pharmacists in Stockholm.	Outcome: Based on telephone questionnaire. Neck symptoms at any time before the interview ("lifetime prevalence"). Further analyzed according to Nordic questionnaire as to duration during last 12 months and during last 7 days, effect on work performance and leisure activities, and sick leave. Exposure: Based on questionnaire. Exposures included: (1) abduction of arm particularly in sit-down dentistry; (2) work hrs/day; and (3) static postures.	54% Male: 45% Female: 63%	Pharma-cists: 26% Male: 18% Female: 32%	2.1 2.6 2.0	1.4-3.1 1.2-5.0 1.3-3.1	Participation rate: 99%. Analysis stratified by gender. No difference in leisure time exposure, smoking, systemic disease, exposure to vibration. Symptoms increased with age in female dentists only. Duration of employment highly correlated with age: dentists (r=0.84), pharmacists (r=0.89). No relation between symptoms and duration of employment. Equal problems dominant and nondominant sides. Genders “equally prone to develop neck symptoms when subjected to equal work-related musculoskeletal strain.” No analysis of exposure factors. Only discussion of “probable reasons” for high risk using work positions, flexing neck.

(Continued)

Table 2–7 (Continued). Epidemiologic studies evaluating work-related neck musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Ohlsson et al. 1995	Cross-sectional	Industrial Workers (n=82 females) exposed to repetitive tasks with short cycles mostly far <30 sec, usually with a flexed neck and arms elevated and abducted intermittently; 68 former workers (mean employment time 21 years) who had left the factory during the seven years before the study; these workers were compared to 64 referents with no repetitive exposure at their current jobs.	Outcome: Pain in the last 7 days and physical exam (PE) diagnosing tension neck syndrome, cervical syndrome. Tension neck: Tightness of muscles, tender spots in the muscles. Cervical syndrome: Limited neck movement, radiating pain provoked by test movements, decreased sensibility in hands/fingers; muscle weakness of upper limb. Exposure: Videotaping and observation. Analysis of postures, flexion of neck (critical angles 15E and 30E). 74 workers videotaped $10 min from back and sides. Average counts of two independent readers for frequencies, duration, and critical angles of movement used. Repetitive industrial work tasks divided into 3 groups: (1) fairly mobile work, (2) assembling or pressing items, and (3) sorting, polishing and packing items Weekly working time, work rotation, patterns of breaks, individual performance rate (piece rate). Only exposure readings from right arm were used.	Tension neck: 40% Cervical syndrome: 1%	Tension neck: 13% Cervical syndrome: 0%	Tension neck syndrome (industrial workers compared to referents): OR=3.6 Õ	1.5-8.8 Õ	Participation rate: Current workers: 96%; past workers: 86%; referents: 100%. Controlled for age. No exposure information available to examiners, "not possible to completely blind the examiners." Questionnaire included individual factors, work/environment, symptoms, psychosocial scales. Muscle strength measured by (maximum voluntary capacity) at elevation, abduction, and outward rotation of both arms measured by dynamometer. Videotape analysis revealed considerable variation in posture even within groups performing similar assembling tasks. Logistic models replacing repetitive work with videotape variables found muscular tension tendency and neck flexion movements significantly associated with neck/shoulder diagnoses. Inverse relationship between duration of industrial work and MSDs, largest OR employed <10 years. Assembly group has high OR (6.7) with regard to neck/shoulder MSD compared to referents. Significant association between time spent in neck flexion positions < 60E.

(Continued)

Table 2–7 (Continued). Epidemiologic studies evaluating work-related neck musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	RR, OR, or PRR	95% CI	Comments
Ohlsson et al. 1989	Cross-sectional	Electrical equipment and automobile assemblers (n=148), 76 former female assembly workers who quit within 4 years compared to 60 randomly sampled female from general population.	Outcome: Determined by questionnaire—any neck pain, neck pain affecting work ability, and neck pain in the last 7 days and the last 12 months. Exposure: Based on job categorization and questionnaire—number of items completed/hr. Work pace divided into four classes: (1) slow: <100 items/hr; (2) medium: 100 to 199 items/hr; (3) fast: 200 to 700 items/hr; (4) very fast: >700 items/hr.	Pain in last 12 months: 39% Work inability in last 12 months: 13% Pain in last 7 days: 21%	Pain in last 12 months: 32% Work inability in last 12 months: 7% Pain in last 7 days: 17%	1.9 2.8 1.9	0.9-3.7 0.9-8.8 0.7-3.6	Participation rate: Not reported. For younger females, increase in pain occurred with increased duration of employment. OR increased with increasing work pace, except for very high paces, which there was a decrease. Logistic models checked for interaction and controlled for age. Study group consisted of females only. Significant association between symptoms and duration of employment much stronger for workers <35 years old than workers >35 years old.

(Continued)

Table 2–7 (Continued). Epidemiologic studies evaluating work-related neck musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Onishi et al. 1976	Cross-sectional	The following were compared to 101 female office workers: Film rolling workers: 127 (females). Subjects categorized as: Group I: Without symptoms of cervico-brachial disorder. Group II: Subjective symptoms in the neck, shoulder, or upper limbs. Group III: Symptoms and clinical signs.	Outcome: Based on (1) symptoms of neck stiffness, dullness, pain, numbness; (2) pressure (<1.5 kv/cm²) measured by strain transducer at which subject felt pain; (3) physical exam: range of motion, tests, nerve compression tenderness. Exposure: Observation of job tasks, then job categorization. Film rollers wind 1 roll of 35 mm film every 2.5 to 5 sec over 7.5 hr/day. Loading of trapezius was examined in two workers during work activities by electromyography.	Group I: 29% Group II: 39% Group III: 23%				Participation rate: Not reported. Body weight, weight skin fold thickness, muscle strength and grip strength obtained. Body height and weight differences not statistically significant. No difference between workers with tenderness threshold above 1.5 kg/cm² and those below with respect to age, height, weight, skin fold thickness, grip strength, upper arm abduction strength, back muscle strength. Authors noted that continuous loading of the trapezius seems characteristic to repetitive operations where the upper limbs are used.

(Continued)

Table 2–7 (Continued). Epidemiologic studies evaluating work-related neck musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Ryan and Bampton 1988	Cross-sectional	Data process operators (n=143). Group with highest scores (n=41) designated "cases," compared to lowest scores (n=28).	Outcome: Symptoms (pain, ache, sore, hurts, numb, swollen, etc.) occurring $3 times/week with no physical exam signs or $ weekly with physical exam signs of muscle tenderness present; diagnosed "myalgia" as diffuse muscle pain and tenderness. Exposure: Ergonomic assessment measuring angles and distances of each operator seated at his/her workstation. Wrist extension, ulnar deviation, elbow angle, shoulder abduction, and shoulder flexion were measured. Also measured: person and furniture fit, eye-copy and eye-keyboard fit, elbow-keyboard height difference, popliteal-chair height difference, and copy placement.	Shoulder: 44% symptom only Neck: 43% symptoms only Neck/shoulder symptoms occurring $ 3 times weekly with no signs or weekly with signs: 44%	õ õ	Not reported	õ õ	Participation rate: 99%. Interviewers blinded to questionnaire responses. No adjustment for confounders; cases for analysis were those with either neck, shoulder, or lower arm scales having higher symptom scores compared to those with low scores. Cases had higher visual glare index, feeling there was insufficient time for rest breaks, more boredom, more work stress, and needed to push themselves >3 times/week; lower peer cohesion, autonomy, clarity. Higher staff support and work pressure. Significant differences in those trained in adjustment of their chairs. No differences for height, weight, age, marital and parental status, handedness, time in current job, time spent keying or typing, whether this was their first job, length of training time. Significant difference in smaller mean elbow angle and shoulder flexion of the left arm, and smaller eye-copy distance.

(Continued)

Table 2–7 (Continued). Epidemiologic studies evaluating work-related neck musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	95% CI	Comments
Sakakibara et al. 1987	Cross-sectional	Orchard workers (n=48, 20 males and 20 females). Compared symptoms after completion of thinning of pears, bagging of pears and bagging of apples (covering fruit with paper bags while on the trees). Internal comparison using same study population.	Outcome: Shoulder pain described as the presence of stiffness and pain daily. Exposure: Observation of jobs. Angles of flexion of the shoulder and extension of the neck on one subject were measured every 25 min during a whole day doing each task. No observation was made on neck repetition. Farmers worked approximately 8 hr/day for 10.6 to 13.6 days each year bagging or thinning pears and bagging apples.	Estimated from histograms Pears: Rt. side: 20% Lt. side: 20%	Estimated from histograms Apples: Rt. side: 9% Lt. side: 9%	 *p*<0.05 *p*<0.01	õ õ	Participation rate: 77%. Stratified by gender. General fatigue, gastric disturbances, appetite loss and headache showed no difference in frequency between tasks. Exposure data based on measurement of one worker may not be generalized to others. The angle of forward flexion in the shoulder and that of extension in the neck was statisticallly significantly positively correlated (r=0.88, p#0.01). The proportion of workers with >90E forward shoulder flexion was significantly higher for thinning out pears and bagging pears than for bagging apples. The authors presumed that the symptoms of dizziness and tinnitus may be associated with the cochlear-vestibular symptoms of vertebral insufficiency due to continuous extension of the head. Results presented in paper in histograms.

(Continued)

Table 2–7 (Continued). Epidemiologic studies evaluating work-related neck musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Sakakibara et al. 1995	Cross-sectional	Of 65 female Japanese farmers. 52 completed the questionnaire and physical exam in late June for bagging pears and late July for bagging apples.	Questionnaire: Stiffness and pain in neck region. Symptoms in past 12 months for $one day, or symptoms in past 12 months for $8 days. Exam: Pain in motion of the neck joint such as flexion/extension, lateral bending, and rotation. Exposure: Observation of tasks and measurements of representative workers (only two workers measured) . Angle of arm elevation during bagging was measured in one subject.	Pear bagging Neck pain=40% Neck pain in joint motion: 55.8%	Apple bagging Neck pain=25% Neck pain in joint motion: 36.5% controls	Workers bagging pears with neck pain vs. apple bagging with neck pain, *p*<0.05 Workers bagging pears with pain in joint motion vs. apple bagging with pain in joint motion: PRR=1.5	0.99-2.35	Participation rate: 80%. Examiners not blinded to case status due to design of study. Same population examined two times. 2nd exam occurred one month after first. These results used in analyses for comparison of two tasks. Stiffness and pain during apple bagging may have been pain that was a residual of pear bagging operations. Number of fruit bagged/day was significantly more in pear bagging than in apple bagging. Exposure measurements only obtained on 2 workers and generalized to all workers.

(Continued)

Table 2–7 (Continued). Epidemiologic studies evaluating work-related neck musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Schibye et al. 1995	Cohort	Follow-up of 303 sewing machine operators at nine factories representing different technology levels who completed questionnaire in 1985. In April 1991, 241 of 279 traced workers responded to same 1985 questionnaire. Operators still working were compared to those who moved to other employment in 1991.	Outcome: Nordic Questionnaire— discomfort, ache, or pain in the neck during the previous year; whether they had neck pain in last 7 days, and whether pain prevented them from doing daily duties. Exposure: Assessed by questions regarding type of machine operated, work organization, workplace design, units produced/day, payment system, and duration of employment as a sewing machine operator.	Neck symptoms in previous year for employees maintaining a piece-work groups of <100 units/day: 36% Neck symptoms in previous year for employees maintaining a piece-work groups of 100 to 125 units/day: 53% Neck symptoms in previous year for employees maintaining a piece-work groups of >125 units/day: 61%		Developing neck symptom improvement in 1991 among operators compared to other employment group OR=0.85 Neck symptom improvement in other employment group vs. operator group: 12 month symptoms: OR=3.3 7 day symptoms: OR=3.9	0.29-2.4 1.4-7.7 1.3-11.9	Participation rate, 1985: 94%. Participation rate, 1991: 86%. All participants were female. 77 of 241 workers still operated a sewing machine in 1991. 82 workers had another job in 1991. Among those 35 years or below, 77% had left job; among those above 35 years, 57% left job. 20% reported musculoskeletal symptoms as the reason for leaving job. No significant changes in prevalences among those employed as sewing machine operators from 1985 to 1991; significant decrease in those who changed employment. As many as 50% of respondents reported a change in the response to positive or negative symptoms from 1985 to 1991. Operators always working at the same machines showed significantly higher neck symptoms compared to those working at different machines Although the authors state that the analysis did not show the development of neck (or shoulder) symptoms among workers who had worked as a sewing machine operator to be significantly related to exposure, exposure time, or age, there was a significant drop-out rate of those above 35 years.

(Continued)

Table 2–7 (Continued). Epidemiologic studies evaluating work-related neck musculoskeletal disorders

				MSD prevalence				
Study	**Study design**	**Study population**	**Outcome and exposure**	**Exposed workers**	**Referent group**	**RR, OR, or PRR**	**95% CI**	**Comments**
Veiersted and Westgaard 1994	Cohort	30 female chocolate manufacturing workers. 17 who contracted trapezius myalgia within 6 to 51 weeks compared to those workers without.	Outcome: Trapezius myalgia—neck and shoulder pain lasting >2 weeks of a degree making it difficult to continue work. At least one tender or trigger point present. Prospective interviews every 10 weeks to detect symptoms of muscle pain. Daily "pain diaries" kept by subjects. Exposure: Static muscle tension during work was between 1 and 2% of maximal voluntary activity of the trapezius muscles recorded by electromyographic measurements of trapezius muscle in earlier study. Interviews conducted prospectively every 10 weeks concerning exposure at work for 1 year.	56%	õ õ	Perceived strenuous postures: OR=7.2 Physical environment: OR=0.9 Psychosocial factors: OR=3.3 Perceived strenuous previous work: OR=6.7	2.1-25.3 0.5-1.7 0.8-14.2 1.6-28.5	Participation rate: 55%. Drop-out rate may limit generalizability of results although drop-outs did not differ in exposure estimates and complaints. Excluded subjects with: (1) no similar occupation during last 5 years; (2) known musculoskeletal disorder predisposing for myalgia; (3) neck or shoulder pain sufficient to initiate medical visit, (4) if employed <26 weeks. Several anthropometric, non-work-related, general health, personality, psychosocial, and previous employment variables included in initial interview and follow-ups. Subjects on a fixed-wage system. Work was mainly machine-paced. Nine of 17 with trapezius myalgia had sick leave after medical consultation. No difference in general health status, anthropometric measures. None of the models showed any effect of the "physical environment." Parameters which included exposure to draft, vibration (floor or machine), or noise. Observation time was considerably shorter for workers who contracted neck pain compared to status used in analysis. Non-patients had more opportunities to report a positive answer. The perceived strenuous postures were not reflected in any of the conventional EMG parameters (static, median or peak loads).

(Continued)

Table 2–7 (Continued). Epidemiologic studies evaluating work-related neck musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Viikari-Juntura et al. 1994	Cohort longitudinal; 2 questionnaires 3 years apart	688 machine operators and 553 carpenters compared to 591 office workers. All male.	Outcome: Neck trouble, categorized on 5 point scale ("not any" to "daily"). Exposure: Based on job category. Machine operators—static work with whole body vibration, carpenters—dynamic physical work, office workers—sedentary work. For initial evaluation, observation of work sites were performed.	12 month prevalence for severe neck pain for 1984/1987 Machine operators: 28/40% Carpenters: 25/32% Office workers: 9/12%	õ õ	Carpenters vs. office workers: No neck pain to moderate: OR=1.6 No neck pain to severe: OR=1.6 Persistently severe: OR=3.0 Machine operators vs. office workers: No neck pain to moderate: OR=1.8 No neck pain to severe: OR=3.9 Persistently severe: OR=4.2	 1.0-2.5 0.8-3.0 1.4-6.4 1.1-2.8 2.3-6.9 2.0-9.0	Participation rate: 81% machine operators; 79% carpenters; 89% office workers. Adjusted for occupation, smoking, and physical exercise, age, duration or current occupation. 2% had retired. In multivariate analysis; "occupation" was only significant predictor in change from no neck trouble to moderate neck trouble. Twisting or bending trunk not a significant predictor of neck pain. In multivariate analysis: occupation, age, and current smoking were significant predictors in change from no neck trouble to severe neck trouble. Interaction between age and occupation not significant. Job satisfaction not associated with neck trouble and other predictors.

(Continued)

Table 2–7 (Continued). Epidemiologic studies evaluating work-related neck musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Welch et al. 1995	Cross-sectional	39 of 47 sheet metal workers attending a screening for occupational lung disease. Cases compared to those without symptoms.	Outcome: Symptom survey; pain, aching, stiffness, burning, numbness or tingling in neck $ once/month, or lasting > one week, no history of previous traumatic injury. Symptoms began after working as a sheet metal worker and prior to retirement. Exposure: Questionnaire survey obtaining types of tasks performed, tools used, frequency of task performance. Hanging duct work dichotomized into > and <40% of time worked.	21%	Comparison group with no symptoms	Percent time hanging duct: OR=7.5	0.8-68	Participation rate: 83%. Smoking cigarettes, average number of years working not found to be significantly different between symptomatic and asymptomatic; other confounders (age, gender) not mentioned. Average length of employment in trade: 33 years. Pilot study. Hrs/week using hand tools, percent of time in the shop vs. time in the field not significant. Duration of employment not included in article.

(Continued)

Table 2–7 (Continued). Epidemiologic studies evaluating work-related neck musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	Referent group	RR, OR, or PRR	95% CI	Comments
Wells et al. 1983	Cross-sectional	196 male letter carriers compared to 203 male meter readers and postal clerks. 104 letter carriers had weight increased from 25 to 35 lbs. in the year prior to the study.	Outcome: Telephone interview case status based on current pain; frequency, severity, interference with work, etc.; score of 20 required to be a case—more points given to neck and shoulder problems that interfered with routine daily activities. Exposure: Based on job category; based on self-reported information on weight carried, previous work involving lifting and work-related injuries.	All letter carriers: 12% Letter carriers with increased weight: 12% Letter carriers with no weight increase: 12%	Postal clerks: 5% Meter readers: 7%	All letter carriers vs. clerks and readers: OR=2.57 Letter carriers with increased weight vs. clerks: OR=2.63 Letter carriers with no weight increase vs. clerks: OR=2.87	1.13-6.2 0.9-8.8 0.9-9.8	Participation rate: 99% among letter carriers, 92% meter readers, 97% postal clerks. No significant difference in schooling and marital status. Comparison group (gas meter readers) used because of similar "walking rate" without carrying weight compared to letter carriers. Postal clerks neither walk nor carry weight. More weight given to scoring neck and shoulder. Outcome influenced results when ranking of body MSDs though would not influence group comparisons. Adjusted for age, number of years on the job, Quetelet ratio and previous work experience. Study limited to males. Letter carriers with increased bag weight walked on average 5.24 hr; those with no change in bag weight walked 4.83 hr. Letter bag straps usually carried on the shoulder.

(Continued)

Table 2–7 (Continued). Epidemiologic studies evaluating work-related neck musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Yu and Wong 1996	Cross-sectional	151 VDT users from an international bank in Hong Kong; of these 90 were data entry, data processing, computer programmers; 61 infrequent users of VDTs.	Outcome: Questionnaire survey used to collect information on discomfort or ache during work after starting the current job. Exposure: Questionnaire survey on "undesirable postures" including frequent bending of the back and inclining the neck forwards.	31.4%		Frequent users of VDTs vs. infrequent users: *p*=0.0025 Logistic model for neck pain inclining neck at work: OR=784.4 Fixed keyboard height: OR=90.1 Frequent VDT use: OR=28.9 Female gender: OR=1.6 Age (years): OR=1.2	 33.2-18,630 7.6-1056 2.8-291.8 0.35-6.8 1.02-1.5	Participation rate: 80%. Ages ranged from 18 to 41 years, 74% between 21 to 30 years. Analysis controlled for "age and gender, and other covariates." Queried about personal particulars, job nature and characteristics, working posture, general health conditions. Males with significantly longer mean VDT working experience compared to females (5 vs. 2.7 years). Non-workplace factors not examined.

Table 2–8. Epidemiologic studies evaluating work-related neck/shoulder disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Åaras 1994	Prospective	15 female assembly workers making telephone exchanges. 27 female VDT users. 25 female data entry operators. 29 male VDT users.	Outcome: Assembly Workers: musculoskeletal sick leave/man-labor years; pre- and post-intervention. Data Entry and VDT Users: Survey: Pain intensity for the neck and shoulder region according to Nordic questionnaire. Exposure: Load on trapezius as measured by EMG. Quantification of the muscle load done by ranking the interval estimate (0.1 s) to produce an amplitude probability distribution function. Both total duration and number of periods/min. when muscle activity was below 1% MVC were calculated. Intervention: Replacing workstands with fixed heights to workplaces easily adjustable for both sitting and standing. Hand tools were counter- balanced and adjustable arm rests introduced. For VDT operators, tables and chairs adjusted to give more relaxed position of the shoulders, operators given more work surface for keyboard and mouse, and distances between operators and screen/documents adjusted.	Number of musculoskeletal diagnoses: pre-intervention, 1967 to 1974: 52 (30.6%) Number of musculoskeletal diagnoses post-intervention, 1975 to 1982: 35 (14.3%)		Duration of sick-leave/man-labor year (days) Median sick days pre-intervention: 22.9 Median sick days post-intervention: 1.8 Shoulder pain intensity: 3.4 2.2	4.4-50.8 0-34.4 2.3-4.4 1.3-3.3	Participation rate: Not reported. Study designed to evaluate if there is a relationship between trapezius load and incidence of MSD. Other intervening variables that may have reduced symptoms or sick leave were not discussed. Mean static trapezius load in assemblers was reduced from 4.3% MVC to 1.4% (post-intervention); mean static trapezius load in VDT users reduced from 2.7% MVC to 1.6% MVC (post-intervention). The mean intensity and duration of neck pain showed no significant reduction after intervention in the data dialogue females.

(Continued)

Table 2–8 (Continued). Epidemiologic studies evaluating work-related neck/shoulder disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Andersen and Gaardboe 1993a	Cross-sectional	701 female sewing machine operators, compared to 781 females from the general population of the region and internal referent group of 89 females from the garment industry.	Outcome: Case of chronic neck pain was defined as continuous pain lasting for a month or more after beginning work and pain for $ 30 days within the past year. Exposure: Categorization broken down according to current occupational status by job title. Classification into exposure groups based on author's experiences as occupational health physicians and involved crude assessment of exposure level and exposure repetitiveness. High exposure jobs were those involving high repetition/high force or high repetition/low force or medium repetition/high force. Medium exposure jobs were those involving medium repetition/low force and low repetition and high force. Low exposure jobs were low repetition/low force. For the analysis, "length of employment as a sewing machine operator" was considered the variable of interest, the rest were confounders.	34.2%	General population: 12.9% Internal referent group: 10.1%	Sewing machine operators compared to: (1) General population: OR=3.5 (2) Internal referent group OR=4.6 Logistic model Years as sewing machine operator (0 to 7 years): OR=3.17 (8 to 15 years): OR=11.2 (>15 years): OR=36.7 Age >40 years: OR= 1.96 Current high exposure (-/+): OR=0.32 Children (>0): OR =0.35 Exercise (-/+): OR=1.28 Smoking (=/-): OR=2.3	2.6-4.7 2.2-10.2 0.6-16.1 2.4-52.3 7.1-189 0.8-5 0.1-1 0.1-1.9 0.5-3.4 0.9-6.1	Participation rate: 78.2%. Examiners blinded to case status. Respondents excluded if had previous trauma to neck, shoulder, or arms or had inflammatory disease at time of response. Odds ratios adjusted for age, having children, not doing exercise, socioeconomic status, smoking, and current neck/shoulder exposure. Age-matched exposure groups and controls. Presented study as "general survey of health in the garment industry" to minimize information bias.

(Continued)

Table 2–8 (Continued). Epidemiologic studies evaluating work-related neck/shoulder disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Andersen and Gaardboe 1993b	Cross-sectional	From a historical cohort of 424 sewing machine operators, 82 were randomly selected and categorized by number of years of employment: 0 to 7 years, 8 to 15 years and greater than 15 years. These were compared to a referent group composed of 21, 25 and 36 operators from each group and 25 of 55 auxiliary nurses and home helpers who participated in the study.	Outcome: Measured by health interview and exam of the neck, shoulder and arm. Case of chronic pain was defined as continuous pain lasting for a month or more after beginning work and pain for $ 30 days within the past year. Physical examination: Restricted movements in the cervical spine and either palpatory tenderness in cervical segments or irradiating pain or tingling at maximum movements or positive foraminal test. Exposure: Exposure categorization broken down according to current occupational status by job title. Classification into exposure groups based on author's experiences as occupational health physicians and involved crude assessment of exposure level and exposure repetitiveness. High exposure jobs: Involved high repetition/ high force or high repetition/ low force or medium repetition/ high force. Medium exposure jobs involved medium repetition/ low force and low repetition and high force. Low exposure jobs were low repetition/low force.	50.9% Tension neck syndrome: 40% Cervical Syndrome: 20%	46.2%	Referents: OR=1 0 to 7 years: OR=2.3 8 to 15 years: OR=6.8 >15 years: OR=16.7 Age $ 40 years: OR=1.9 Children >0 years: OR= 0.5 Exercise: OR=1.4 Smoking: OR=1.5 Current high exposure: OR=1.6	 0.5-11 1.6-28.5 4.1-67.5 O.9-4.1 0.1-1.7 0.6-2.96 0.7-3.3 0.7-3.6	Participation rate: 78.2%. Logistic regression limited to a combined neck/shoulder case definition. Age-matched exposure groups and controls. Examiners blinded to control/subject status. Controlled for age, having children, not doing leisure exercise, smoking, socioeconomic status. Poor correlation between degenerative X-ray neck changes and cervical syndrome. Most frequent diagnosis among study group was "cervicobrachial fibromyalgia" significant for test of trend with exposure time in years. Chronic neck pain vs. palpatory findings: Sensitivity: 0.85; Specificity: 0.93.

(Continued)

Table 2–8 (Continued). Epidemiologic studies evaluating work-related neck/shoulder disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Bergqvist et al. 1995a	Cross-sectional	260 office workers using VDTs, (198 females); symptomatic cases compared to non-cases.	Outcome: Neck/shoulder discomfort: Any discomfort over the last 12 months; intense neck discomfort: As above, if occurred in last 7 days and interfered with work. Physiotherapist's diagnosis of (1) Tension neck syndrome: Ache/pain in the neck; feeling of tiredness and stiffness in neck; possible headache; pain during movements; muscular tenderness; (2) Cervical diagnoses: Ache/pain in neck and arm; headache; decreased mobility due to cervical pain during isometric contraction; often root symptoms such as numbness or parathesias. Exposure: Based on observation an ergonomic evaluation using data on each individual's most common work situations: Static work posture, nonuse of lower arm support, hand in non-neutral position, insufficient leg space at table, repeated movements with risk of tiredness, specular glare present on VDT. Measured: Height difference of VDT keyboard-elbow, High visual angle to VDT.	Neck/shoulder: 61.5% Female: 63% Male: 57%		Intensive neck/shoulder discomfort: stressful stomach reactions: OR=5.4 Repeated work movements: OR=3.6 Too highly placed VDT: OR=4.4	1.6-17.6 0.4-29.6 0.9-60.3	Participation rate: 92% of 353 office workers, of which 260 were VDT users. Adjusted for age and gender. Examiner and workplace investigators blinded to case and exposure status. Factors included in analysis: Age, gender, smoking, children at home, negative affectivity, tiredness-related stress reaction, stomach-related stress reaction, use of spectacles, peer contacts, rest breaks, work task flexibility, overtime, static work position, non-use of lower arm support, hand in non-neutral posture, repeated movements with risk of tiredness, height differences keyboard/elbow, high visual angle to VDTs, glare on VDTs. There are problems with interpreting results because of multiple comparisons and multiple models. Not all significant findings presented in paper.

(Continued)

Table 2–8 (Continued). Epidemiologic studies evaluating work-related neck/shoulder disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Bergqvist et al. 1995b	Cross-sectional	322 office workers from 7 Stockholm companies; VDT users compared to non-VDT users 52% interactive, 29% data entry, 19% non-VDT users.	Outcome: Neck/shoulder discomforts: Any discomfort over the last 12 months; intense neck/shoulder discomfort: As above, if occurred in last 7 days and interfered with work. Physiotherapist's diagnosis of tension neck syndrome: Ache/pain in the neck; feeling of tiredness and stiffness in neck; possible headache; pain during movements; muscular tenderness. Exposure: Video display terminal use: Based on self-reporting of VDT use. VDT users categorized into data entry or interactive VDT users. Ergonomic Factors: Same as Bergqvist 1995a.	Neck/shoulder discomfort: 60% Intense neck/shoulder discomfort: 7.4%		Neck/shoulder discomfort: Current VDT work vs. no VDT work: OR=1.4 For accumulated VDT work > 5 PY²: OR=1.3 Intense neck/shoulder discomfort: Current VDT work vs. no VDT work: OR=0.5 For accumulated VDT work >5 PY²: OR=0.8	0.8-2.4 0.7-2.5 0.2-1.8 0.3-2.5	Participation rate: 92% questionnaire; 91% physiotherapy exam; 82% workplace exam. Examiner and workplace investigators blinded to case and exposure status. Intensive neck/shoulder discomfort was associated with VDT work over 20 hr and having "stomach reactions" often and repetitive movements. OR=3.9 (1.1-13.8). Originally 535 workers queried in 1981, of those 182 had left the workplace (quit, retired, etc.)–possible bias from "Healthy Worker Effect." Covariates considered: Children at home, smoking, negative affectivity, stomach-related stress reactions, tiredness-related stress reactions; organizational factors considered limited or excessive peer contacts, limited rest break opportunity, limited work task flexibility, frequent overtime. For cervical diagnoses: Excess OR suggested for combined occurrence of VDT work of >20 hr/wk and specular glare on the VDT screen.

(Continued)

Table 2–8 (Continued). Epidemiologic studies evaluating work-related neck/shoulder disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Bjelle et al. 1981	Case-control	13 workers of industrial plant consecutively seen at health clinic with acute, nontraumatic neck/shoulder pain not due to causative disease or malformation compared to 26 controls. Matched on age, gender, and place of work.	Outcome: Physician diagnosed neck/shoulder pain. Exposure: Anthropometric and isometric muscle strength were tested with strain gauge instruments. Patients asked to perform their maximal efforts. Measurements made for the following contractions: Shoulder elevation at the acromion, abduction and forward flexion of the shoulder joints at neutral position, and semi-pronated. Grip strength measured by vigorimeter. Video recording of arm movements at work. Shoulder loads estimated from videos. Consisted of measuring the duration and frequency of shoulder abduction or forward flexion of >60E. Electromyography measurement of shoulder load during assembly work on 3 patients and 2 healthy volunteers. Muscular load level determination made by computer analysis of myoelectric amplitude.	6 with tendinitis	Controls without tendinitis	Cases had significantly longer duration and higher frequency of abduction or forward flexion than controls, 2.5/min. (p<0.001). Cases had significantly higher shoulder loads than controls. Median number of sick-leave days significantly different between cases and controls (p<001).		Participation rate: Not reported. Investigators completed the video analyses blinded to case status. Anthropometric data, age no difference between cases and controls. Isometric strength test: Controls significantly stronger in 6 of 14 tests but probably influenced by pain inhibition in cases. No significant difference in cycle time (9 vs. 12 min).

(Continued)

Table 2–8 (Continued). Epidemiologic studies evaluating work-related neck/shoulder disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Blåder et al. 1991	Cross-sectional	Of 224 sewing machine operators from 4 plants, 199 completed a symptom survey. Of 155 who reported shoulder or neck pain in the past 12 months, 131 were examined.	Outcome: Survey: Shoulder or neck pain in past 12 months. Exam: Tenderness on palpation, range of motion, pain during motion or isometric muscle contraction, active and passive range of motion was measured by use of a goniometer. Diagnoses were not made during the examinations, but test forms were later analyzed by criteria from Waris [1979]. Exposure: From questionnaire: employment duration, hr/wk. Plants selected by representatives of Swedish Labour Union familiar with work sites with similar loads.	Muscle tenderness: Acromioclavicular joint: 15% Biceps tendon: 35% Decreased ROM: 30% Acromioclavi-cular: 5%	ò	Age Nationality Employment duration Working >30 hr/wk	p <0.05 non-significant p <0.05 p <0.05	Participation rate: 89% for questionnaire, 87% for physical exam. Only those with symptoms given physical exam. Physicians and physiotherapist not blinded to symptom status. High rate of turnover in plant. Authors state that study involved control group taking into account psychosocial factors, but results not included in this article. Questionnaire included information on background, family situation, employment, job conditions, health. Physical exam occurred 1 to 3 months after questionnaire. In 3 consecutive years 147 sewing machine operators left this work in the factories. 48% answered follow-up questionnaire. (17% left because of neck problems contributing to decision to leave work.)

(Continued)

Table 2–8 (Continued). Epidemiologic studies evaluating work-related neck/shoulder disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Ekberg et al. 1994	Case-control	Study population were aged 18 to 59 years, had to have yearly incomes of SEK 45,000 and not been on sick leave for more than 2 months in past 6 months, not employed in large rubber industry in area. "Cases" had consulted a community physician for musculoskeletal disorders of the neck, shoulder, arm, or upper thorax during the study period from semi-rural community in southern Sweden. Cases had to have been ill immediately prior to physician visit and have been on sick leave at most less than 4 weeks. No trauma, infectious cause, accident, malignancy, rheumatic disease, abuse, or pregnancy. Controls were randomly selected from Swedish insurance registry.	Outcome: Self-administered questionnaire; a modified version of the Nordic questionnaire asking about musculoskeletal symptoms in the past 6 months. Questionnaire included background factors, age, gender, ethnic background, family situation, smoking habits, and exercise. Exposure: Assessed by questionnaire; seven determinants were: uncomfortable sitting position, uncomfortable standing position, physically demanding work, light lifting (less than 6 kg), repetitive movements demanding precision, work with lifted arms, and monotonous work position. Rating scales were based on average duration of hours per day of each item of exposure. 52 items on psychosocial work conditions reduced to 8 factors by factor analysis: psychological work climate, quality of work content, work pace, demands on attention, work planning, job security, job constraints, and work role ambiguity.	ð	ð	Female gender: OR=15.5 Immigrant: OR=28.3 Current smoker: OR=8.2 Repetitive Precision Movements: Low: OR=1 Med: OR=3.8 High: OR=15.6 Light Lifting: Low: OR=1.0 Med + High: OR=49.7 Lifted arms: Low: OR=1.0 Med: OR=5.9 High: OR=3.7 Work Pace: Low: OR=1 Med: OR=7.6 Rushed: OR=10.7 ORs for controls with MSD symptoms in both neck and shoulder and other body parts: Repetitive Precision Movements: OR=7.5 Light lifting: OR=13.6 Lifted arms: OR=4.8 Uncomfortable sitting positions: OR=3.6	90% CI used in this paper 3.4-71 3.1-257 2.3-29 0.7-20 2.2-113 9.0-273 0.9-37 0.4-30 1.6-36 2.2-52 2.4-23 4.8-39 1.3-18 1.4-9.3	Participation Rate: 73%. Logistic analysis adjusted for age, gender, smoking, having preschool children. Age and having preschool children were not significant factors. Ambiguity of work role, demands on attention and work content also statistically significant.

(Continued)

Table 2–8 (Continued). Epidemiologic studies evaluating work-related neck/shoulder disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Ekberg et al. 1995	Cross-sectional	637 of 900 residents between the ages of 18 to 59 years, with an average yearly income of $ $8000 U.S. dollars.	Outcome: Based on modified Nordic questionnaire; case defined as the presence of symptoms during the past 6 months. Exposure: 20 questionnaire items on physical work conditions which were factor analyzed. Self-reported perception of physical work environment factors considered: Uncomfortable sitting or standing position; physically demanding work; light lifting; repetitive movements demanding precision; work with lifted arms, monotonous work position. Questionnaire on work organization, work content and relations in the work situation.	Symptoms neck: Male: 33% Female: 53% Shoulder: Male: 35% Female: 40%	ð	Gender: OR=1.3 Immigrant Status: OR=1.3 Repetitive movements demanding precision: OR=1.2 High work pace: OR=1.2 Low work content lack of stimulation and variation: OR=1.3 Work role ambiguity: OR=1.2	1.1-1.5 1.0-1.6 1.0-1.3 1.0-1.3 1.1-1.5 1.0-1.3	Participation rate: 73%. Symptom responses in neck and shoulder correlated (r=0.56) and collapsed into one variable for the analyses. Age, smoking, exercise habits, family situation with preschool children not significantly associated with symptoms. Social work climate, demands on attention, work planning, job security and job constraints not significantly associated with symptoms.

(Continued)

Table 2–8 (Continued). Epidemiologic studies evaluating work-related neck/shoulder disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Holmström et al. 1992	Cross-sectional	Of 2500 construction workers randomly selected from 4,159 active members of trade union registry of the south of Sweden, 1,773 (71%) participated. This group was represented by all construction trades except painters, electricians and plasterers. All participants must have worked in the past 6 months, including short periods of sick leave or unemployment.	Outcome: Self-reported history of musculoskeletal problems was obtained through a mail survey. Case of "neck and shoulder pain" defined as: Pain, ache, discomfort from the neck/shoulder are experienced sometimes often or very often during the past 12 months. Case of "considerable neck and shoulder pain" defined as neck and/or shoulder trouble with "severe" or "very severe" functional impairment. Exposure: Data on physical workload, psychosocial factors and individual and employment related factors obtained from mail survey.	Hands above shoulder <1 hr/day 1 to 4 hr/day >4 hr/day Hands at waist <1 hr/day /1 to 4 hr/day >4 hr/day Stooping <1 hr/day 1 to 4 hr/day >4 hr/day Kneeling <1 hr/day 1 to 4 hr/day >4 hr/day Sitting <1 hr/day 1 to 4 hr/day >4 hr/day Roofers Plumbers Floor Machines/ Tools.	ŏ	1.1 1.5 2.0 1.0 1.1 1.2 1.0 1.4 1.5 1.4 1.4 1.5 0.6 1.6 0.7 1.6 1.5 1.3 1.1	0.8-1.5 1.2-1.9 1.4- 2.7 0.7-1.3 0.9-1.3 0.8-1.6 0.8-1.3 1.1-1.8 1.1-2.1 1.1-1.8 1.1-1.8 1.1-2.1 0.3-1.0 0.9-2.7 0.4-1.2 ŏ ŏ ŏ ŏ	Participation rate: 71%. Neck/shoulder pain related to increasing age, smoking, weight inactivity during free time, height under 185 cm. Controlled for age, physical factors. Dose-response relationship for working with hands above shoulder level. Stress index showed a dose-response. Stress questions pertained to rushing, job pressure, and inability to relax. Psychosocial factors strongly associated with neck and/or shoulder trouble and neck and shoulder pain when age and physical factors kept constant in logistic models for psychosocial pre-rate ratio, "high" level compared with "low" level for considerable neck pain; the following psychosocial scales were significant: Qualitative demands: 1.4 (1.0-2.0) Quantitative demands: 3.0 (2.1-4.0) Solitary work: 1.5 (1.2-1.8) Anxiety (health): 3.2 (2.5- 4.0) Psychosomatic: 5.0 (3.6-6.9) Psychological: 4.7 (3.6-6.0) Stress: 3.4 (2.6-4.2) The following were not significant: Discretion, support, under-stimulation, anxiety (work), job satisfaction, quality of life.

(Continued)

Table 2–8 (Continued). Epidemiologic studies evaluating work-related neck/shoulder disorders

				MSD prevalence				
Study	**Study design**	**Study population**	**Outcome and exposure**	**Exposed workers**	**Referent group**	**RR, OR, or PRR**	**95% CI**	**Comments**
Hünting et al. 1981	Cross-sectional	VDT users: 53 data entry; 109 conversational VDT users; 78 typists; compared to 55 "traditional office workers" not using VDTs or typewriters.	Outcome: Questionnaire: Symptoms of pain, stiffness fatigue, cramps, numbness, tremor scaled as: Daily, occasionally, seldom, never; Medical Exam: Included an anamnesis and palpation of painful pressure points and tendons and tendon insertion points in the shoulders, arms, and hands. Exposure: (1) Questionnaire, (2) Observation and measurements of work-station, and (3) Body posture measured using method described by Hünting et al. 1980b.	Medical findings in shoulder and neck: Conversational VDT users: 28% Typewriter: 35% Data Entry terminal VDT users: 38%	Medical findings in shoulder and neck: Traditional office workers: 11%	Medical findings: Conversational terminal VDT users vs. trad. office workers: OR=1.35 Typewriter vs. trad. office workers: OR=3.18 Data entry terminal users vs. trad. Office workers: OR=9.9	 0.6-3.1 1.3-2.6 3.7-26.9	Participation rate: Not reported. No adjustment for age and gender. Blinding of examiners not mentioned in paper. Medical findings in neck and shoulder significant in data entry workers for head inclination greater than 56E vs. <56E. Not significant in conversational terminal workers or typewriters. Medical findings in neck and shoulder significant for typists with head rotation greater than 20E compared to <20E. The lower the table and keyboard heights, the more frequently pains in the shoulder, neck, and arms. No document holders used. Authors concluded the higher the table, the higher the documents, the better the posture of the head and trunk. Increased neck/shoulder findings occurred with increased turning of the head or head inclination. Job satisfaction, relationship with colleagues, superiors, decision making abilities, use of skills not significantly different among groups.

(Continued)

Table 2–8 (Continued). Epidemiologic studies evaluating work-related neck/shoulder disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Jonsson et al. 1988	Cohort	Electronics Workers (n=69 female) out of initial 96 workers.	Outcome: Three separate physical exams at yearly intervals (one initially) assessing tenderness on palpation, pain or restriction with active and passive movements; symptoms in previous 12 months with regard to character, frequency, duration, localization, and relation to work or other physical activities. Analyzed if score on any symptom of 2 or greater than on a 4 point scale; "severe" symptom score = 4. Carried out at outset of study: MVC of forearm flexors, shoulder strength, handgrip, heart rate using a bicycle ergometer and rating of perceived exertion. Exposure: Computerized via two video recordings (rear and side), real time; obtained frequency and duration of working postures and movements, neck flexion greater than 20E.	Severe neck disorders: After 1 year: 24% 22% at 2nd exam At 3rd exam, 38 subjects reallocated to varied tasks had improved (16% of these had severe symptoms) 26% with unchanged working conditions deteriorated further	Severe neck disorders: 11% initially	Predictors of change of health status from 2nd to 3rd examination: Palpation tenderness, neck/ shoulder angle: OR=1.6 Shoulder elevated, % of work-cycle: OR= 1.04 Satisfaction with work colleagues: OR=25 Satisfaction with work tasks: OR=24.5		Participation rate: 72%. Predictors of deterioration were previously physically heavy jobs, high productivity (after 1 year), and previous sick leave. Predictors of improvement were reallocation, physical activity in spare time, and high productivity (after 2 years). Predictors of remaining healthy were work without elevating the shoulders and satisfaction with work tasks. Subjects reallocated to new tasks characterized as more dynamic and varied: Non-sitting, no inspection of small details on printed circuit boards, standing and walking, occasionally sitting, caretaking work, surveillance of machinery, assembling of bigger and heavier equipment.

(Continued)

Table 2–8 (Continued). Epidemiologic studies evaluating work-related neck/shoulder disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Kilbom et al. 1986 Kilbom and Persson 1987	Cross-sectional	106 of 138 female assemblers in two electronic manufacturing companies agreed to participate; 10 excluded because of symptoms in past 12 months. 96 underwent medical, physiological, and ergonomic evaluation.	Outcome: Three separate physical exams at yearly intervals (one initially) assessing tenderness on palpation, pain or restriction with active and passive movements; symptoms in previous 12 months with regard to character, frequency, duration, localization, and relation to work or other physical activities. Analyzed if score on any symptom of 2 or >on a 4 point scale; "severe" symptom score = 4. Exposure: Carried out at outset of study: MVC of forearm flexors, shoulder strength, handgrip, heart rate using a bicycle ergometer and rating of perceived exertion. Included video analysis of postures and movements of the head, shoulder and upper arm including durations and frequencies. Recorded work cycle time and number of cycles/hr, time at rest for the arm, shoulder and head, rest periods, and average and total duration/work cycle and hr. The mean number of neck forward flexions >20E/hr was 728 (s.d. 365) in the initial 96 workers.	MSD symptoms in the neck/ shoulder using a 4 point severity scale: None: 78% Slight: 8% Moderate: 7% Severe: 3%	ð	Logistic Regression model (all variables significant at the *p*<0.05 level) Headache Average time/work cycle with upper arm 0-30E abducted Average time/work cycle in neck flexion Excessive general fatigue at end of working day		Participation rate: 77%. The authors followed up on the non-participants and found no significant differences from participants. No relation between maximal static strength and symptoms. Examiner blinded to case status. Questions included spare time physical activities, hobbies, perceived psychosocial stress at work, work satisfaction, number of breaks, rest pauses. Clinically diagnoses found were largely myofascial symptoms. Headache, sleep problems, dizziness showed a weak positive correlation. Age, years of employment, productivity, muscle strength were not related to symptoms. There was large inter-worker variation in working posture and working techniques. The more dynamic working technique, the less symptoms in the neck and neck/shoulder symptoms. Authors note: "a strong positive relationship to disorders was obtained with VIRA variables describing neck forward flexion and upper arm elevation." See Jonsson et al. 1988 for follow-up.

(Continued)

Table 2–8 (Continued). Epidemiologic studies evaluating work-related neck/shoulder disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Linton and Kamwendo 1989	Cross-sectional	420 of 438 medical secretaries and office personnel at a Swedish hospital. Those reporting frequently having neck and shoulder pain (1 to 3) compared to those less frequently having pain (4 to 6) points).	Outcome: 3-point scale collapsed from 6-point frequency scale ranging from "almost never" to "almost always" having neck or shoulder discomfort; and Nordic Musculoskeletal Pain Questionnaire. Exposure: 10-question standardized form on the psychological work environment with 1 to 4 categorical scales. Overall score and indexes on work content, psychologic work demand and social support at work. Duties included daily use of typewriter, VDT, plus mail telephone and appointment duties.	Shoulder pain frequency Very often: 16.9% Sometime wk: 3.8% Sometimes a wk: 4.8% Sometimes days: 13.8% Sometimes 1 day: 28.6% Never: 32.1%	ð	Those frequently having neck and shoulder pain vs. those less frequently having pain: Poor Work Content: OR= 2.5 Lack of Social Support: OR=1.6	 1.3-4.9 0.9-2.8	Participation rate: 96%. 75% sat >5 hr/day. 43% worked with office machines each day. Psychosocial scale scored: 10 to 20 as good environment. 20 to 40 as poor environment. Authors noted that: (1) Secretaries exposed to high work demands periodically, (2) they also felt helpless to change the work environment, and that (3) internal conflict within departments may have affected responses.

(Continued)

Table 2–8 (Continued). Epidemiologic studies evaluating work-related neck/shoulder disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Maeda 1982	Cross-sectional	119 accounting machine operators aged 17 to 29 years in a post-check office.	Outcome: Based on questionnaire responses of pain and stiffness in the right and left sides of the neck and shoulder based on frequency of "almost every day, occasionally, and never or seldom" during the previous several wk. Scores were factor analyzed. Exposure: Anthropometric parameters relevant to the job tasks were measured on 51 operators who showed large or small factor scores.		*p*<0.05	Partial correlation coefficient between head neck tilt and factor score 1 to 5, controlling for other angles "A and C", age, and length of service 0.25		Participation rate: Not reported. Examiners blinded to case status: Not reported. Constrained tilted head posture was associated with neck/shoulder stiffness.

(Continued)

Table 2–8 (Continued). Epidemiologic studies evaluating work-related neck/shoulder disorders

				MSD prevalence				
Study	**Study design**	**Study population**	**Outcome and exposure**	**Exposed workers**	**Referent group**	**RR, OR, or PRR**	**95% CI**	**Comments**
Milerad and Ekenvall 1990	Cross-sectional	99 dentists randomly selected from Stockholm dentist registry who practiced $ 10 years compared to 100 pharmacists selected from all pharmacists in Stockholm.	Outcome: Based on telephone questionnaire: Neck symptoms at any time before the interview ("lifetime prevalence"). Further analyzed according to Nordic questionnaire as to duration during last 12 months and during last 7 days, effect on work performance, leisure activities, and sick leave. Exposure: Questionnaire included: (1) abduction of arm particularly in sit-down dentistry, (2) work hr/day, (3) static postures.	All dentists: Neck and Shoulder: 36%	17%	2.1	1.3-3.0	Participation rate: 99%. Analysis stratified by gender.
				Neck and Shoulder and Arm: 16%	3%	5.4	1.6-17.9	No difference in leisure time, smoking, systemic disease, exposure to vibration. Symptoms increased with age in female dentists only. Duration of employment highly correlated with age (r=0.84, 0.89). No relation between symptoms and duration of employment. Equal problems dominant and non-dominant sides.

(Continued)

Table 2–8 (Continued). Epidemiologic studies evaluating work-related neck/shoulder disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Ohara et al. 1976	Cross-sectional and pro-spective	For cross-sectional study: 399 cash register operators compared with 99 office machine operators and 410 other workers (clerks and saleswomen). All female. For prospective study: 56 workers employed <7 months had testing pre- and post-intervention using questionnaire and physical exam. 86 operators, newly hired after interventions, also had evaluation after 10 months of working.	Outcome: Assessed by standard health inventory and medical examination (used clinical classification according to the committee on cervicobrachial disorders of the Japan Association of Industrial Health, in Table 3 in the paper). Periodic physical exam performed twice a year from 1973. Primary exams performed on 371 operators. 130 (35%) received detailed exams. Exposure: To repetitive movements relocating merchandise across counter and bagging, involved muscle activity of the fingers, hands, and arms; extreme and sustained postures. Interventions: (1) a 2-operator system, 1 working the register, one packing articles, changing roles every hr; (2) continuous operating time <60 min; max. working hr/day 4.5 hr; (3) 15-min resting period every hr; (4) electronic cash registers with light touch keyboard substituted for half of previously used	Cash register operators Interventions did not result in reduced muscle fatigue of the neck, shoulders, and upper back brought on presumably by the continuous lifting of the upper limbs.	Office machine operators and other workers (clerks and saleswomen)	NR		Participation rate: for prospective study = 100%. Participation rate: for cross-sectional study, unable to calculate from data presented. Unknown whether examiners blinded to case status. Interventions did not reduce complaints in the shoulder region, but did improve symptoms in the arms, hands, fingers, low back, and legs. The lack of improvement in the shoulder region was stated to be due to the use of the same narrow check stands, unsuitable counter height, and necessity of continuous lifting of the upper limbs. Operators hired after the interventions and then examined after 10 months had less Grade I, II , or III occupational cervicobrachial disorders in examination than those hired before intervention. Only 14.5% with >3 years employment at worksite. Narrow work space and counter height not adjusted for height of worker. mechanical cash registers.

(Continued)

Table 2–8 (Continued). Epidemiologic studies evaluating work-related neck/shoulder disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence				Comments
				Exposed workers	Referent group	RR, OR, or PRR	95% CI	
Ohlsson et al. 1995	Cross-sectional	Industrial Workers (n=82 females) exposed to repetitive tasks with short cycles mostly far <30 sec., usually with a flexed neck and arms elevated and abducted intermittently; 68 former workers (mean employment time 21 years) who had left the factory during the 7 years before the study; these workers were compared to 64 referents with no repetitive exposure at their current jobs (female residents of a nearby town currently employed as customer service, ordering and price marking in supermarkets, as office workers (no constant computer work) or as kitchen workers.	Outcome: Pain in the last 7 days and PE diagnosing tension neck syndrome, cervical syndrome. Tension neck: Tightness of muscles, tender spots in the muscles. Cervical syndrome: Limited neck movement, radiating pain provoked by test movements, decreased sensibility in hands/fingers; muscle weakness of upper limb. Muscle strength measured by MVC at elevation, abduction, and outward rotation of both arms measured by dynamometer. Exposure: Videotaping and observation. Analysis of postures, flexion of neck (critical angles 15E and 30E). 74 workers videotaped $10 min. from back and sides. Average counts of two independent readers for frequencies, duration, and critical angles of movement used. Repetitive industrial work tasks divided into 3 groups: (1) Fairly mobile work; (2) Assembling or pressing items; and (3) sorting, polishing and packing items. Weekly working time, work rotation, patterns of breaks, individual performance rate (piece rate). Only exposure readings from right arm were used.	Industrial workers: 50%	Referents: 16%	All neck/shoulder clinical diagnoses (industrial workers compared to referents): OR=2.7 Logistic Model: Repetitive work vs. none: OR=4.6 Age (57 vs. 37): OR=1.9 Muscular tension tendency: (score 4.5 vs. 1) : OR=2.3 Stress/worry tendency: OR=1.9	1.2-6.3 1.9-12 1.0-3.5 1.3-4.9 1.1-3.5	Participation rate: Current workers: 96% Past workers: 86%; Referents: 100%. No exposure information available to examiners, "not possible to completely blind the examiners." Questionnaire included individual factors, work/environment, symptoms, psychosocial scales. Videotape analysis revealed considerable variation in posture even within groups performing similar assembling tasks. Logistic models replacing repetitive work with videotape variables found muscular tension tendency and neck flexion movements significantly associated with neck/shoulder diagnoses. Inverse relationship between duration of industrial work and MSDs, largest OR in those employed <10 years. Assembly group had high OR (6.7) with regard to neck/shoulder MSD compared to referents. Significant association between time spent in neck flexion positions <60E.

(Continued)

Table 2–8 (Continued). Epidemiologic studies evaluating work-related neck/shoulder disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Punnett et al. 1991	Cross-sectional	254 of 275 (92%) meatcutters and wrappers who attended health and safety training classes. Workers fulfilling outcome case definition (cases) were compared to non-cases; also compared to the U.S. industrial population.	Outcome: Based on self-reported symptom survey. Cases were defined if they met the following: $ 20 episodes in the previous year or usual duration of $ one wk; reported date of pain onset after employment in the retail meat industry; no history of systemic disease related to soft tissue pain; and, no history of acute injury. Exposure: Based on interview and authors observations. Exposure: Repetitive and strenuous activities (it was not stated whether this was for specific area or involved neck and all upper extremity areas) for 0.5 to 8 hr/day in refrigerated areas. Cutters cut an average 121 (+ 278) large pieces of meat/day filled 701 (+ 830 boats). Wrappers filled 374 (+ 602 boats/day). Wrapped 1,299 (+ 1,365 boats and weighed 1,399 boats).	Overall Prevalence Neck/Shoulder: 53%	ô	Male: 1.8 Female: 0.9	1.0-3.2 0.5-1.9	Participation rate: 92%. Stratified by gender and age. Neck/shoulder disorders associated with external duration of static postures (>5 sec.) or lifting $ 5 lbs. while abducting, flexing or extending the shoulder. Neck/shoulder pain did not vary by job category. 98% of respondents performed lifting tasks at work. "They judged lifting an average load/day was 41 (+ 23) lb lifted 33 times and carried 9 feet. Heaviest load = 71 (+ 31 lb), lifted 11 times and carried 9 feet/lift." Listing an average load with a 40 to 50% standard deviation can be misleading. Neck/shoulder cases lifted both the "typical" and "heaviest" loads with greater frequency than non-cases. Association was found for extended duration of and lifting weight in abduction/flexion and extension of the shoulder.

(Continued)

Table 2–8 (Continued). Epidemiologic studies evaluating work-related neck/shoulder disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	Referent group	RR, OR, or PRR	95% CI	Comments
Rossignol et al. 1987	Cross-sectional	191 Computer and data processing services, public utilities of Massachusetts State Department, at 38 work sites selected at random from Massachusetts employers of >50 workers. 28 of the 191 did not use a computer.	Outcome: Self-administered questionnaire case defined as: Neck pain, stiffness, or soreness occurring almost always or missed work due to neck pain, stiffness or soreness. Exposure: Self-reports of number of hr worked each day with a keyboard machine with a VDT. Subjects selected after observation of worksite.	½ to 3 hr of VDT use/day (n=31): 39% 4 to 6 hr of VDT use/day (n=28): 57% 7 or more hr of VDT use/day (n=104): 61%	No VDT use (n=28): 25%	Up to 3 hr of VDT use compared to 0 hr of use: OR=1.8 4 to 6 hr of VDT use compared to 0 hr of use: OR=4.0 >7 hr of VDT use compared to 0 hr of use: OR=4.6	0.5-6.8 1.1-14.8 1.7-13.2	Participation rate: In 6 industry groups 67 to 100%. Participation rate: For individual clerical workers; 94 to 99%. Assessed magnitude of confounding by age, cigarette smoking, industry, educational VDT training. Study presented to participants as a "general health" survey (as opposed to an occupationally related survey) to avoid observation bias.

(Continued)

Table 2–8 (Continued). Epidemiologic studies evaluating work-related neck/shoulder disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Ryan and Bampton 1988	Cross-sectional	143 data process operators; using a 0 to 10 point scale, the group with symptom scores of 8 or above (n=41) were designated "cases," and were compared to group with symptom scores of 2 or less (n=28).	Outcome: Based on symptoms occurring three or more times/wk with no physical exam signs, or $ weekly symptoms with physical exam signs of muscle tenderness or hardening present. Cases were selected by having a combination of symptoms in the lower arm and shoulder/neck area meeting a summary score of eight or more. These cases were compared to a comparison group with a score of 2 or less. Exposure: Ergonomic assessment measuring angles and distances of each operator seated at his/her workstation performed; Questionnaire responses to: Time spent in current job, time spent altogether keying or typing work, training in the adjustment of their chair, desk, or keyboard.	Shoulder: 44% symptom only Neck: 43% symptoms only Neck/shoulder symptoms occurring $ 3 times weekly with no signs or weekly with signs: 44%	Comparison group had symptom scores <2.	More non-cases trained in adjustment of chairs Cases with higher scores of visual discomfort Cases felt there was not enough time for rest breaks compared to non-cases Cases had more boredom, more work stress, and needed to push themselves >3 times/wk; lower peer cohesion, autonomy, clarity in the authority structure. Higher staff support and work pressure.	*p*<0.05 *p*<0.05 *p*<0.05 *p*<0.05	Participation rate: 99%. Interviewers blinded to questionnaire responses. Height, weight, sex, age, marital status, parental status evaluated and not found to be confounders. Handedness, time spent in current job, time spent altogether keying or typing work, training in adjustment of keyboard and desk evaluated in two groups and no significant differences found. Psychosocial and work environment scales included pertaining to job satisfaction as well as the Work Environment Scale [R. Moos 1974]. Authors diagnosed “myalgia” as diffuse muscle pain and tenderness.

(Continued)

Table 2–8 (Continued). Epidemiologic studies evaluating work-related neck/shoulder disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Tola et al. 1988	Cross-sectional	828 Machine operators; 658 carpenters; compared to 657 office workers; All male, ages 25 to 49 years.	Outcome: Postal questionnaire on neck or shoulder symptoms frequency in last year, and influence on work methods, daily duties and activities or leisure time hobbies. Pain Drawing Diagram used to distinguish body areas. For logistic regression model 12 month prevalence of neck and shoulder symptoms on 8 days or more. Exposure: Exposure based on occupation: Machine operators known to be exposed to static loading due to prolonged sitting and low-frequency whole body vibration, fast work pace, and upper trunk twisting. Carpenters exposed to dynamic physical work with varying postures and loads, static loading of neck/shoulder-arm, and male office workers, of whom only 40% were performing routine office tasks.	Daily symptoms: machine operators: 11% carpenters: 8% Change work methods: machine operators: 19% carpenters: 21%	Daily symptoms: office workers: 2% Change work methods: office workers: 10%	Machine vs. office: OR=1.7 Carpenter vs. office: OR=1.4 Machine vs. carpenter: OR=1.3 Use of twisted or bent postures during work Little: OR=1.0 Moderate: OR=1.2 Rather much: OR=1.6 Very much: OR=1.8 Working in a draft: No: OR=1.0 Yes: OR=1.1 Job satisfac-tion Very good: OR=1.0 Rather good: OR=1.1 Moderate or poor: OR=1.2 Age (years) 25 to 29: OR=1.0 30 to 34: OR=1.2 35 to 39: OR=1.3 40 to 44: OR=1.5 45 to 49: OR=1.6	1.5-2.0 1.1-1.6 1.1-1.4 1.0-1.5 (Little) 1.4-1.9 (Moderate) 1.5-2.2 (Rather much) 1.0-1.3 (No) 1.0-1.3 (Very good) 1.1-1.4 (Moderate or poor) 1.0-1.5 (30 to 34) 1.1-1.6 (35 to 39) 1.3-1.8 (40 to 44) 1.4-1.9 (45 to 49)	Participation rate: 74% machine operators, 67% carpenters, 67% office workers. Adjusted for years in occupation, age. Interaction terms tested for, none found. Education, general health, and leisure time activities, car driving included in analysis. Study restricted to males aged 25 to 49 years. Education status ("$ some vocational school" compared to "no > some courses") statistically significant for machine operators' and carpenters' reporting of symptoms.

(Continued)

Table 2–8 (Continued). Epidemiologic studies evaluating work-related neck/shoulder disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	RR, OR, or PRR	95% CI	Comments
Vihma et al. 1982	Cross-sectional	40 Sewing machine operators with short work cycles compared to 20 seamstresses.	Outcome: Neck or shoulder complaints defined by questionnaire: Recurrent pain or aching in present work (during or after work). Exposure: Observation and interview; hr continuously sitting, standing time, survey of work postures, length of work cycle. Sewing machine operator cycle time was 30 to 60 sec. in duration. Seamstresses had longer cycle.	Sewing machine operators with neck/shoulder complaints: 98%	Seam-stresses with neck/ shoulder complaints: 60%	PRR = 1.6	1.1-2.3	Participation rate: Not reported. Random selection of participants. Cases and referent group matched for age and duration of employment. Sewing machine operators found to have significantly greater static work compared to seamstresses.

(Continued)

Table 2–8 (Continued). Epidemiologic studies evaluating work-related neck/shoulder disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Viikari-Juntura et al. 1991a	Cohort	154 subjects (72 female, 82 male) from Helsinki, Finland. Subjects were part of a longitudinal study population that started in Finland in 1955; and from 1961 to 1963. During that time, 1084 subjects underwent cross-sectional examination. In 1985, a questionnaire was sent to all subjects; 801 (74%) responded. Of the respondents, 180 lived in the Helsinki area. It was from this group that 162 responded. Eight were excluded due to illnesses. The proportions of the highest income levels in the sample exceeded the Finnish population.	Outcome: Based on Questionnaire data: Ache, pain, stiffness, numbness in their neck/shoulder in last 12 months. Visual analogue scale of intensity, disability. Severe neck disability: Pain for >7 days in last 12 months and mean disability index $ 15. Physical exam (P.E.): Two tests for cervical nerve root involvement, neck compression test, shoulder abduction test. Because of small number of abnormal physical findings, the P.E. was eliminated from analysis Exposure: Questionnaire: Amount of work with hands overhead, work in forward bent position, work in twisted or bent position.	10% of female and 2% of male reported severe radicular neck pain 21% of female and 2% of male reported any type of severe neck/shoulder pain	õ	Female: Severe neck/shoulder symptoms vs. no symptoms Alexithymia (low verbal productivity) (continuous): OR=1.02 Social confi-dence (mode-rate fears vs. no fears): OR=0.04 (much fear vs. no fears): OR=1.4 Type of income (monthly salary): OR=0.5 Sense of coherence (continuous): OR=0.95 Twisted or bent torso (>3 hr/day vs. <1 hr/day: OR= 0.9 >3 hr/day vs.<1 hr/day Sitting in a forward posture 1-3 hr/day vs. <1hr/day: OR=10.7 >3 hr/day vs. <1 hr/day: OR=1.5	0.97-1.1 0.0-4.5 0.05-42.2 0.05-5.2 0.9-0.99 0.8-10.0 .4-291 0.07,29.6	Participation rate: 90%. Controlled for physical and creative hobbies, no interactions seen. Because of low numbers, males were not included in analysis. Subjects comprised of mostly high socioeconomic status who reported light physical workloads. Data collection in 1955 to 1963: Intelligence, alexithymia, social confidence, hobbies, motor development, verbal development, level of education of parents, type of income of family. Data collection in 1985: Questionnaire on family relationships, socioeconomic status, work history, characteristics of present work, job satisfaction, mental resources. Data collection in 1986 to 1987: Questionnaire: Physical characteristics of work, amount of physical exercise, illnesses, trauma. Measurements taken in adolescence, such as intelligence, alexithymia, social confidence, hobbies and socioeconomic status of the family showed no consistent association with neck/shoulder symptoms in adulthood.

CHAPTER 3
Shoulder Musculoskeletal Disorders: Evidence for Work-Relatedness

SUMMARY

There are over 20 epidemiologic studies that have examined workplace factors and their relationship to shoulder musculoskeletal disorders (MSDs). These studies generally compared workers in jobs with higher levels of exposure to workers with lower levels of exposure, following observation or measurement of job characteristics. Using epidemiologic criteria to examine these studies, and taking into account issues of confounding, bias, and strengths and limitations of the studies, we conclude the following:

There is **evidence** for a positive association between highly repetitive work and shoulder MSDs. The evidence has important limitations. Only three studies specifically address the health outcome of shoulder tendinitis and these studies involve combined exposure to repetition with awkward shoulder postures or static shoulder loads. The other six studies with significant positive associations dealt primarily with symptoms. There is **insufficient evidence** for a positive association between force and shoulder MSDs based on currently available epidemiologic studies. There is **evidence** for a relationship between repeated or sustained shoulder postures with greater than 60 degrees of flexion or abduction and shoulder MSDs. There is evidence for both shoulder tendinitis and nonspecific shoulder pain. The evidence for specific shoulder postures is strongest where there is combined exposure to several physical factors like holding a tool while working overhead. The association was positive and consistent in the six studies that used diagnosed cases of shoulder tendinitis, or a constellation of symptoms and physical findings consistent with tendinitis, as the health outcome. Only one [Schibye et al. 1995] of the thirteen studies failed to find a positive association with exposure and symptoms or a specific shoulder disorder. This is consistent with the evidence that is found in the biomechanical, physiological, and psychosocial literature.

There is **insufficient evidence** for a positive association between vibration and shoulder MSDs based on currently available epidemiologic studies.

INTRODUCTION

Shoulder MSDs and their relationship to work risk factors have been reviewed by several authors [Hagberg and Wegman 1987; Kuorinka and Forcier 1995; Sommerich et al. 1993; Winkel and Westgaard 1992]. Hagberg and Wegman [1987] attributed a majority of shoulder problems occurring in a variety of occupations to workplace exposure. Kuorinka and Forcier [1995] looked specifically at shoulder tendinitis and stated that the epidemiologic literature is “most convincing” regarding work-relatedness, especially showing an increased risk for overhead and repetitive work.

The focus of this review is to assess evidence for a relationship between shoulder tendinitis and workplace exposures to the following: awkward postures, forceful exertions, repetitive exertions, and segmental vibration. Also included are studies relevant to shoulder disorders—as defined by a combination of symptoms and physical examination findings or by symptoms alone, but not specifically defined as tendinitis—and those studies for which the health outcome combined neck and shoulder disorders, but where the exposure was likely to have been specific to the shoulder. Chapter 2 discusses studies involving neck-shoulder disorders where assessment of exposure was likely specific to the neck region.

Pertinent information about the 39 reviewed studies is presented in several ways. Detailed descriptions of the studies are provided in Table 3-5. The text of this section on shoulders is organized by exposure risk factor. The discussion within each risk factor is organized according to criteria presented on Pages 1-1 to 1-10 of the Introduction. Conclusions are presented with respect to the specific MSD of concern, shoulder tendinitis.

REPETITION

Definition of Repetition for Shoulder MSDs

Studies that addressed the physical factor of repetition and its relation to shoulder MSDs were included in this review. Studies usually defined repetition, or repetitive work, for the shoulder as work activities that involved cyclical flexion, extension, abduction, or rotation of the shoulder joint. Repetitiveness was defined in four different ways in the reviewed studies: (1) the observed frequency of movements past pre-defined angles of shoulder flexion or abduction, (2) the number of pieces handled per time unit, (3) short cycle time/repeated tasks within cycle, and (4) a descriptive characterization of repetitive work or repetitive arm movements. Some of the studies that examined repetition as a risk factor for shoulder MSDs had several concurrent or interacting physical work load factors. Therefore, repetitive work should not be considered the primary exposure factor, particularly independent of posture. Some studies indirectly inferred shoulder repetition by characterizing hand, wrist, and forearm movements.

Studies Reporting on the Association of Repetition and Shoulder MSDs

Three of the reviewed studies reported results on the association between repetition and shoulder tendinitis [English et al. 1995; Ohlsson et al. 1994, 1995]. For all three studies, some or all of the results were for associations with a combined exposure to repetition and awkward posture. Six additional studies reported results on the association between repetition and non-specific shoulder disorders [Sakakibara et al. 1995], non-specific shoulder symptoms [Andersen and Gaardboe 1993a; Ohlsson et al. 1989], combined neck-shoulder disorders [Bjelle et al. 1981; Chiang et al. 1993] or combined neck-shoulder symptoms [Kilbom et al. 1986; Kilbom and Persson 1987].

Studies Meeting the Four Evaluation Criteria

Four studies met all four of the criteria [Chiang et al. 1993; Kilbom et al. 1986; Ohlsson et al. 1994, 1995] (Table 3-1, Figure 3-1). Chiang et al. [1993] studied workers in the fish processing industry in Taiwan. The health outcome of “shoulder girdle pain” was defined as self-assessed symptoms of pain in the neck, shoulder or upper arms, and signs of muscle tender points or palpable hardenings upon physical examination. Pain referred from a nerve root or other spinal source was included in the case definition. The force requirements of the jobs were estimated by surface electromyographs (EMGs) in the forearm flexor muscles. This is not a direct measure of shoulder muscle activity. There may be no relationship between the level of activity in the forearm and shoulder girdle muscles. Three categories, based on both force and repetitiveness, were used as the exposure outcome: Group I (low force, low repetitiveness), Group II (high force or high repetitiveness), and Group III (high force and high repetitiveness). Force was also evaluated independently in multivariate analyses.

Kilbom et al. [1986] performed a prospective study in which female employees in the electronics manufacturing industry were observed for a 2-year period. The health outcome in the neck, shoulder, or arm regions was based on symptoms and physical findings. Symptom severity was coded on the basis of its character, frequency, and/or duration. Changes in severity status at follow-up evaluations were used as the dependent variables in multiple regression analyses. Neck, shoulder, and upper arm posture was determined by VIRA. Although the health outcome combined symptoms from different body regions, knowledge of biomechanical theory can be used to identify significant predictors related to the shoulder symptom severity.

For the two Ohlsson et al. [1994, 1995] studies, the authors reported that the examiners could not be completely blinded to exposed versus referent status, but that a standard protocol was followed and observer bias was likely to have been minimal. As examiners were blinded to objective exposure measures, analyses testing associations between neck-shoulder disorders and specific postures would not have been biased [Ohlsson et al. 1995].

In the first of the Ohlsson et al. studies, a cross-sectional study, women in the fish industry were compared to a control population of women employed in municipal workplaces in the same towns [Ohlsson et al. 1994]. Diagnoses of shoulder disorders (e.g., tendinitis, acromioclavicular syndrome, frozen shoulder) were made on the basis of symptoms determined by interview and a physical exam. Exposure evaluation of each work task held by the fish industry population was evaluated with ergonomic workplace analysis (EWA). Ten different factors were rated on a scale from 1 to 5 and the combined ratings were used as a profile of the work task. Based on this profile, the authors reported that fish industry work was found to be “highly repetitive” and to include “poor work postures.”

Ohlsson et al. [1995] compared a group of women who performed industrial assembly work to a referent group of women from a nearby town who were employed in jobs characterized as having varied and mobile work tasks. One examiner assessed signs and symptoms. The examiner was blinded to specific exposure information, but not completely blinded to factory worker versus referent group status. Shoulder tendinitis included supraspinatus, infraspinatus, and bicipital tendinitis. Another health outcome combined neck and shoulder disorders (tension neck, cervical syndrome, thoracic outlet syndrome, frozen shoulder, tendinitis, acromioclavicular syndrome). In a descriptive assessment, it was reported that the work tasks in the study group involved repetitive arm movements with static muscular work of the neck and shoulder muscles. The percentage of time spent in specific upper arm postures was determined from videotaped observation of 74 (out of 82) workers. The average result from two independent videotape analyses was used. Posture category demarcations included 0, 30, and 60 degrees for arm elevation, and 30, 60, and 90 degrees for arm abduction.

Studies Not Meeting the Four Evaluation Criteria

Bjelle et al. [1981] compared cases with acute, non-traumatic shoulder-neck pain to age- and sex-matched, paired controls. To determine exposure, each case and control was filmed and a biomechanical analysis was performed to determine the frequency and duration of shoulder abduction or forward flexion > than 60 degrees.

In the study by English et al. [1995], cases were determined by medical diagnosis and controls were selected from patients evaluated at specified orthopedic clinics. For statistical analyses, all diagnoses were grouped by anatomical site. The diagnoses for shoulder cases were rotator cuff injury, rupture of long head of biceps, shoulder capsulitis, and symptomatic acromioclavicular arthritis. It is assumed that shoulder tendinitis is included in this group. Exposure measures were determined by a standardized interview conducted by an interviewer who was "unaware of the case-control status of the individual wherever this was possible."

In a study by Sakakibara et al. [1995], the health status of a group of women farm workers was assessed during the performance of two different tasks, with a 1-month interval between the tasks. The health outcome was defined by self-assessed symptoms of shoulder stiffness and pain and a physical examination for muscle tenderness and joint pain on movement. Whether the examining physician was aware of the prior hypothesis regarding differing exposures between the two tasks (bagging pears versus bagging apples) was not stated. Exposure was based on self-report of the number of hours per day spent bagging, the number of pears or apples bagged per day, and the total number of days spent bagging each fruit. One worker was observed for 3 hours while performing each bagging job, with repeated goniometric measures of shoulder forward flexion angles done each minute. While there was no difference in the total number of days or number of hours per day spent bagging each fruit, significantly more pears than apples were bagged per day. The proportion of time spent with the angle of shoulder forward flexion greater than 90 degrees was significantly larger when bagging pears (75%) than when bagging apples (41%).

One study did not meet any of the criteria. In a cross-sectional study by Ohlsson et al. [1989], the exposed population was factory employees who produced and assembled plastic components. Work exposure was characterized as "repetitive arm and hand movements in constrained work postures." The referent population was composed of women randomly sampled from the general population in a nearby area. The health outcome was determined by self-reported symptoms of shoulder pain during the previous seven days. The exposure measure was the self-reported number of items completed per hour. The range was from less than 100 items completed per hour (slow category) to more than 700 items per hour (very fast category). Self-reporting was believed to be accurate because workers were paid by the piece.

Strength of Association: Repetition and Shoulder MSDs

Using the data presented in the study by Ohlsson et al. [1994], for supraspinatus, infraspinatus, or bicipital tendinitis the odds ratio (OR) for working in the fish industry (repetitive work, poor posture) was calculated as 3.03 (95% CI 2.5–7.2). For shoulder tendinitis alone, the PRR was calculated as 3.5 (95% CI 2.0–5.9). For clinical diagnoses of the neck and shoulder, the OR for working in the fish industry versus the referent population was 3.2 (95% CI 2.0–5.3).

Using data presented in the study by Ohlsson et al. [1995] for supraspinatus, infraspinatus, or bicipital tendinitis, the OR for being an assembly worker (repetitive arm movements with static load on shoulders) versus the referent population was 4.2 (95% CI 1.35–13.2). For neck-shoulder disorders, the OR for being an assembly worker versus the referent group was 5.0 (95% CI 2.2–11.0).

Using multiple logistic regression analysis with age, gender, and force as covariates, Chiang et al. [1993] found that highly repetitive upper extremity movements were associated with shoulder girdle pain (OR 1.6, 95% CI 1.1–2.5). When tested in the same model with force and repetition, the interaction term for force and repetition was also significant (OR 1.4, 95% CI 1.0–2.0). Several factors could have resulted in an underestimation of the strength of association: no requirement that symptoms had begun on current job means that some symptomatic workers may have transferred to lower risk jobs. Relative to shoulder MSDs, the major limitation of this study was that the exposure assessment was not specific to movement at the shoulder joint and may therefore have either over- or underestimated repetition at the shoulder. In some cases the exposure assessment may have been a measure of repetitive upper arm movements, but it may also have been a measure of repetitive hand and distal upper extremity activity occurring in the context of a static load on the shoulder muscles.

For the shoulder diagnoses used to form their group of cases, English et al. [1995] found an association with repeated shoulder rotation with an elevated arm (OR 2.30, $p < 0.05$). They also found what appeared to be a protective effect associated with elbow flexion (OR 0.4, 95% CI 0.2–0.8). This effect was greatest at low amounts of daily cumulative exposure to elbow flexion; the protective effect decreased (RR increased) as the number of hours of total daily elbow flexion increased. In a laboratory study of shoulder muscle activity in relation to different combinations of shoulder and elbow joint postures (a total of 21 different postures), Herberts et al. [1984] found that humeral rotation and elbow flexion had insignificant effects on shoulder muscle activity. However, the postures tested by that study were stationary, whereas the associations reported by English et al. [1995] appear to be related to repetitive movements.

For symptoms of shoulder pain within the previous 7 days, the OR for assembly workers versus the referent group was 3.4 (95% CI 1.6–7.1) [Ohlsson et al. 1989]. A significantly higher proportion of the farm workers studied by Sakakibara et al. [1995]

had signs of shoulder muscle tenderness while bagging pears than while bagging apples. There was no way to analyze the relative contribution to risk of repetitive shoulder exertions (increased number of pears picked per day) and awkward posture (greater portion of each day spent with extreme forward flexion when picking pears).

Consistency of Association

Repetitiveness was defined in four different ways in the reviewed studies: (1) the observed frequency of movements past pre-defined angles of shoulder flexion or abduction, (2) the number of pieces handled per time unit, (3) short cycle time/repeated tasks within cycle, and (4) a descriptive characterization of repetitive work or repetitive arm movements.

Repetition Characterized as Frequency of Movements Past Pre-Defined Shoulder Angles

Bjelle et al. [1981] and Ohlsson et al. [1995] found a significant positive association between the prevalence of neck-shoulder disorders and the frequency of upper arm movements past 60 degrees of flexion or abduction. English et al. [1995] found a significant association between diagnosed cases of shoulder disorders and repeated shoulder rotation with an elevated arm posture.

Repetition Characterized as the Number of Pieces Handled per Time Unit

A significant positive association was found between both nonspecific shoulder symptoms [Ohlsson et al. 1989] and nonspecific shoulder disorders [Sakakibara et al. 1995] and the number of pieces handled per hour or per day.

Repetition Characterized as Short Cycle Time

Chiang et al. [1993] found a significant association between a very short or repetitive cycle (<30 seconds or >50% spent repeating same task) and shoulder girdle pain.

Repetition Characterized Descriptively

Three studies by Ohlsson et al. found a significantly higher proportion of shoulder MSDs in exposed populations with work characterized as involving repetitive arm and hand movements than in referent populations [Ohlsson et al. 1989, 1994, 1995].

Repetition Combined with Static Shoulder Load

Except for the study by Sakakibara et al. [1995], in which the increased number of pears bagged per day was associated with an increased proportion of the work day spent with extreme shoulder flexion, the studies using measures of piece work or repetitive arm movements as the exposure outcome did not specify which joints or body regions participated in the repetitive action. Ohlsson et al. [1995] described the assembly work performed by the exposed population as combining repetitive arm movements with a static shoulder load. It is possible that the association between piece work, short cycles, or repetitive hand-arm movements and shoulder disorders reported by the other authors is related to a sustained, static load on the shoulder muscles as the upper arm is stabilized in a posture of mild to severe flexion or abduction, while repetitive movements are performed by the hand-wrist-forearm.

Temporal Relationship

In the prospective study by Kilbom et al. 1986; Kilbom and Persson 1987; and Jonsson et al. 1988 the number of shoulder elevations per hour was a strong predictor for a change to severe status at the 1- and 2-year follow-up evaluations. Although the change in status included problems in the neck and arm, as well as the shoulder, it is reasonable to assume that repetitive shoulder elevations would have had the greatest effect on disorders of the shoulder.

Several studies with a cross-sectional design used techniques to determine whether the health outcome of interest had occurred since, or was present during, exposure to hypothesized risk factor(s) of interest. Case definitions which required a positive physical examination finding [Chiang et al. 1993; Ohlsson et al. 1994, 1995] or where symptoms had occurred within the recent past [Chiang et al. 1993; Ohlsson et al. 1989, 1994] were designed to focus on disorders most likely to have been caused or aggravated by current work exposures.

Exposure-Response Relationship

Chiang et al. [1993] found a significant increasing trend in the prevalence of shoulder girdle pain from Group I (low force, low repetitiveness) to Group III (high force, high repetitiveness). However, the health outcome was not specific to shoulder disorders, and the exposure categories combine increasing repetitiveness—as defined by either less than a 30-second cycle time or a repeated task within the job cycle—and increasing forearm flexor muscle activity. Ohlsson et al. [1995] found that neck and shoulder disorders among assembly workers were significantly associated ($p<0.05$) with both the number of arm elevation movements from less than to greater than 60 degrees and the number of arm abduction movements from less than to greater than 60 degrees. Bjelle et al. [1981] found that the frequency of shoulder abduction or forward flexion (past 60 degrees) was significantly greater ($p<0.005$) for cases with neck-shoulder disorders than for controls.

In the study of assembly workers by Ohlsson et al. [1989], the number of pieces completed per hour was categorized as follows: slow: <100, medium: 100–299, fast: 300–699, very fast: >700. In this study, the ORs are shown in a figure, rather than reported in the text. Compared with the slow-paced group, the odds for symptoms of shoulder pain is approximately seven times that for those workers in the medium-paced group and approximately nine times that for those in the fast-June 26, 1997 pace group. While adjusting for age and length of employment, the OR for shoulder pain was significantly higher for the medium- and fast-paced groups than for the slow-paced group ($p=0.0006$). The OR for the very fast-paced group compared to the slow-paced group was between 1.0 and 2.0 and was not significantly different from the slow-paced group. The authors hypothesized that symptomatic workers may have self-selected out of the very fast paced jobs or that other unknown factors may have mitigated the effects of work pace.

When comparing fish industry workers to the reference population, Ohlsson et al. [1994] found that among those workers younger than age 45, the ORs for disorders of the neck and shoulders were significantly elevated and increased with duration of employment [0–5 years, OR 3.2 (95% CI 1.5–7.0); >5 years, OR 10 (95% CI 4.5–24)]. In their study of assembly workers, Ohlsson et al. [1989] found a statistically significant increase in the odds for pain in the shoulder with duration of employment (p=0.03) which was dependent on age. The increase with duration of employment had a steeper slope for younger (<35 years) assembly workers than for the older subgroup (i.e., among those workers employed for short durations, older women had more symptoms, and among those workers employed for long durations, younger women had more symptoms). This was thought to be a reflection of both survivor bias as well as the possibility that older new hires may have experienced a relatively more rapid onset of symptomatic problems than do younger women.

Coherence of Evidence

Repetitive movements of the upper extremity involving flexion or abduction of the glenohumeral joint would increase the frequency of effects such as fatigue and tendon circulation disruption hypothesized to occur as a result of such postures. These effects could be magnified by the addition of a hand-held load. Repetition may also be solely related to the development of tendinitis. In a laboratory study, Hagberg [1981] induced acute shoulder tendinitis in female subjects performing repetitive shoulder elevations for one hour. Six female students, ages 18–29, all developed shoulder tenderness (two with tendinitis) when exposed to 15 shoulder flexions (from 0 to 90 degrees) per minute for 60 minutes while holding up to 3.1 kg (6.4 lb) of weight.

Some of the significant associations reported may have been related to exposure to repetitive work in the distal upper extremity while the shoulder and upper arm were maintained in a static posture [Chiang et al. 1993; Ohlsson et al. 1989, 1994, 1995]. Winkel and Westgaard [1992] have pointed out that, “It is not possible to use the arm/hand without stabilizing the rotator cuff girdle and the glenohumeral joint. Therefore, work tasks with a demand of continuous arm movements generate load patterns with a static load component.”

The finding that the supra- and infraspinatus muscles were particularly prone to fatigue when subjects performed overhead work led Herberts et al. [1984] to hypothesize that the rotator cuff muscles may develop high intramuscular pressures at relatively low contraction levels. These high intramuscular pressures could lead to an impairment of intramuscular circulation, which could contribute to the early onset of fatigue. Intramuscular pressure increases with the muscle contraction level, and impaired circulation has been demonstrated at levels of contraction as low as 10–20 percent of maximal voluntary contraction (MVC). [Hagberg 1984].

The increased pressure in rotator cuff muscles and increased pressure on the supraspinatus tendon may trigger two different events that are both related to impaired microcirculation. The impaired microcirculation in the tendon may also result from tension within the tendon produced by forceful muscle contractions [Rathburn and Macnab 1970]. An inflammatory infiltrate with increased vascularity and edema within the rotator cuff tendons, especially the supraspinatus tendon may be a result of or a contributor to the process. If the inflammation process is sufficiently intense, then shoulder tendinitis may occur. If the process is less intense, and more chronic, then it may contribute to a degenerative process in the tendons of the rotator cuff. In the muscles of the rotator cuff, the impaired microcirculation may lead to small areas of cell death. A reasonable hypothesis is that repeated or sustained episodes of muscle ischemia result in localized cell death and persistent inflammation.

Neither of these proposed models for shoulder muscle pain or tendinitis suggest that all muscle activity is potentially harmful. Both muscles and tendons are strengthened by repeated activity if there is sufficient recovery time. However, the models present plausible mechanisms by which work tasks with substantial shoulder abduction could contribute both to shoulder pain and tendinitis.

There is evidence of a relationship between shoulder tendinitis and highly repetitive work. However, there are several limitations to the evidence. In the three studies for which the health outcome was shoulder tendinitis, the exposure combined repetition with awkward shoulder posture and/or a static shoulder load [English et al. 1995; Ohlsson et al. 1994, 1995]. Five out of the eight studies reviewed used either nonspecific shoulder disorders, nonspecific shoulder symptoms or combined neck-shoulder disorders as the health outcome.

Despite the limitations of the evidence, significant and positive relationships between repetitiveness, regardless of the measurement method, and shoulder MSDs or symptoms were found in all studies. Of the eight studies in which the effect of repetition was examined, three studies found ORs above 3.0 [Ohlsson et al. 1989, 1994, 1995] and three studies found ORs from 1.0 to 3.0 [Chiang et al. 1993; English et al. 1995; Sakakibara et al. 1995]. The remaining studies were prospective studies [Jonsson et al. 1988; Kilbom and Persson 1987] or studies that reported risk indicators other than OR [Bjelle et al. 1981].

In none of these studies is it likely that age, the most important personal characteristic associated with shoulder tendinitis and other shoulder disorders, or nonoccupational factors such as sports activities, caring for young children, or hobbies explained these associations. There is evidence of a relationship between shoulder tendinitis and highly repetitive work.

FORCE

Definition of Force for Shoulder MSDs

Studies that examined force or forceful work or heavy loads to the shoulder, or described exposure as strenuous work involving the shoulder abduction, flexion, extension, or rotation that could generate loads to the shoulder region were also included. Most of the studies that examined force or forceful work as a risk factor for shoulder symptoms or tendinitis had several concurrent or interacting physical work load factors. However, there is still a need to summarize present knowledge about the relationships between forceful work and shoulder MSDs. This section summarizes that knowledge, while acknowledging that other factors can modify the response.

Neck-shoulder disorders are discussed in Chapter 2.

Studies Reporting on the Association of Force and Shoulder Tendinitis

There are five studies which reported results on the association between force and adverse shoulder health outcomes (Table 3–2, Figure 3–2). The epidemiologic studies that addressed forceful work and shoulder MSDs tended to compare working groups by classifying them into broad categories based on an estimated amount of resistance or force of exertion and a combination of estimated rate of repetition [Andersen and Gaardboe 1993a; Chiang et al. 1993] or in terms of overall load [Herberts et al. 1984; Stenlund et al. 1992; Wells et al. 1983].

Studies Meeting the Four Evaluation Criteria

Chiang et al. [1993] studied workers in the fish processing industry. (This study was described in detail in the section on shoulder MSDs and repetition.) Chiang et al. [1993] did not report an exposure specific to the shoulder.

Studies Not Meeting the Four Evaluation Criteria

Andersen and Gaardboe [1993a] performed a cross-sectional study in which a cohort of sewing machine operators was compared to a random sample of women in the general population of the same region. Chronic shoulder pain was defined as a having experienced a continuous pain episode lasting more than 1 month and either daily pain or pain lasting more than 30 days in the same location within the previous year (per self-administered questionnaire). In order to compare the current exposure of sewing machine operators and those in the control group, the authors' experience and knowledge of the jobs were used to assign job titles to exposure categories based on crude assessments of force and repetitiveness. High exposure was characterized as a combination of high repetitiveness (activity repeated several times per minute) and low or high force, or medium repetitiveness (activity repeated many times per hour) and high force. Medium exposure was characterized as medium repetitiveness and low force, or low repetitiveness (jobs with more variation) and high force. Those in teaching, academic, self-employed, or nursing professions were classified as low exposure. The exposure classification scheme in this study does not allow separation of the effects of force from those of repetition. More sewing machine operators than referents were considered to have high exposure (41% versus 15%), but more in the referent population were considered to be in the medium exposure group (44% versus 22%). Because the outcome of interest was duration of historical exposure, current exposure was included as an independent variable in multivariate regression analyses.

Herberts et al. [1984] added to the 1981 study by comparing the prevalence of supraspinatus tendinitis between plate-workers and office clerks. Tendinitis in welders was determined by a combination of self-reported symptoms and positive physical examination findings. The only information given regarding plate-work is that it is dynamic in character. It is presumed that plate-workers handled heavy loads more frequently than office clerks.

In a cross-sectional study, the prevalence of osteoarthrosis in the acromioclavicular joint, as determined by radiography, was compared among three groups of workers in the construction industry [Stenlund et al. 1992]. The three groups were bricklayers, rock blasters, and construction foremen. The foremen did not perform manual work currently, or in the past, and were considered the control population. A standardized interview was used to determine exposure factors, including job title and the sum of loads lifted during all working years (expressed in tonnes). Analyses were performed separately for right and left sides.

In a study of letter carriers, Wells et al. [1983] evaluated the effect of a load carried on the shoulder. Letter carriers, who carry a load and walk, were compared to gas meter readers (who walk without carrying a load) and postal clerks. Utilizing information from telephone interviews, points were assigned to symptom characteristics such as frequency, length of episodes, and interference with work ability. Case definition required a report of recurrent shoulder pain with greater than 20 points. A subset of letter carriers had experienced an increased load during the previous year. (The Postal Service had increased maximum weight carried from 25 to 35 pounds, but not all locations had implemented this change.)

Strength of Association—Force and Shoulder MSDs

The studies are presented in alphabetical order in Table 3-2. Results of studies where ORs, or other measures of association, were specifically associated with a measure of exposure, are presented in the section on Exposure-Response Relationship.

Andersen and Gaardboe [1993a] found that current work as a sewing machine operator was associated with chronic shoulder pain (OR 1.72, 95% CI 1.17–2.55). Using multiple logistic regression analysis with age, gender, and repetitiveness as covariates, Chiang et al. [1993] found that high force exertions measured in the forearm were associated with shoulder girdle pain (OR 1.8, 95% CI 1.2–2.5). When tested in the same model with force and repetition, the interaction term for force times repetition was also significant (OR 1.4, 95% CI 1.0–2.0). Two factors could have resulted in an underestimation of the strength of association: (1) no requirement that symptoms have started on current job meant that some symptomatic workers may have transferred to lower risk jobs, and (2) no matching of health status and exposure status by side (left, right, or both) may have caused non-differential misclassification. For supraspinatus tendinitis, Herberts et al. [1984] calculated a prevalence rate ratio (PRR) for plate-workers versus office clerks of 16.2 (90% CI 10.9–21.5) "under the assumption that missing data had the same characteristics as those considered." The absence of specific exposure information was a major limitation of this study.

The age-adjusted OR associated with osteoarthritis of the acromioclavicular joint was 2.16 (95% CI 1.14–4.09) (right side) and 2.56 (95% CI 1.33–4.93) (left side) for manual construction workers versus foremen [Stenlund et al. 1992]. Because there was a lower participation rate among bricklayers and blasters, self-selection into the study because of having symptoms could have resulted in overestimation of the strength of association. While some of the items handled required a bilateral lift (e.g., jackhammer), other loads may have been specific to the right or left hand. Because the exposure measure did not separate load by sides, non-differential misclassification may have caused underestimation of the strength of association.

Consistency of Association: Force and Shoulder MSDs

Despite different outcome and exposure measures, all of the studies had positive associations. Each study used a different case definition, ranging from relatively mild symptoms to radiographic evidence of osteoarthritis, and a different measure of exposure. Chiang et al. [1993] used EMG measures of forearm flexor muscle activity. Wells et al. [1983] evaluated the effect of a direct load on the shoulder. Stenlund et al. [1992] used an estimate of the cumulative, lifetime load carried. Andersen and Gaardboe [1993a] compared sewing machine operators to a referent population. However, positive and significant associations were found, regardless of the measure of health outcome or exposure.

Temporal Relationship: Force and Shoulder MSDs

All of the studies of forceful exertions used a cross-sectional study design. To increase the likelihood that shoulder symptoms were caused or aggravated by current exposure, Chiang et al. [1993] required that symptoms had occurred within the previous 30 days.

Wells et al. [1983] used several analytical methods to increase confidence in a relationship between carrying the increased load and having shoulder disorders. The use of age, the number of years on the job, and previous heavy work experience as covariates when performing analysis of covariance helped ensure that the difference in the proportion of shoulder disorders between letter carriers with and without the increased load was related to current exposure rather than past peak exposures or cumulative duration. Although baseline symptom status in the group with the increased load could not be obtained, there was no significant difference in the prevalence of shoulder problems between the two groups when results were adjusted for the amount of weight currently carried. Therefore, the difference in symptom prevalence was likely related to the load increase rather than prior differences in symptom status. The cross-sectional studies are consistent with exposure occurring before the onset of the shoulder MSDs.

Exposure-Response Relationship

When sewing machine operators were compared with an external control population, there was a trend of increasing ORs for chronic shoulder pain with increasing duration of work as a sewing machine operator [Andersen and Gaardboe 1993a]. The OR for 0–7 years was 1.38 (95% CI 0.86–2.39), for 8–15 years it was 3.86 (95% CI 2.29–6.50), and for >15 years it was 10.25 (95% CI 5.85–17.94), while controlling for other factors including age and current exposure.

Chiang et al. [1993] found a significant increasing trend in the prevalence of shoulder girdle pain from Group I (low force, low repetitiveness) to Group III (high force, high repetitiveness). However, the health outcome is not specific for shoulder tendinitis and the exposure categories combine increasing force, as measured in the forearm flexor muscles, and increasing repetitiveness.

In the study of bricklayers and blasters, and acromioclavicular osteoarthritis, Stenlund et al. [1992] found that for the left side, ORs increased with the level of lifetime load lifted. For a lifetime load of 710–24,999 tonnes versus less than 710 tonnes, the left side OR was 7.29 (95% CI 2.49–21.34), and for greater than 25,000 tonnes versus less than 710 tonnes, the left side OR was 10.34 (95% CI 3.10–34.46).

For severe, but not disabling, shoulder pain, the OR for letter carriers versus postal clerks was 3.6 (95% CI 1.8–7.8) [Wells et al. 1983]. For those letter carriers who had experienced a weightload increase within the previous year, versus postal clerks, the OR was 5.7 (95% CI 2.1–17.8). Furthermore, letter carriers who had experienced the weightload increase had significantly more shoulder problems than those whose bag weight had not been increased. If letter carriers tend to keep the mail-bag strap on one shoulder, the fact that the side of the load was not matched with the side of the shoulder problem could have resulted in non-differential misclassification and an underestimation of the strength of association. However, some of the health effects may have been related to activation of contralateral muscles involved in stabilizing the shoulder girdle [Winkel and Westgaard 1992].

Coherence of Evidence

High shoulder muscle force requirements can cause increased muscle contraction activity, which may lead to an increase in both muscle fatigue and tendon tension, and may possibly impair microcirculation as well.

Force may also be related to a static load on shoulder muscles. Sjøgaard et al. [1988] found that muscular fatigue will occur at EMG levels as low as 5% of maximal voluntary contraction (MVC) if sustained for 1 hour. Other studies have demonstrated that when the period of muscle contraction is extended to more than an hour, the endurance limit of force may be as low as 8% MVC [Jonsson 1988]. Workers performing repetitive work with the hands and wrists, while maintaining static upper arm elevation may experience fatigue even at low load levels. Jonsson [1988] reported that many constrained work situations are characterized by static load levels near or exceeding 5% MVC, even when characterized by a fairly low mean muscular load.

Because the five studies reviewed had a considerable diversity of exposure assessment approaches and health outcomes, there is insufficient epidemiologic evidence to conclude that forceful exertions are associated with rotator cuff or bicipital tendinitis. The one study that used shoulder tendinitis as the health outcome reported a strong association related to job category (OR for plate-workers versus clerks: 16.2 (95% CI 10.9–21.5), but did not describe or measure specific exposure risk factors [Herberts et al. 1984]. One of the reviewed studies did present evidence for an association between acromioclavicular osteoarthrosis and cumulative, lifetime load on the shoulder muscles [Stenlund et al. 1992]. Another study reported a significant association between severe shoulder pain and a direct shoulder load [Wells et al. 1983].

POSTURE

Definition of Awkward Posture for Shoulder MSDs

For the shoulder, a relaxed, neutral posture is one in which the arm hangs straight down by the side of the torso. As the arm is flexed, abducted, or extended, the included angle between the torso and the upper arm increases. In one study, postures in which the included angle was equal to or greater than 45 degrees required substantial supraspinatus muscle activity, while deltoid muscle activity underwent a pronounced increase as the angle of shoulder flexion or abduction increased from 45 to 90 degrees [Herberts et al. 1984]. As the arm is elevated, the space between the humeral head and the acromion narrows such that mechanical pressure on the supraspinatus tendon is greatest between 60 and 120 degrees of arm elevation [Levitz and Iannotti 1995]. While there is a continuum of severity from an included angle of 30 degrees to a maximally abducted arm, postures with shoulder abduction or flexion past 60 degrees are considered awkward.

Studies Reporting on the Association of Awkward Postures and Shoulder MSDs

Six of the reviewed studies reported results on the association between awkward postures and shoulder tendinitis [Baron et al. 1991; Bjelle et al. 1979; English et al. 1995; Herberts et al. 1981; Ohlsson et al. 1994, 1995] (Table 3-3, Figure 3-3). Seven additional studies reported results on the association between awkward postures and non-specific shoulder disorders [Sakakibara et al. 1995], non-specific shoulder symptoms [Hoekstra et al. 1994; Milerad and Ekenvall 1990; Schibye et al. 1995] combined neck-shoulder disorders [Bjelle et al. 1981; Jonsson et al. 1988; Ohlsson et al. 1995] or combined neck-shoulder symptoms [Kilbom and Persson 1987].

Studies Meeting the Four Evaluation Criteria

Four studies met all four of the evaluation criteria.

Using a prospective study design, Jonsson et al. [1988] assessed the health and exposure status of 69 electronics manufacturing plant employees at the beginning of the study and after one and two years. Employees who dropped out before completion of the study were compared to those who fully participated; there was no significant difference in medical status, working technique, or work history. Employees who had upper extremity disorders resulting in a physician visit or sick leave were excluded from the initial study group. The dependent variables related to health status were of two types: a change in symptom severity and being symptom free. Symptom status was assessed by interview and a physical examination by a physiotherapist. The symptoms severity index compiled data from the five body regions combined and was not specific for the shoulder region. Because the exposure was determined by direct observation for each individual, and clearly separated ergonomic risk factors by body region, it was still possible to evaluate associations likely to specifically involve the shoulder.

Kilbom and Persson [1987] and Kilbom et al. [1986] performed a study in which female employees in the electronics manufacturing industry were observed for a 2-year period. The health outcome of fatigue, ache, or pain in the neck, shoulder, or arm regions was based on symptoms information. Symptom severity was coded on the basis of its character, frequency, and/or duration. Changes in severity status at follow-up evaluations were used as the dependent variables in multiple regression analyses. Neck, shoulder, and upper arm posture was determined by computerized analysis (VIRA) of videotapes of individuals. Although the health outcome combined symptoms from different body regions, knowledge of biomechanical theory can be used to identify significant predictors related to the shoulder symptom severity.

Two of the reviewed studies in which tendinitis was the health outcome are Ohlsson et al. [1994, 1995]. For both studies, the authors reported that the examiners could not be completely blinded to exposed versus referent status, but that a standard protocol was followed and observer bias was likely to have been minimal. Because examiners were blinded to objective exposure measures, analyses testing associations between neck-shoulder disorders and specific postures would not have been biased [Ohlsson et al. 1995].

In a cross-sectional study, women in the fish industry were compared to a control population of women employed in municipal workplaces in the same towns [Ohlsson et al. 1994]. Diagnoses of shoulder disorders (e.g., tendinitis, acromioclavicular syndrome, frozen shoulder) were made on the basis of symptoms determined by interview and a physical exam. Exposure evaluation of each work task held by the fish industry population was evaluated with ergonomic workplace analysis (EWA). Ten different factors were rated on a scale from 1 to 5 and the combined ratings were used as a profile of the work task. Based on this profile, the authors reported that fish industry work was found to be "highly repetitive" and include "poor work postures."

Ohlsson et al. [1995] compared a group of women who performed industrial assembly work to a referent group of women from a nearby town who were employed in jobs characterized as having varied and mobile work tasks. One examiner assessed signs and symptoms. The examiner was blinded to specific exposure information, but not completely blinded to factory worker versus referent group status. Shoulder tendinitis included supraspinatus, infraspinatus, and bicipital tendinitis. Another health outcome combined neck and shoulder disorders (tension neck, cervical syndrome, thoracic outlet syndrome, frozen shoulder, tendinitis, and acromioclavicular syndrome). In a descriptive assessment, it was reported that the work tasks in the study group involved repetitive arm movements with static muscular work of the neck and shoulder muscles. The percentage of time spent in specific upper arm postures was determined from videotaped observations of 74 (out of 82) workers. The average result from two independent videotape analyses was used. Posture category demarcations included 0, 30, and 60 degrees for arm elevation, and 30, 60, and 90 degrees for arm abduction.

Studies Not Meeting the Four Evaluation Criteria

Summaries of studies that specifically evaluated associations with shoulder tendinitis are presented next [Baron et al. 1991; Bjelle et al. 1979, 1981;

English et al. 1995; Herberts et al. 1981]. Summaries of other studies are presented in alphabetical order.

In the study by Baron et al. [1991], grocery store workers who performed the job of checker were compared to a non-checker group that performed a variety of other jobs (e.g., general stocking, working in the produce section, the bakery, salad bar, pharmacy, and courtesy counter). There was a low participation rate among non-checkers (55%), which could have resulted in an underestimation of the OR for checkers if symptomatic non-checkers were more likely to participate than those non-checkers without symptoms. The authors evaluated this possibility by performing a sufficient number of telephone interviews with non-participants to raise the non-checker participation rate for interviews to 85%. The OR for shoulder symptoms among the full participant population was similar to the OR for the full participant plus telephone interview population. The case definition was shoulder symptoms lasting at least one week or occurring at least once per month during the previous year that began while the worker was performing her current job and positive physical examination findings consistent with a shoulder tendinitis. Detailed descriptions of the checker jobs were presented based on both on-site and videotape analyses of a few representative workers per workstation. No videotaping of non-checkers was performed. Shoulder flexion and/or abduction ($90 degrees) was observed during a variety of different tasks performed by the checkers. The exposure measures used in statistical analyses were: (1) checker versus non-checker and, (2) for exposure-response assessment among checkers, the total number of months and the number of hours per week working as a checker.

Bjelle et al. [1979] compared cases with persistent shoulder pain to controls employed as manual workers. After an extensive medical evaluation, a diagnosis of bicipital and/or supraspinate tendinitis was made for a majority (12/17) of the cases. Physical workload was categorized in relation to sitting or standing posture, weight lifting, and carrying. The work height of the hands was categorized based on position relative to the acromion height, per individual. Placement of workers into exposure categories was determined by the combined efforts of each study participant and a physician.

Bjelle et al. [1981] compared cases with acute, non-traumatic shoulder-neck pain to age- and sex-matched, paired controls. An extensive physical examination was performed and workers with inflammatory rheumatoid diseases were excluded. To determine exposure, each case and control was filmed and a biomechanical analysis was performed to determine the duration and frequency of shoulder abduction or forward flexion greater than 60 degrees.

In a study by English et al. [1995], cases determined by medical diagnosis, and controls were selected from patients evaluated at specified orthopedic clinics. For statistical analyses, all diagnoses were grouped by anatomical site. The diagnoses for shoulder cases included rotator cuff injury, rupture of the long head of the biceps, shoulder capsulitis, and symptomatic acromioclavicular arthritis. It is assumed that shoulder tendinitis was included in this group. Exposure measures were determined by a standardized interview conducted by an interviewer who was, “unaware of the case-control status of the individual wherever this was possible.”

In a study by Herberts et al. [1981], the prevalence of supraspinatus tendinitis was compared between welders and office workers. Tendinitis cases were based on a combination of symptoms reported on a nurse-administered questionnaire and a positive physical examination done by a physiotherapist. For welders, an “experienced physiotherapist” rated work-load on the shoulder as low, high, or very high; no description of the classification scheme was given.

Hoekstra et al. [1994] evaluated government office workers at two locations. The case definition for shoulder symptoms was symptoms that began after starting current job, lasting greater than one week, or occurring at least once per month during the past year with an intensity greater than two on a five point scale, and no preceding acute, non-occupational injury. A self-administered questionnaire was used to determine exposure to factors such as “perceived adequacy of adjustment of video display terminal (VDT).” Walk-through ergonomic evaluations of factors such as workstation surface height and furniture adjustability were used to provide descriptive differences between the two office locations.

Milerad and Ekenvall [1990] compared the prevalence of self-reported, non-specific shoulder symptoms between dentists and pharmacists. Dentistry, as a profession, was described as work “with the arms abducted and unsupported” whereas, pharmacists had “physically light and varied work.”

In a prospective study by Sakakibara et al. [1995], the health status of a group of women farm workers was assessed during the performance of two different tasks, with a 1-month interval between the tasks. The health outcome was defined by self-assessed symptoms of shoulder stiffness and pain and a physical examination for muscle tenderness and joint pain on movement. Whether the examining physician was aware of the prior hypothesis regarding differing exposures between the two tasks (bagging pears versus bagging apples) was not stated. Exposure was based on self-report of the number of hours per day spent bagging, the number of pears or apples bagged per day, and the total number of days spent bagging each fruit. One worker was observed for 3 hours while performing each bagging job, with repeated goniometer measures of shoulder forward flexion angles done each minute. While there was no difference in the total number of days or number of hours per day spent bagging each fruit, significantly more pears than apples were bagged per day. The proportion of time spent with the angle of shoulder forward flexion greater than 90 degrees was significantly larger when bagging pears (75%) than when bagging apples (41%).

Schibye et al. [1995] performed a prospective study of a population of sewing machine operators in which the change in self-reported shoulder symptom status was compared with those sewing machine operators who continued to work and those operators that moved into other occupations (e.g., shop assistant, health care worker, and fishing industry worker).

Strength of Association—Awkward Posture and Shoulder MSDs

Results are presented in the section on Exposure-Response Relationship (Table 3-3, Figure 3-3) for studies where ORs, or other measures of association, were specifically associated with a measure of exposure.

Using data presented in the study by Ohlsson et al. [1994], for supraspinatus, infraspinatus, or bicipital tendinitis, the PRR for working in the fish industry (repetitive work, poor posture) versus the referent population was calculated as 3.03 (95% CI 2.0–4.6). For shoulder tendinitis alone, the PRR was calculated as 3.5 (95% CI 2.0–5.9). In the same study, the authors also interviewed a large group of former fish industry employees and found that a quarter of those workers who left employment had done so because of problems with their neck or upper limbs. This proportion increased with age and also occurred after a shorter duration of employment among the oldest workers. This evidence of a survivor bias highlights the importance of controlling for age. Higher risks were found for the workers less than 45 years old and these risks may be a more accurate assessment of the true risk.

Using data presented in the study by Ohlsson et al. [1995], for supraspinatus, infraspinatus, or bicipital tendinitis, the OR for being an assembly worker (repetitive arm movements with static load on shoulders) versus the referent population was 4.2 (95% CI 1.35–13.2). For neck-shoulder disorders, the OR for being an assembly worker versus the referent group was 5.0 (95% CI 2.2–11.0).

For shoulder disorders consistent with tendinitis, Baron et al. [1991] found that the OR for being a checker versus a non-checker was 3.9 (95% CI 1.4–11.0). Because non-checkers also performed work requiring awkward postures, the reported OR may underestimate the risk for checkers. Short stature (# 5'2") was associated with an elevated, but not statistically significant, OR for shoulder disorders (2.1, 95% CI 0.7–6.9). Because work-station height was fixed, it is likely that short stature workers experienced more frequent and/or more severe episodes of shoulder flexion and/or abduction.

The OR for work performed at or above acromion height (i.e., hands above the shoulder) versus work performed below acromion height was 10.6 (95% CI 2.3–54.9) [Bjelle et al. 1979]. In this study, all cases were patients who had been examined by the same physician. Placement of cases and controls into exposure categories was performed by each subject in collaboration with a physician who "had personal knowledge of the work involved in each case." Whether or not the physician who performed the clinical examinations is the same person as the physician involved in exposure classification is not stated. If this was the same person, a potential bias towards assigning cases to higher exposure categories could have resulted in overestimation of the strength of association. However, two other factors could have resulted in an underestimation of the strength of association. The exposure outcome was based on current work load without any stated restriction that cases' symptoms had started on their current job. If some of the cases, defined as having problems non-responsive to therapy lasting longer than 3 months, had transferred to a lower risk job, the strength of association may have been underestimated. Location of the disorder and exposure were not matched by side (left, right, or both) and this would have caused non-differential misclassification, resulting in some underestimation of the strength of association.

English et al. [1995] found that the risk of having a medically diagnosed shoulder condition was increased by repeated shoulder rotation with an elevated arm (OR 2.30, $p<0.05$). Non-differential misclassification due to a combination of complicated exposure definitions using a questionnaire, and the fact that analyses did not relate health outcomes and exposure on a temporal basis, or by left/right side, may have caused an under-estimate of the strength of association.

For supraspinatus tendinitis, Herberts et al. [1981] found that the PRR for welders (characterized as using awkward postures to perform overhead work) versus clerks was 18.3. However, in determining this PRR, the authors performed extrapolation based on an assumption that, "the drop-out group does not deviate from the examined group," without any data to support this assumption. To determine a more reliable indicator of risk, unextrapolated data presented in the study were used to calculate a crude OR=8.3 (95% CI 0.63–432). The office clerks were older than the welders, so that confounding by age may have caused an under-estimation of the strength of association.

In a study of teleservice employees, there was an association between reporting shoulder symptoms and working at one location versus another location; the OR was 4.0 (95% CI 1.2–13.1) [Hoekstra et al. 1994]. Descriptive differences between workstation design at the two locations provided a plausible explanation for this finding. At the higher risk location, the workstation surface was too high to serve as a keyboard support, there were nonadjustable chairs, and it was observed that "nonadjustable furniture universally promoted undesirable postures (i.e. elevated arms, hunched shoulders)." Having shoulder symptoms was also positively associated with using a non-optimally adjusted desk height (OR 5.1, 95% CI 1.7–15.5) and a non-optimally adjusted VDT screen (OR 3.9, 95% CI 1.4–11.5). Because exposure was self-reported without any indication of whether or not study participants had received education regarding good VDT workstation design, the phrase, "non-optimally adjusted," may have had various meanings to the study participants. This could have caused non-differential misclassification of exposure and an under-estimation of the strength of association. On the other hand, a possible reporting bias related to self assessment of both symptoms and exposure could have resulted in an overestimation of the strength of the association. A plausible explanation for the association between shoulder symptoms and these workstation design factors is that the non-optimally adjusted workstation components forced the employees to abduct the upper arms and/or hunch the shoulders.

For shoulder symptoms without concomitant neck symptoms, Milerad and Ekenvall [1990] found that the OR for being a dentist (work with both arms abducted) versus being a pharmacist was 3.8 (95% CI 1.2– 10.3). As with most cross-sectional studies, the survivor bias may have resulted in underreporting of the strength of exposure. Conversely, the exposed group may have had better recall of self-reported symptoms with a resultant overestimation of the OR.

In the study of farm workers by Sakakibara et al. [1995], the point prevalence of muscular tenderness in the shoulder regions (per physical examination) was significantly higher when performing pear bagging (48%) than when performing apple bagging (29%). The proportion of time spent with the shoulder in forward flexion greater than 90 degrees was significantly larger when bagging pears (75%) than when bagging apples (41%). Whether or not there was a recovery period between pear and apple bagging is not stated. If there was insufficient recovery after pear bagging, persistent muscle tenderness or increased susceptibility may have caused underestimation of the difference in shoulder disorder prevalence between these two work ta sks.

With the exception of the study by English et al. [1995], in which the strength of association may have been underestimated, for the studies in which the health outcome was shoulder tendinitis [Baron et al. 1991; Bjelle et al. 1979; Herberts et al. 1981; Ohlsson et al. 1994, 1995], the magnitude of association was strong. ORs ranged from 2.0 to 10.6. In none of these studies is it likely that nonoccupational factors such as sports activities or personal characteristics such as age explain these associations.

Consistency of Association

All but one of the reviewed studies relevant to posture and shoulder disorders found a positive association between shoulder disorders or shoulder symptoms and awkward shoulder posture. Awkward postures were consistently described as overhead work, arm elevation, and specific postures relative to degrees of upper arm flexion or abduction. This association was found in cross-sectional, case-control, and prospective studies among a great variety of types of work performed.

Temporal Relationship

It is important to determine whether symptoms or MSDs occur as a consequence of work-related exposures. This can be done most clearly with a prospective study design.

In the study by Jonsson et al. [1988], the percent of the work cycle spent with the shoulder elevated was negatively associated with remaining healthy (symptom free). Because workers with pre-existing shoulder conditions were excluded from study participation, the onset of new symptoms may have been associated with the daily and/or cumulative duration of exposure to elevated shoulder postures. In the study by Kilbom and Persson [1987], three of the work exposure variables that were strong predictors for a change to severe status at the 1- and/or 2-year follow-up evaluations were related to shoulder posture: (1) percent of work cycle time with arm abduction greater than 30 degrees, (2) percent of work cycle time with arm abduction greater than 60 degrees, and (3) percent of work cycle time with arm extension.

A few studies utilized techniques to improve the ability to detect possible relationships despite a cross-sectional study design. The case definition used by Baron et al. [1991] required that symptoms began while the worker was on the currently held job. Bjelle et al. [1979] filmed and analyzed the job held at the time the worker/case became symptomatic. The results of the prospective studies are similar to the cross-sectional studies. There is no evidence that shoulder disorders predicted the onset of exposure.

Exposure-Response Relationship

The level of an exposure can be described in two different ways. It may be related to the amount of exposure over a relatively short time period, such as a day or week, or it may be related to cumulative or life-time exposure over a number of years. Studies that tested associations related to daily or weekly variation in exposure are presented first, followed by studies that evaluated cumulative exposure by using independent variables, such as duration of employment or estimated lifetime exposure.

Four studies have some evidence of exposure-response relationships. Baron et al. [1991] found a significantly larger OR for shoulder disorders among employees working greater than 25 hours/wk as a checker compared to those working less than 20 hours/wk. Bjelle et al. [1981] found that the duration of hours worked per day with the shoulder flexed or abducted >60 degrees was significantly higher ($p<0.025$) for cases with neck-shoulder disorders than for controls. Ohlsson et al. [1995] found that neck and shoulder disorders among assembly workers were significantly associated ($p<0.05$) with the percent of time spent with the shoulder abducted or elevated >60 degrees. Although it is more difficult to detect associations with homogenous exposure, this association was significant despite very little variability in exposure to arm abduction greater than 60 degrees. While the analysis among assembly workers was performed without controlling for age, there is no evidence to suggest that older workers were more likely to be on high exposure jobs, and therefore a substantial bias is unlikely.

When comparing fish industry workers to the reference population, Ohlsson et al. [1994] found that among those workers younger than 45 years, the ORs for disorders of the neck and shoulders were significant and increased with duration of employment (0–5 years, OR 3.2; 95% CI 1.5–7.0) (>5 years, OR 10; 95% CI 4.5–24). Ohlsson et al. [1995] found a decreasing trend when they compared OR after stratifying the factory workers by employment duration (<10 years, OR 9.6; 10–19 years, OR 4.4 and $20 years: 3.8). Given the cross-sectional study design, this finding could be an artifact caused by the survivor bias (i.e., workers with disorders left, while symptom-free ‘survivors’ stayed; see Table 3-5). The assumption of a survivor bias is based on the finding that 28% of a group of former assembly workers reported pain in the musculoskeletal system as their reason for leaving employment at the factory. In the study by Schibye et al. [1995], improvement in shoulder symptoms among those who were no longer sewing machine operators appeared greater at follow-up, but was not significant. The fact that many of those who left sewing jobs moved into industries such as health care and fishing, where awkward postures and high force loads may occur, might explain why a large difference between sewing machine operators and non-sewing machine operators was absent. These four studies provide some support for the relationship between shoulder abduction and shoulder MSDs.

Coherence of Evidence

Discussions of the probable influence of workplace exposure factors in the pathophysiology of localized muscle fatigue, myalgia, and tendinitis have been presented by a number of authors [Bjelle et al. 1981; Hagberg 1984; Herberts and Kadefors 1976; Herberts et al. 1984; Levitz and Iannotti 1995]. Posture is important: when the arm is raised or abducted, the muscle activity in supraspinatus and other muscles increases, and the supraspinatus tendon comes in contact with the undersurface of the acromion. The mechanical pressure on the tendon from the acromion is greatest between 60 and 120 degrees of arm elevation. [Levitz and Iannotti 1995]. The degree of upper arm elevation is also important in the onset and intensity of localized muscle fatigue in the trapezius, deltoid, and rotator cuff muscles. [Hagberg 1981; Herberts and Kadefors 1976; Herberts et al. 1984]. In a laboratory study, EMG signals from these muscles were analyzed. The supraspinatus muscle was found to be highly active at $45 degrees of abduction. The deltoid muscle underwent a pronounced increase in activity as shoulder flexion or abduction increased from 45 to 90 degrees [Herberts et al. 1984]. The earlier sections on Coherence of Evidence also discussed the rate of fatigue and role of impaired micro-circulation in shoulder tendinitis.

Overall, there is epidemiologic evidence for a relationship between repeated or sustained shoulder postures with more than 60 degrees of flexion or abduction and shoulder MSDs. There is evidence for both shoulder tendinitis and nonspecific shoulder pain. The evidence for increased risk of MSDs due to specific shoulder postures is strongest when there is a combination of exposures to several physical factors such as force and repetitive work. An example of this combination would be holding a tool while working overhead. The strength of association was positive and consistent in the six studies that used diagnosed cases of shoulder tendinitis, or a combination of symptoms and physical findings consistent with tendinitis, as the health outcome [Baron et al. 1991; Bjelle et al. 1979; English et al. 1995; Herberts et al. 1981; Ohlsson et al. 1994, 1995]. Only one [Schibye et al. 1995] of the thirteen studies failed to find a positive association with exposure and symptoms or a specific shoulder disorder. However, in this study discontinuing employment as a sewing machine operator was associated with a reduction in neck and shoulder symptoms. While most of the studies that considered specific shoulder postures as an exposure variable were cross-sectional, the two prospective studies found that the percent of work cycle spent with the shoulder elevated [Jonsson et al. 1988] or abducted [Kilbom et al. 1986; Kilbom and Persson 1987] predicted change to more severe neck and shoulder disorders. While there is insufficient evidence to develop a quantitative exposure-disorder relationship, three studies reported a significant association with shoulder flexion or abduction greater than 60 degrees [Bjelle et al. 1981; Kilbom and Persson 1987; Ohlsson et al. 1995]. Among the studies for which shoulder tendinitis was the health outcome, the largest ORs were associated with work above acromion height [Bjelle et al. 1979;

Herberts et al. 1981]. These results are consistent with the current models for the pathophysiology of shoulder tendinitis and stressful shoulder muscle activities. In none of these studies does “age,” an important personal characteristic associated with shoulder tendinitis, explain the positive results. Most of the studies controlled for a variety of confounders, such as occupational sports activities in their analyses. In summary, there is evidence that repeated or sustained shoulder abduction or flexion is associated with shoulder tendinitis, and the evidence is stronger for highly repetitive, forceful work.

VIBRATION

Three of the studies evaluated exposure to low-frequency vibration found in industrial settings (Table 3-4, Figure 3-4). Because of the small number of studies, the full outline used for the sections on repetition, force, and posture will not be repeated here. The study by Stenlund et al. [1992] is summarized in the section on force. Vibration exposure occurred in one of the three job categories: rock blaster. The exposure outcome, lifetime exposure to vibration expressed in hours, was determined from a weighted summary of the number of self-reported hours using specific tools. However, because the rock blaster job category was also the only one where workers performed heavy lifts several times per day, the authors concluded that, “vibration exposure is indivisible from static load and heavy lifting in the present data.” When both cumulative lifting exposure and cumulative vibration exposure were included in the same multivariate model of an association with acromioclavicular osteoarthrosis, the OR for lifting and right- side osteoarthrosis remained significant while the weaker ORs for vibration became non-significant.

In the study by Stenlund et al. [1993], the same population of bricklayers, rock blasters, and foremen described in Stenlund et al. [1992] were evaluated to determine whether signs of tendinitis or muscle attachment inflammation in the shoulders were related to lifetime work load, years of manual work, lifetime exposure to vibration, or job title. The case definition for “signs of shoulder tendinitis” was pronounced (i.e., grade 3 out of 3) pain upon palpation of the muscle attachment or pronounced pain in response to isometric contraction of any of the rotator cuff muscles or the biceps muscle. The case definition of “clinical entity of tendinitis” was “signs of shoulder tendinitis” plus the subject’s report of shoulder pain during the past year. Using multivariate models that included age and hours spent in arm intensive sports activities, a significant association with cumulative vibration exposure was found when it was tested in isolation from the other exposure variables. For “clinical entity of tendinitis” the OR for the left side was 1.86 (95% CI 1.00–3.44) and the OR for the right side was 2.49 (95% CI 1.06–5.87). For “signs of shoulder tendinitis” the OR for the left side was 1.66 (95% CI 1.06–2.61) and the OR for the right side was 1.84 (95% CI 1.10–3.07). When cumulative vibration exposure was tested in the same model with cumulative lifting load, significant associations were not found for either variable. Several factors could have resulted in an underestimation of the strength of association: (1) bricklayers or rock blasters with tendinitis may have been more likely to leave their jobs than foremen, (2) subjects may have had difficulty recalling exposure throughout their lifetimes, (3) the inability to separate exposure by left and right sides. These factors may have caused nondifferential misclassification. Most important is the authors' observation that vibration exposure occurred through the used of hand-held, heavy tools (e.g., jack-hammers) and thus is intertwined with exposure to a static load on the shoulders (from stabilizing the upper extremity while using the tool) as well as being associated with the heavy lifting tasks performed by rock blasters.

In a cross-sectional study by Burdorf and Monster [1991], riveters and control subjects in an aircraft company were investigated for vibration exposure and self-reported symptoms of pain or stiffness in the shoulder. Riveters were exposed to hand-arm vibration from working with hand drills, riveting hammers, bucking bars, and grinders. Controls were manual workers selected from the machine shop, maintenance, and welding departments in the same factory. In order to focus on the effect of vibration alone, a walk-through survey was performed to confirm that there were "no striking differences in dynamic and static joint loads during normal working activities." Participation was 76% among riveters and 64% among controls. An analysis of non-respondents revealed that controls with health complaints were more likely to have participated than those without, while riveters with health complaints were less likely to have participated. The health outcome, determined by a self-administered questionnaire, was shoulder pain or stiffness occurring for at least a few hours during the prior year. Only subjects who reported having no symptoms before starting their present work were included in logistic regression analyses. The vibration transmitted by hand-tools was measured and weighted according to International Standards Organization (ISO) standards. Tool vibration profiles and time-work studies of riveters and controls were used to determine daily vibration exposure for each group. For riveters, on the basis of daily tool operating time, the equivalent frequency-weighted acceleration for a period of 4 hours was 2.8 m s^{-2}. For controls, it was 1.0 m s^{-2}. Using a multiple logistic regression model that included age, there was a weak association between shoulder symptoms and the number of years riveting (0.05# p<0.10). When the age-adjusted ORs for riveters compared to controls were plotted by the duration (in years, from 0 to 20) of riveting, the slope for shoulder symptoms was very gradual, with ORs ranging from 1.0 to 2.0. While the results of the analysis of non-respondents described above suggest that the strength of association may have been underestimated, the reported associations are weak and it is unlikely that the response bias would have resulted in a large increase in the magnitude of association.

There is insufficient evidence for an association between shoulder tendinitis and exposure to segmental vibration. In four separate evaluations, stratified by "signs of tendinitis" (positive physical examination findings), "clinical entity of tendinitis" (signs plus symptoms), left and right side, Stenlund et al. [1993] found an association between shoulder tendinitis and vibration exposure to segmental vibration; the range of ORs was from (OR for right side 1.66, 95% CI 1.06–2.61) (OR for left side 1.84, 95% CI 1.10–3.07). However, work with vibration exposure also placed a large, static load on shoulder muscles so that the effects of forceful shoulder muscle exertions could not be separated from vibration.

ROLE OF CONFOUNDERS

Shoulder MSDs are multifactorial in origin and may be associated with both occupational and non-occupational factors. The relative contributions of these covariates may be specific to particular disorders. For example, the confounders for non-specific shoulder pain may differ from those for shoulder tendinitis. Two of the most important confounders or effect modifiers for shoulder tendinitis are age and sport activities. Most of the shoulder studies considered the effects of age in their analysis. Some studies considered sport activities [Baron et al. 1991; Stenlund et al. 1993; Jonsson et al. 1988; Kilbom et al. 1986]. Some studies also used multivariate methods to simultaneously adjust for several confounders or effect modifiers. For example, Ohlsson et al. [1995] found that for shoulder/neck diagnoses, repetitive work was the strongest predictor 4.6 (95% CI 1.9–12); age, muscle tension, and stress/worry tendency were also significant predictors. It is unlikely that the majority of the positive associations between physical exposures and shoulder MSDs are due to the effects of non-work confounders.

CONCLUSIONS

There are over 20 epidemiologic studies that have examined workplace factors and their relationship to shoulders (MSDs). These studies generally compared workers in jobs with higher levels of exposure to workers with lower levels of exposure, following observation or measurement of job characteristics. Using epidemiologic criteria to examine these studies, and taking into account issues of confounding, bias, and strengths and limitations of the studies, we conclude the following:

There is **evidence** for a positive association between highly repetitive work and shoulder MSDs. The evidence has important limitations. Only three studies specifically addressed the health outcome of shoulder tendinitis and these studies investigated combined exposure to repetition with awkward shoulder postures or static shoulder loads. The other six studies with significant positive associations dealt primarily with symptoms. There is **insufficient evidence** for a positive association between force and shoulder MSDs based on currently available epidemiologic studies. There is epidemiologic **evidence** for a relationship between repeated or sustained shoulder postures with greater than 60 degrees of flexion or abduction and shoulder MSDs. There is evidence for both shoulder tendinitis and nonspecific shoulder pain. The evidence for specific shoulder postures is strongest where there is combined exposure to several physical factors like holding a tool while working overhead. The strength of association was positive and consistent in the six studies that used diagnosed cases of shoulder tendinitis, or a combination of symptoms and physical findings consistent with tendinitis, as the health outcome. Only one [Schibye et al. 1995] of the thirteen studies failed to find a positive association with exposure and a specific shoulder disorder or symptoms of a shoulder disorder.

This is consistent with the evidence that is found in the biomechanical, physiological, and psychosocial literature.

There is **insufficient evidence** for a positive association between vibration and shoulder MSDs based on currently available epidemiologic studies.

Table 3-1. Epidemiologic criteria used to examine studies of shoulder MSDs associated with repetition

Study (first author and year)	Risk indicator (OR, PRR, IR, or *p*-value)*,†	Participation rate $70%	Physical examination	Investigator blinded to case and/or exposure status	Basis for assessing shoulder exposure to repetition
Met all four criteria:					
Chiang 1993	1.6†	Yes	Yes	Yes	Observation or measurements
Kilbom 1986, 1987	NR†,‡	Yes	Yes	Yes	Observation or measurements
Ohlsson 1994	3.5†	Yes	Yes	Yes	Observation or measurements
Ohlsson 1995	5.0†	Yes	Yes	Yes	Observation or measurements
Met at least one criterion:					
Bjelle 1981	NR†	NR	Yes	Yes	Observation or measurements
English 1995	2.3†,§	Yes	Yes	Yes	Job titles or self-reports
Sakakibara 1995	1.7†	Yes	Yes	NR	Job titles or self-reports
Met none of the criteria:					
Ohlsson 1989	3.4†	NR	No	NR	Job titles or self-reports

*Some risk indicators are based on a combination of risk factors—not on repetition alone (i.e., repetition plus force, posture, or vibration). Odds ratio (OR), prevalence rate ratio (PRR), or incidence ratio (IR).

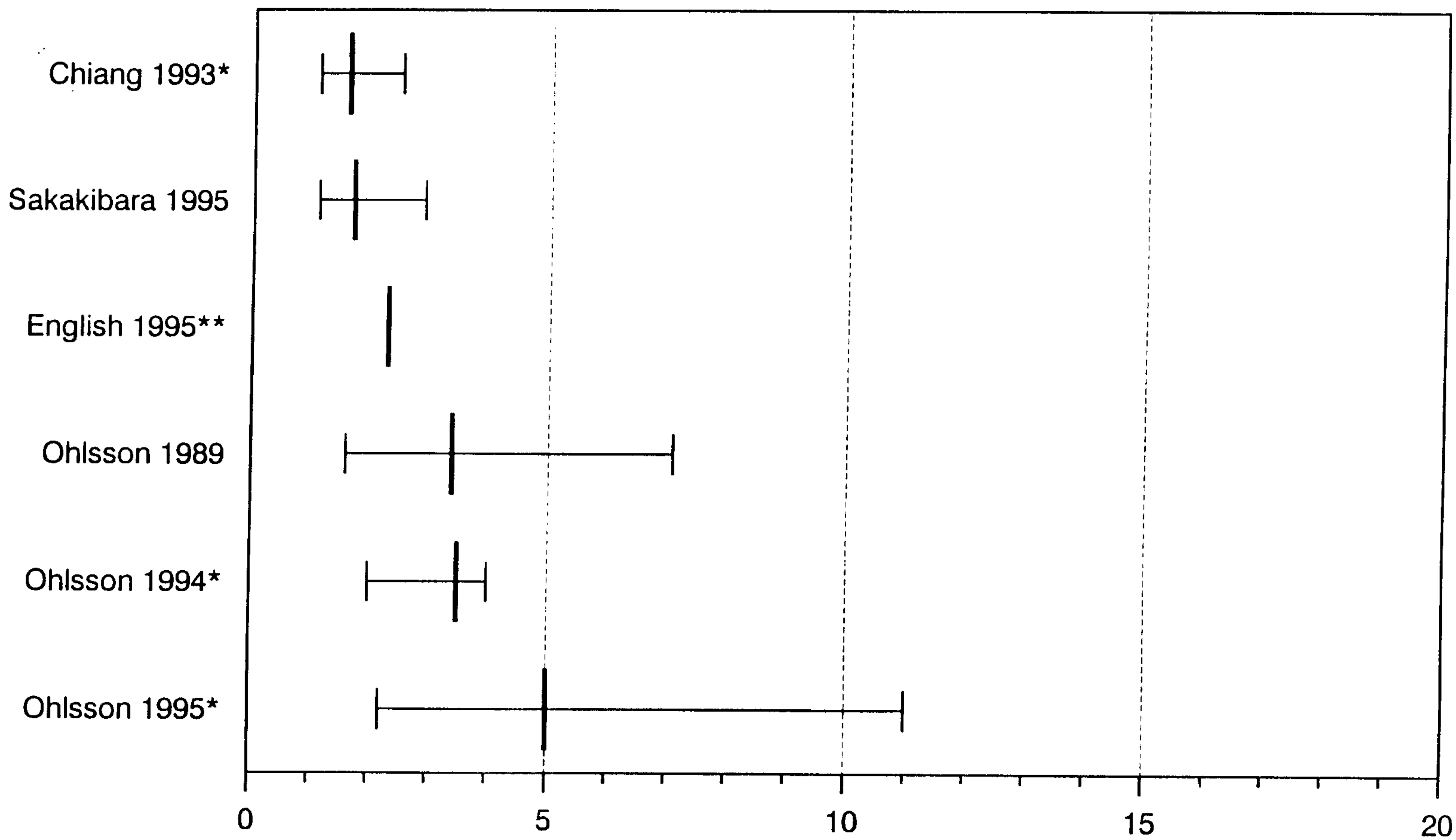
†Indicates statistical significance. If combined with NR, a significant association was reported without a numerical value.

‡Not reported.

§Repeated shoulder rotation with elevated arm.

Figure 3-1. **Risk Indicator for "Repetition" and Shoulder Musculoskeletal Disorders**

(Odds Ratios and Confidence Intervals)



* Studies which met all four criteria.
**Risk indicator reported without confidence limits.
Note: Two studies indicated statistically significant associations without reporting odds ratios. See Table 3-1.

Table 3-2. Epidemiologic criteria used to examine studies of shoulder MSDs associated with force

Study (first author and year)	Risk indicator (OR, PRR, IR or *p*-value)[*,†]	Participation rate $70%	Physical examination	Investigator blinded to case and/or exposure status	Basis for assessing shoulder exposure to force
Met all four criteria:					
Chiang 1993	1.8[†]	Yes	Yes	Yes	Observation or measurements
Met at least one criterion:					
Andersen 1993a	1.38–10.25[†]	Yes	No	Yes	Job titles or self-reports
Herberts 1981, 1984	15–18[†]	NR[‡]	Yes	NR	Job titles or self-reports
Stenlund 1992	2.2–4.0[†]	Yes	Yes	Yes	Job titles or self-reports
Wells 1983	5.7[†]	Yes	No	NR	Job titles or self-reports

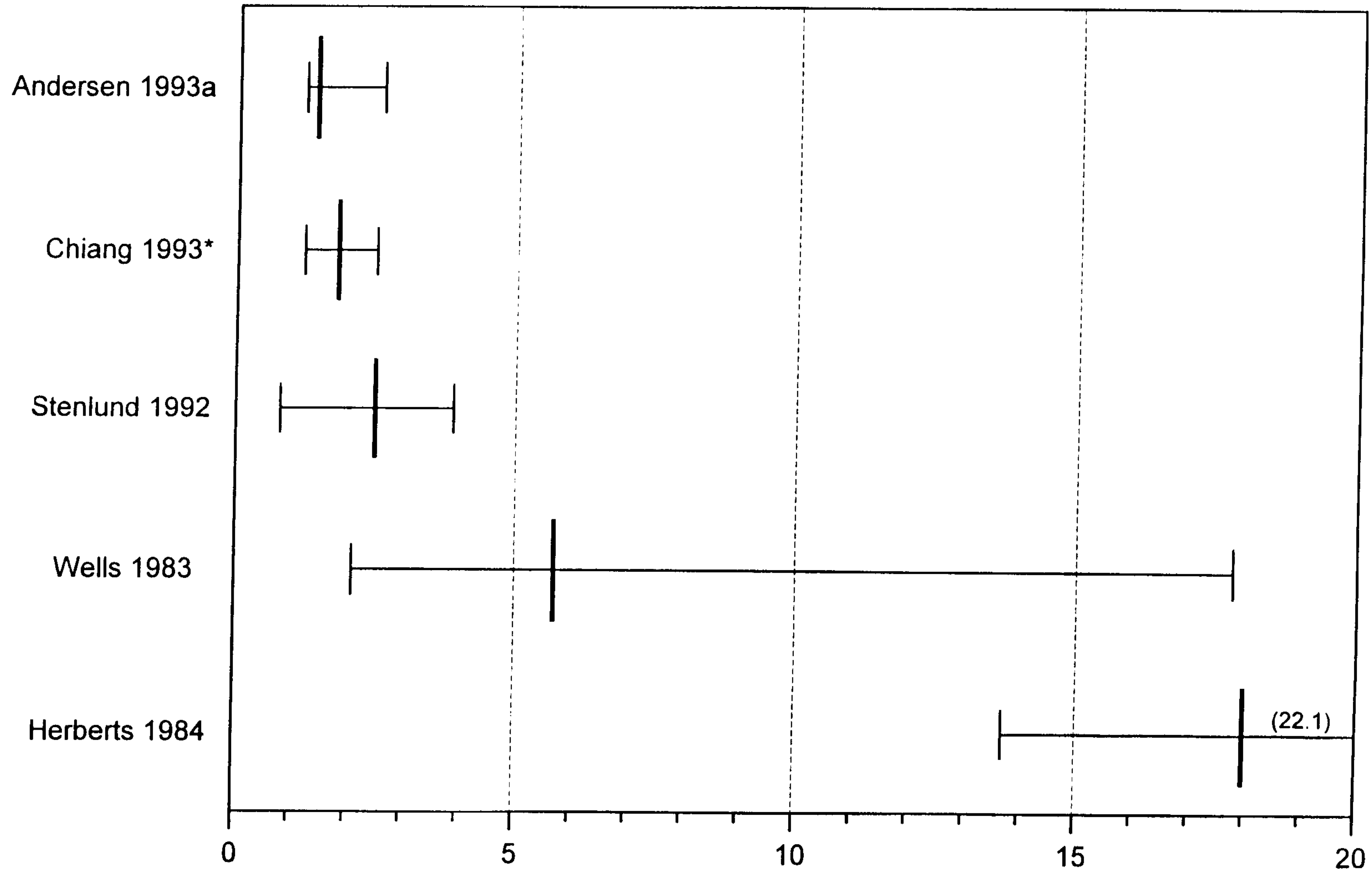
[*]Some risk indicators are based on a combination of risk factors—not on force alone (i.e., force plus repetition, posture, or vibration). Odds ratio (OR), prevalence rate ratio (PRR), or incidence ratio (IR).

[†]Indicates statistical significance.

[‡]Not reported.

Figure 3-2. **Risk Indicator for "Force" and Shoulder Musculoskeletal Disorders**

(Odds Ratios and Confidence Intervals)



* Studies which met all four criteria.

Table 3-3. Epidemiologic criteria used to examine studies of shoulder MSDs associated with posture

Study (first author and year)	Risk indicator (OR, PRR, IR, or *p*-value)*,†	Participation rate $70%	Physical examination	Investigator blinded to case and/or exposure status	Basis for assessing shoulder exposure to posture
Met all four criteria:					
Jonsson 1988	NR†,‡	Yes	Yes	Yes	Observation or measurements
Kilbom 1986, 1987	NR†	Yes	Yes	Yes	Observation or measurements
Ohlsson 1994	3.5†	Yes	Yes	Yes	Observation or measurements
Ohlsson 1995	5.0†	Yes	Yes	Yes	Observation or measurements
Met at least one criterion:					
Baron 1991	3.9†	No	Yes	Yes	Observation or measurements
Bjelle 1979	10.6†	NR	Yes	No	Observation or measurements
Bjelle 1981	NR†	NR	Yes	Yes	Observation or measurements
English 1995	2.3†,§	Yes	Yes	Yes	Job titles or self-reports
Herberts 1981	8.3	NR	Yes	NR	Job titles or self-reports
Hoekstra 1994	5.1†	Yes	No	Yes	Job titles or self-reports
Milerad 1990	2.4†	Yes	No	NR	Job titles or self-reports
Sakakibara 1995	NR†	Yes	Yes	NR	Observation or measurements
Schibye 1995	NR	Yes	No	NR	Job titles or self-reports

*Some risk indicators are based on a combination of risk factors—not on posture alone (i.e., posture plus force, repetition, or vibration). Odds ratio (OR), prevalence rate ratio (PRR), or incidence ratio (IR).

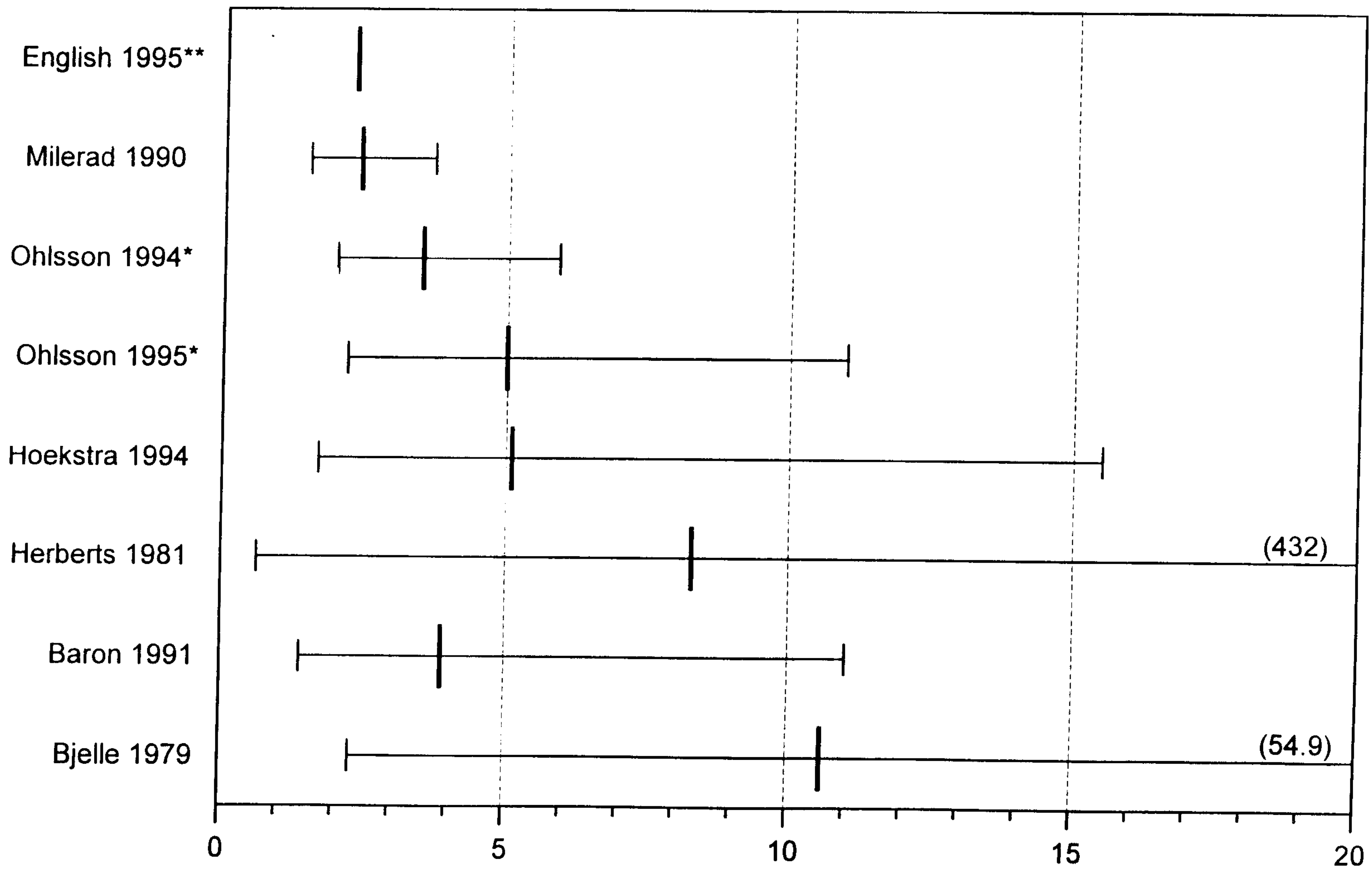
†Indicates statistical significance. If combined with NR, a significant association was reported without a numerical value.

‡Not reported.

§Repeated shoulder rotation with elevated arm ($p < 0.05$ level, most of study used 0.01 level).

Figure 3-3. **Risk Indicator for "Posture" and Shoulder Musculoskeletal Disorders**

(Odds Ratios and Confidence Intervals)



* Studies which met all four criteria.

**Risk indicator reported without confidence limits.

Note: Four studies indicated statistically significant associations without reporting odds ratios. See Table 3-3.

Table 3-4. Epidemiologic criteria used to examine studies of shoulder MSDs associated with vibration

Study (first author and year)	Risk indicator (OR, PRR, IR, or *p*-value)*†	Participation rate $70%	Physical examination	Investigator blinded to case and/or exposure status	Basis for assessing shoulder exposure to vibration
Met at least one criterion:					
Burdorf 1991	1.5	No	No	NR‡	Observation or measurements
Stenlund 1992	2.2–3.1†	Yes	Yes	Yes	Self-reports, weight of tools
Stenlund 1993	1.7–1.8†	Yes	Yes	Yes	Job titles or self-reports

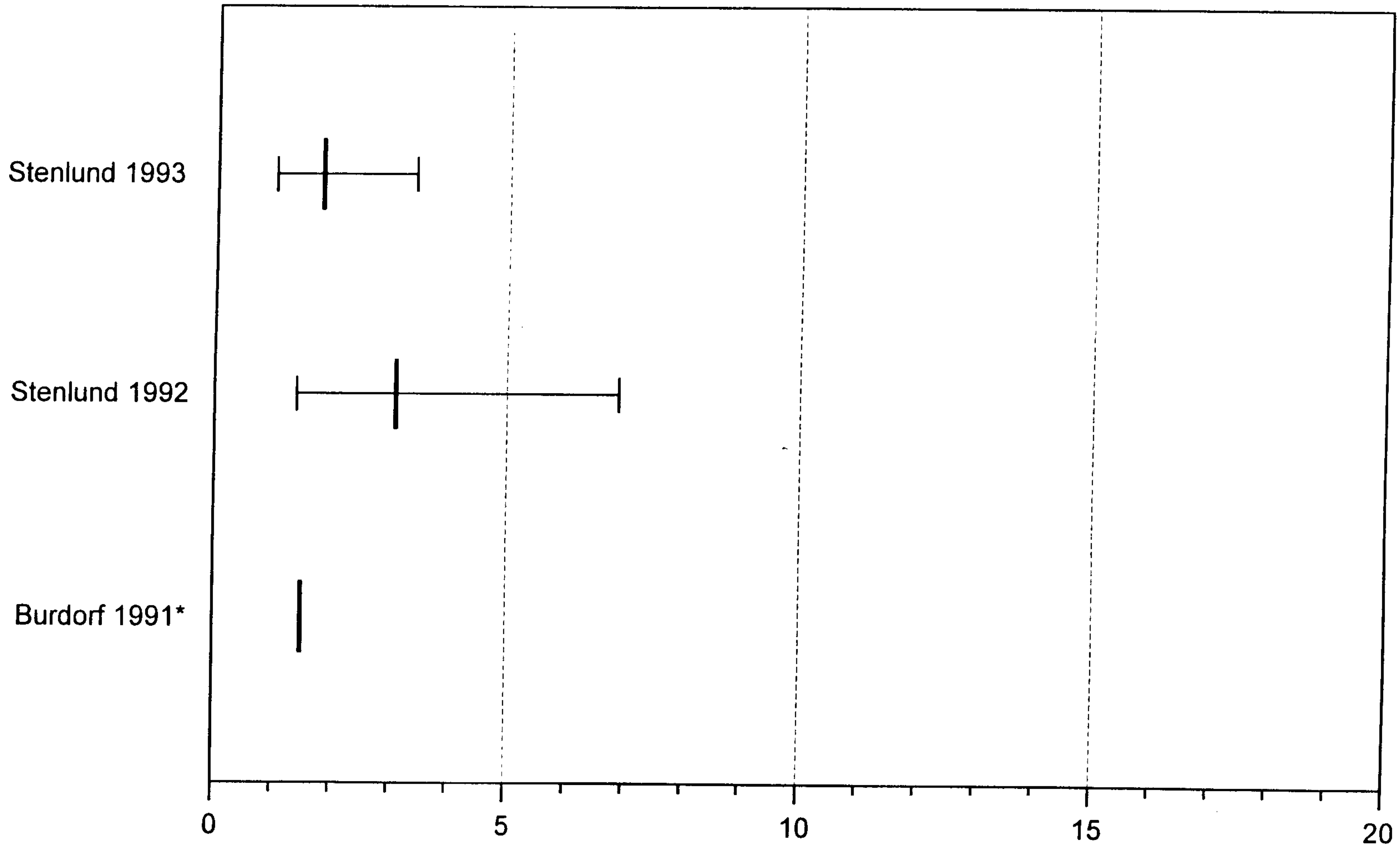
*Some risk indicators are based on a combination of risk factors—not on vibration alone (i.e., vibration plus force, posture, or repetition). Odds ratio (OR), prevalence rate ratio (PRR), or incidence ratio (IR).

†Indicates statistical significance.

‡Not reported.

Figure 3-4. **Risk Indicator for "Vibration" and Shoulder Musculoskeletal Disorders**

(Odds Ratios and Confidence Intervals)



* Risk indicator reported without confidence limits.

Table 3-5. Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Andersen and Gaardboe 1993a	Cross-sectional	424 female sewing machine operators (SMO), compared to 781 females from the general population of the region and internal referent group of 89 females from the garment industry.	Outcome: Case of chronic shoulder pain was defined as continuous pain lasting for a month or more after beginning work and pain for at least 30 days within the past year. Exposure: Categorization broken down according to current occupational status by job title. Classification into exposure groups based on author's experiences as occupational health physicians and involved crude assessment of exposure level and exposure repetitiveness. High exposure jobs were those involving high repetition/high force or high repetition/low force or medium repetition/high force. Medium exposure jobs were those involving medium repetition/low force and low repetition and high force. Low exposure jobs were low repetition/low force. For the analysis, "length of employment as a sewing machine operator" was considered the variable of interest, the rest were confounders.	Shoulder pain: Sewing machine operators, 25.2%	8.5%	3.21	1.68-7.39	Participation rate: 78.2%. Examiners blinded to case status. Respondents excluded if had previous trauma to neck, shoulder, or arms or had inflammatory disease at time of response. ORs adjusted for age, having children, not doing exercise, socioeconomic status, smoking, and current neck/shoulder exposure. Age-matched exposure groups and controls. Presented study as "general survey of health in the garment industry" to minimize information bias.
				Years of exposure: 0-7=12.3%		1.56	0.76-3.75	
				8-15=33.7%		4.28	2.14-10.0	
				>15=57.1%		7.27	3.82-16.3	

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Andersen and Gaardboe 1993b	Cross-sectional	From a historical cohort of 424 sewing machine operators, 120 were randomly selected and 82 exposed workers were categorized by number of years of employment: 0 to 7 years, 8 to 15 years and greater than 15 years. These were compared to a referent group of 25 auxiliary nurses and home helpers. A total of 107 subjects participated.	Outcome: Measured by health interview and exam of the neck, shoulder and arm. Case of chronic pain was defined as continuous pain lasting for a month or more after beginning work and pain for at least 30 days within the past year. Physical examination: Restricted movements in the cervical spine and either palpatory tenderness in cervical segments or irradiating pain or tingling at maximum movements or positive foraminal test. Exposure: Exposure categorization broken down according to current occupational status by job title. Classification into exposure groups based on author's experiences as occupational health physicians and involved crude assessment of exposure level and exposure repetitiveness. High exposure jobs: Involved high repetition/high force or high repetition/low force or medium repetition/high force. Medium exposure jobs involved medium repetition/low force and low repetition and high force. Low exposure jobs were low repetition/low force.	Rotator cuff syndrome: Number of workers by exposure time in years: 0-7: 1; 8-15: 6; >15: 11	Controls: 1	Chi sq for trend=9.51, *p*<0.01		Participation rate: 78.2%; logistic regression limited to a combined neck/shoulder case definition. Age-matched exposure groups and controls. Examiners blinded to control/subject status. Controlled for age, having children, not doing leisure exercise, smoking, socioeconomic status. Poor correlation between degenerative X-ray neck changes and cervical syndrome. Most frequent diagnosis among study group was "cervicobrachial fibromyalgia" significant for test of trend with exposure time in years. Chronic neck pain vs. palpatory findings: Sensitivity: 0.85; Specificity: 0.93.

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

				MSD prevalence				
Study	**Study design**	**Study population**	**Outcome and exposure**	**Exposed workers**	**Referent group**	**RR, OR, or PRR**	**95% CI**	**Comments**
Baron et al. 1991	Cross-sectional	124 Grocery checkers using laser scanners (119 females, 5 males) compared to 157 other grocery workers (56 females, 101 males). Excluded 18 workers in meat, fish, and deli departments, workers under 18, and pregnant workers.	Outcome: Based on symptom questionnaire and physical exam. (1) Rotator cuff syndrome—pain with resisted abduction or deltoid palpation (2) Bicipital tendinitis—pain on Yergason's maneuver. Case defined as having positive symptoms in shoulder and a positive physical exam of a particular body part. Symptoms must have begun after employment at the supermarket and in the current job; lasted one week or occurred once a month during the past year; and where there was no history of acute injury to body part in question. Exposure: Job category and estimates of repetitive and average and peak forces based on observed and videotaped postures, weight of scanned items, and subjective assessment of exertion.	Checkers: 15% Checkers using scanners: 34% Checkers 5'2" or less in height: 21%	Other grocery workers: 7% Other grocery workers 5'2" or less in height: 13%	Checkers vs. others: OR=3.9 Checkers using scanners vs. others: OR=8.6 Checkers <5'2" vs. other grocery workers <5'2": OR=2.1	1.4-11.0 1.0-72.2 0.7- 6.9	Participation rate: 85% checkers; 55% non-checkers in field study. Following telephone survey 91% checkers and 85% non-checkers. Examiners blinded to worker's job and health-status. Logistic regression model adjusted for duration of work. No difference in groups between age, gender, and hobbies so that these were not controlled for. Number of hr worked/week as a checker statistically significantly related to shoulder disorders for workers checking >25-hr/ /week (OR=3.5, *p*<0.05) (OR estimated from figure). Total repetitions/hr ranged from 1,432 to 1,782 for right hand and 882 to 1,260 for left hand. Average forces were low and peak forces medium. Multiple awkward postures recorded for upper extremities among cashiers. No statistical significance associated between duration of employment as a checker and shoulder MSDs.

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Bergenudd et al. 1988	Cross-sectional	574 of 830 survey respondents participated in a health exam. In 1983, 1,070 residents of Malmö, Sweden, responded to questions on shoulder pain in a health survey as part of a longitudinal study begun in 1,938 of 1,542 residents.	Outcome: Based on symptom survey: Occurrence of shoulder pain lasting $24 hr during the last month and physical exam (joint motion, tenderness on palpation of supraspinatus, biceps, tendons and acromioclavicular joint). Exposure: Based on job classification; classified as: Light physical demands (white collar) =275; Moderate physical demands (nurses, light industry)=237; Heavy (blue collar, e.g., carpenters, bricklayers)=50.	Prevalence of occupational workload in subjects with shoulder pain Heavy work: 11% Moderate work: 49% Light work: 40%		ò	ò	Participation rate: 69%. Unknown whether examiners blinded to case status. Analysis stratified by gender. Only 9% of workers included in study were in the Heavy Physical Demands Jobs category, compared to 49% in Light category and 42% in moderate category. Only 1% of females were in Heavy Physical Demand Jobs category. Sick leave due to shoulder pain was restricted to males in jobs with moderate or heavy physical demands (*p*<0.05) (data not shown in article). At one year follow-up, 61 (77%) of 79 subjects with shoulder pain re-examined. 35 had continued shoulder pain. Misclassification of work categories a possibility: Likely no observation of job tasks performed.. No differences in overall physical demands of jobs among subjects with shoulder pain compared to those without shoulder pain, but females with signs of supraspi-natus tendinitis more often had jobs with physical demands. Authors state that shoulder pain may be related to intelligence in males in this study; "more talented" males had less shoulder joint symptoms. We question author's conclusions. Females showed significant association with shoulder pain and dissatis-faction. No association with relation to family or friends or level of life success. Author states both groups of females rated their life success low, and subjects with shoulder pain did not rate level of success differently.

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Bernard et al. 1994	Cross-sectional	Of a total population of 3,000 workers in the editorial, circulation, classified advertising, and accounting departments, 1,050 were randomly selected for study and 973 participated; 894 responded to the shoulder questions. Cases fulfilling shoulder definition compared to non-cases.	Outcome: Health data and psychosocial information were collected using a self-administered questionnaire. Definition: Presence of pain, numbness, tingling, aching, stiffness or burning in the shoulder occurring $once a month or 7 days continuously within the past year, reported as moderately severe. The symptom must have begun during the current job. Workers with previous injuries to the relevant area were excluded. Exposure: Based on observation of work activity involving keyboard work, work pace, posture, during a typical day of a sample of 40 workers with symptoms and 40 workers without symptoms. Exposure to work organization and psychosocial factors based on questionnaire responses.	17% (case) 3% (case with daily pain)	ó	Female: OR=2.2 Perceived lack of decision making participation: OR=1.6 Years at the newspaper: OR=1.4 Perceived increased job pressure: OR=1.5	1.5-3.3 1.2-2.1 1.2-1.8 1.0-2.2	Participation rate: 93%. Examiners blinded to case and exposure status. For calculation of the ORs of the psychosocial scales, the responses were divided into quartiles, then the 75th percentile was compared to 25th percentile. Model adjusted for race, age, gender, height, psychosocial factors, medical conditions. Age, height, hr typing away from work, other medical conditions were not found to be significant. In a sub-analysis of jobs with comparable number of males and females, there were no significant factors related to shoulder MSDs.

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Bjelle et al. 1979	Case-control	17 cases of shoulder tendinitis from a population of male industrial workers who were patients at an occupational health center. These 17 were chosen from 20 consecutive male patients from 6 industries and had been suffering from pain over a period of >3 months in one or both shoulders. 34 non-cases were matched for age and workshop.	Outcome: Cases were non-responsive to analgesics, non-steroidal anti-inflammatory agents, physiotherapy, and outcome measured by exam. Case defined as shoulder pain lasting >3 months with no resolution post-treatment. Exposure: Defined as work with hands at or above shoulder level. 3 classes work performed: (A) with hands below shoulder or acromion height, (B) at or above acromion 3 to 8 times/day (<1/hr plus for duration >1 min) (C) $8 times at or above acromion ($1/hr. plus duration >1 min). Exposure assessed by interview and physician observation and knowledge of work. Electromyographs on 15 cases. Open muscle biopsies on 11 cases.	With work at or above shoulders: 65%	With work at or above shoulders: 15%	10.6	2.3-54.9	Participation rate: Not reported. Matched for age, gender and workshop. Three of the 20 were diagnosed with inflammatory rheumatoid diseases not previously diagnosed, 17 had no inflammatory rheumatic disease. Mean age (53 years) of cases significantly older than other workers (37.6 years). Myopathic signs not found on EMG or muscle biopsies. Muscle enzymes (creatine phosphokinase and/or aldolase) were elevated in 6 cases. Present and previous employment, physical workload not different between cases and referents. Work performed with hands above acromion height significantly greater for cases than referents. 2-year follow-up showed that only 8 cases working in the same or less heavy types of work, 7 of these had slight shoulder complaints.

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Bjelle et al. 1981	Case-control	20 workers of industrial plant consecutively seen at health clinic with acute, nontraumatic shoulder-neck pain. Of these, 13 were not due to causative disease or malformation. These 13 were compared to 26 controls, matched on age, gender and place of work.	Outcome: Physician evaluated all patients with acute non-traumatic shoulder-neck pains referred to the outpaient clinic of the rheumatology department. Each patient had to undergo an extensive clinical examination, including local anaesthesia for the definition of pain location. Exploratory puncture of the glenohumeral joint was performed in patients with tenderness over the joint. Exposure: Anthropometric and Isometric muscle strength were tested with strain gauge instruments. Patients asked to perform their max-mal efforts. Measurements made for the following contractions: shoulder elevation at the acromion, abduction and forward flexion of the shoulder joints at neutral position and semipronated. Grip strength measured by vigorimeter. Video recording of arm movements at work. Shoulder loads estimated from videos. Consisted of measuring the duration and frequency of shoulder abduction or forward flexion of >60°. EMG measurement of shoulder load during assembly work on 3 patients and 2 healthy volunteers. Muscular load level determination made by computer analysis of myo-electric amplitude.	6 with right shoulder tendinitis: 46%	No Controls with tendinitis: 0%	Cases had significantly longer duration and higher frequency of abduction or forward flexion than controls, $p<0.001$. Cases had significantly higher shoulder loads than controls. Median number of sick-leave days significantly different between cases and controls ($p<0.01$).		Participation rate: Not reported. Video analyses were done blinded to case status. No significant difference between cases and controls in anthropometry. Isometric strength test: controls significantly stronger in 6 of 14 tests but probably influenced by pain inhibition in cases. No significant difference in cycle time (9 vs. 12 min) between cases and controls. The supraspinatus muscle showed a significant change of the mean power frequency ($p<0.05$) towards lower levels, indicating a fatiguing process for four of the five investigated assemblers during work.

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Burdorf and Monster 1991	Cross-sectional	194 riveters exposed to vibration compared to 194 workers in the same plant with little or no exposure to vibration.	Outcome: Standardized Nordic questionnaire, pain or stiffness. Exposure: Employed >12 months, not exposed to hand/arm vibration. Observation, time-work studies, measurements of vibrating tools. No shoulder measurements. Occupational history treated as dichotomous variable with "1" for heavy physical work.	31%	20%	1.5		Participation rate: Riveters=76%, controls=64%. Examiners blinded to exposure or case status: Not reported. Confounders controlled for included height, weight, and smoking habits. Age and height significantly different between groups. Years of riveting work associated with pain or stiffness in shoulder (0.05#*p*#0.10). Follow-up of nonrespondants showed no difference in age or work experience. Sick leave significantly different.

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

				MSD prevalence				
Study	**Study design**	**Study population**	**Outcome and exposure**	**Exposed workers**	**Referent group**	**RR, OR, or PRR**	**95% CI**	**Comments**
Burt et al. 1990	Cross-sectional	836 Newspaper employees in the Editorial Department and selected jobs in the Advertising, Circulation, Data Processing, and Finance Departments from 4 company locations, (460 female and 376 male). Cases compared to non-cases.	Outcome: Based on symptom questionnaire. Case defined as pain, aching, stiffness, burning, numbness or tingling in shoulder lasting >1 week or occurring one time/month in the past year. Symptoms must have begun on current job; no previous accident or acute injury to the joint, no related systemic disease. Exposure: Based on questionnaire and job sampling. Exposure variables included work time spent typing on computer; typing speed; keyboard type; hr worked/week; workload; number of years worked.	Time spent typing: 50% Typing Speed: Slow: 6% Moderate: 11% Fast: 15%	42%	õ Typing Speed: Moderate: 2.6 Fast: 4.1 Pre-existing Arthritis: OR=2.3 Dissatisfied with job: OR=2.3	õ 1.1-5.9 1.8-9.4 1.2-4.4 1.2-4.3	Participation rate: 81%. (Authors note that those out on assignment or ill or on vacation counted as non-participants.) Number of workers in number of non-typing jobs not reported. Reporters characterized by high periodic demands (deadlines) although they had high control and job satisfaction. Job analysis found significant correlation (r=0.56) between reported average typing time/day and observed 8 hr period of typing (*p*<0.0001). Length of employment and symptoms in shoulder not significant.

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Chiang et al. 1993	Cross-sectional	207 fish processing workers, 67 males and 140 females, divided in 3 groups: (I) Low force, low repetition (comparison group, n=61); (II) High force or high repetition (n=118); (III) High force and high repetition (n=28).	Outcome: Shoulder girdle pain as defined by Anderson (1984) (the painful condition of the shoulder with limitation of movement, which may occur in association with tension neck or merge with pain in the suprascapular or upper dorsal regions). Symptoms in these regions occurring in last 30 days and physical exam findings of $two tender points or palpable hardenings which may either be caused or aggravated by work conditions. Exposure: Assessed by observation and recording of tasks and biomechanical movements of three workers each representing one of 3 study groups. Highly repetitive jobs with cycle time k=<30 sec or >50% of cycle time performing the same fundamental cycles. Hand force estimate from EMG recordings of forearm flexor muscles. Classification of workers into 3 groups according to the ergonomic risks of the shoulders and upper limbs: Group I: Low repetition and low force; Group II: Low repetition or low force; Group II: High repetition and high force.	Prevalence of Physician-observed Disorders: Group II: 37% (male 31%; female 39%) Group III: 50% (male 50% female 50%)	Prevalence of Physician-observed Disorders: Group I: 10% (male 9% female 10%)	Repetitive movement of the upper limb (Rep): OR=1.6 Sustained forceful movement of the upper limb (force): OR=1.8 Rep times force: OR=1.4 Age: OR=1.0 Gender: OR=1.1	 1.1-2.5 1.2-2.5 1.0-2.0 0.9-1.1 0.7-1.7	Participation rate: Not quantified; however, authors stated that "all of the workers who entered the fish processing industry before June 1990 and were employed there full-time were part of the cohort." Of the 232 employees who agreed to participate, 207 met study criteria. Examiners blinded to exposure status. ("Workers examined in random sequence to prevent observer bias.") Workers with hypertension, diabetes, history of traumatic injuries to upper limbs, arthritis, collagen disease excluded from study group. Eight plants used in study. Authors reported "no plant effect". Case definition based on physician diagnosis not significantly different from definition based on symptoms in Groups II : 37% vs. 44% or Group III: 50% vs. 50%. Group I about 2/3 the prevalence (10% vs. 15%). Dose-response for physician observed shoulder girdle pain among three exposure groups. Dose-response for physician observed shoulder girdle pain by gender in three exposure groups. Logistic model controlled for age and gender. Significant trend found for duration of employment and exposure group in workers <12 months, 12 to 60 months, but not in workers employed >60 months.

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
English et al. 1995	Case-control	Cases: n=580; 174 males and 406 females with diagnosed soft tissue conditions of the upper limb at 2 orthopedic clinics; ages 16 to 65 years. Controls: 996 controls; 558 males and 438 females attending the same clinics; diagnosed with conditions other than diseases of the upper limb, cervical or thoracic spine; ages 16 to 65 years.	Outcome: Based on standard diagnosis for rotator cuff injury; rupture of the long head of biceps, shoulder capsulitis, symptomatic acromioclavicular arthritis. Exposure: Based on self-reported risk factors at work for musculoskeletal disorders concentrating on detailed components of movements and activities at work: awkward postures, grip types, wrist motions, lifting, shoulder postures, static postures, hand tool use, and job category. Questionnaire obtained information on repetitive movements of the upper limb: Shoulder flexion, shoulder rotation with elevated arm, keeping the whole arm raised >1 min, shoulder rotation with elbow flexed.	Frequency of shoulder problems Rotator cuff: 8.3% Rupture of long head of biceps: 0.3% Shoulder capsulitis: 3.6% Symptomatic acromiocla-vicular arthritis: 0.2%	ð ð ð ð	Per 5 years of age: 1.4 For elbow flexion: 0.4 Per hr of total daily elbow flexion: 1.1 Repeated shoulder rotation with elevated arm: RR=2.3 Wrist rotation at low rates: RR=0.18 Wrist rotation with increasing rates: RR=2.02/30 reps/min.	1.2-1.5, *p*<0.01 0.2-0.8, *p*<0.01 0.9-1.2, *p*<0.01 Not reported *p*<0.05 Not reported *p*<0.05 Not reported *p*<0.05	Participation rate: 96%. Administered questionnaire blinded to case status. Controlled for age, height, gender, weight, whether MSD was due to an accident, study center. Total daily exposure to elbow flexion did not contribute to shoulder injury. Risks highest for female hairdressers. "Repetitive" defined as a frequency of >once/min of 14 specific movements. Sporting activities, hobbies; average hr of driving/week; whether claim for compensation made were analyzed in models. Jobs with pinching between thumb and forefinger protective against shoulder disorders. May reflect hand movement and exertion with no shoulder movement or exertion. Small number of subjects/group limits power to detect significant differences.

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Flodmark and Aase 1992	Cross-sectional	58 industrial workers making ventilation shafts (51 males and 7 females) compared to symptom prevalence in 170 blue-collar workers in Örebro, Sweden. Compared workers with symptoms to those workers without symptoms for risk factor analysis.	Outcome: Questionnaire survey using Nordic questionnaire for symptoms as to duration during last 12 months and during last 7 days, effect on work performance and leisure activities, and sick leave. Type A behavior assessed by Bortner questionnaire. Exposure: No objective measurements.	Symptoms in past 12 months: 40%	Symptoms in past 12 months: 23%	2.2	1.4-4.4	Participation rate: 87%. Aim of the study was to further investigate relationship between Type A behavior and musculoskeletal symptoms. The Bortner Score for Type A behavior significantly higher for those with shoulder symptoms than those without. No difference in headache, tiredness, sleeping, irritation, lack of concentration or problems with eyes, nose, stomach, skin. Authors suggest that Type A persons more likely to ignore symptoms to minimize their potential effect on work capacity.

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Hales and Fine 1989	Cross-sectional	Of 96 female workers employed in 7 high exposure jobs in poultry processing, 89 were compared to 23 of 25 female workers in low exposure jobs.	Outcome: By questionnaire: Period Prevalence: Symptoms in last 12 months. Case defined as: pain, aching, stiffness, numbness, tingling or burning in the shoulder, and symptoms began after employment at the plant; were not due to a previous injury or trauma to the joint; lasted >8 hr; and, occurred 4 or more times in the past year.	Any symptom of the shoulder: 49% (high exposure group)	43% (low exposure group)	1.2	0.7-2.0	Participation rate: 91%. Examiner blinded to case and exposure status. Analysis adjusted for age and duration of employment.
				Period prevalence for shoulder case: 19%	4%	3.8	0.6-22.8	Although shoulder MSDs surveyed by questionnaire, exposure assessment was based on hand/wrist exposure, so that risk for shoulder may not be accurate.
			Point Prevalence: Determined by physical exam of the upper extremity using standard diagnostic criteria case must also fulfill symptom definition (listed above).	Point prevalence for shoulder case: 7%	4%	0.9	0.1-7.3	High exposure departments: Breast trim, thigh debone, leg cut/disjoint, tender cut, knuckle cut, breast, knuckle cut, thigh fat trim.
			Exposure: Observation and walk-through; jobs categorized as High exposure and Low exposure based on estimated hand force and hand repetition, not shoulder exposure.					Lower exposure departments: Breast, thigh, or quality control inspectors.

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Hales et al. 1994	Cross-sectional	533 Telecommunication workers (416 females and 117 males) in 3 offices, employed $6 months. "Cases" fulfilling shoulder WRMSD definition compared to non-cases.	Outcome: Self-administered questionnaire and standard physical examination; case defined as: pain, aching, stiffness, burning, numbness or tingling >1 week or >12 times a year; no previous traumatic injury to the area; occurring after employment on current job within the last year and positive physical exam: moderate to worst pain experienced with positive physical finding of the symptomatic joint. Exposure: Work practices and work organization assessed by questionnaire and observation; number of keystrokes/day. Physical workstation and postural measurements obtained but not used in final analyses.	Rotator cuff tendinitis: 6% (n=513) Bicipital tendinitis: less than 1% (n=516) Overall shoulder: 6%		Fear of replacement by computers: 1.5 Number of times arising from chair: 1.9	1.1-2.0 1.2-3.2	Participation rate: 93%. Physician examiner blinded to worker case study. Logistic analysis adjusted for demographics, work practices, work organization, individual factors; electronic performance monitoring; DAO keystrokes; Denver DAO keystrokes/day. ORs for psychosocial variables represent risk at scores one standard deviation above mean score compared to risk at scores one SD below mean. Because of readjustments and changes of workstations during study period, measurements of VDT workstations considered unreliable and excluded from analyses. Number of hr spent in hobbies and recreational activities not significant. Although keystrokes/day was found to not be significant, data available was for workers typing an average of 8 words/min over 8-hr period. 97% of participants used VDT $6 hr/day, so not enough variance to evaluate hr of typing. Over 70 variables analyzed in models may have multiple comparison bias.

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Herberts et al. 1981	Cross-sectional	131 male shipyard welders with >5 years of work experience compared to 57 male office clerks. All workers participated in the shipyard's medical program which offered medical exams every 5 years.	Outcome: Positive answers to questions about repeated occurrences of shoulder pain during work; shoulder stiffness that affected work and weakness in shoulder that affected work or weakness or numbness in arm or hand and participation in a follow up exam. Clinical examination with joint range of motion, active and passive and simultaneous pain analysis, rating of gross power in flexion, abduction and rotation, rating of tenderness to palpation. Exposure: Estimation of workload with assessment of the workplace into 3 groups very high, high or low. Static loading while holding tools; awkward postures; shoulder level or overhead work.	Supraspinatus tendinitis (ST) results of 23 welders called back for clinical follow-up exams: 16 welders had supraspinatus tendinitis. Shoulder Pain reports from the questionnaire: 27%	Shoulder Pain Prevalence from questionnaire: 1.8%	Prevalence rate ratio (PRR) of shoulder pain results from questionnaire, welders vs. office workers: PRR=15.2 PRR from estimated prevalence ("proportionation" of cases) reported in article: PRR=18.3	2.1-108 (90% CI) 14.7-22.1 (90% CI)	Participation rate: Not reported. Incidence estimated to be 15 to 20% a year. Welders with and without tendinitis were age-matched. We question the methods used to approximate the prevalence of shoulder tendinitis. Authors stated that they took into account the missing data in the investigation and assumed that the drop-out group did not deviate from the examined group, so they used "proportionation" to obtain the number of cases of supraspinatus tendinitis cases in the welders for calculations of prevalence rate ratios; number of supraspinatus tendinitis cases increased from 16 to 24. Number of years active welding, shoulder load, and welding years showed no significant difference. However, a sample size of 11 matched pairs may not have enough power to detect a difference. Turnover of shipyard welders mentioned at 33%. Shoulder tendinitis was not found to be associated with increasing age.

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Herberts et al. 1984	Cross-sectional	131 male shipyard welders and 188 plate workers compared to 57 male office clerks. Welders and plateworkers chosen had >5 years of job experience. 23 symptomatic welders, 30 symptomatic plate workers compared to 18 asymptomatic welders and 30 plate workers by clinical exam. Age-matched pairs: 11 welders; 15 plateworkers.	Nurse-administered symptom questionnaire: Case defined as pain, weakness, stiffness in shoulder excluding effects originating from neck, plus clinical exam with tenderness, range of motion gross power measured by dynamometer. Exposure: Observation of jobs; workers compared by use of job title; EMG measurements of muscles of shoulder region. Electromyographic analysis of the shoulder muscle load completed on 9 volunteers to study the influence of hand tool mass and arm posture.	Question-naire results, shoulder pain of the supra-spinatus tendinitis type Welders: 27% Plate-workers: 32% Supraspi-natus tendinitis results of 23 welders called back for clinical follow-up exams: 16 welders had supra-spinatus tendinitis Supraspi-natus tendinitis results of 30 plate-workers called back for clinical follow-up exams: 15 plateworkers had supra-spinatus tendinitis	Question-naire results, shoulder pain of the supraspi-natus tendinitis type: Office worker: 2%	PRR=18.3 PRR=16.2	13.7-22.1 (90% CI) 10.9-21.5 (90% CI)	Participation rate: Not reported. Not mentioned whether examiners blinded to case or exposure status. Controls were matched for age and gender. Plateworkers with shoulder pain averaged 6 years older than welders with shoulder pain. EMG analysis using fine monopolar wire electrodes showed that in work where the hand was positioned overhead, the intramuscular pressure in the supraspinatus muscle had extremely high pressure levels compared to pressure levels in other skeletal muscles. Turnover rate of welders was 30%; may be explanation for lack of association with duration. Welding seen as static work; plateworking dynamic work.

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Hoekstra et al. 1994	Cross-sectional	108 of 114 teleservice representatives working at 2 Government administration centers: A and B.	Outcome: Self administered questionnaire. Case defined as the presence of pain, numbness, tingling, aching, stiffness or burning in the shoulder, and no previous injury; symptoms began after starting the job; lasting >1 week or occurred once a month within the past year; reported as "moderate" or greater on a 5-point scale. Exposure: Observation of work stations, measurement and evaluation of work station; observation of postures.	Center A: 13% Center B: 44% Non-optimally adjusted desk height work Non-optimally adjusted screen		õ 4.0 5.1 3.9	õ 1.2-13.1 1.7-15.5 1.4-11.5	Participation rate: 95%. Representatives perceived little control over actions of others; little participation in decision making; little freedom to regulate own activities. Perception that workload was high and variable. Analysis controlled for gender and location and interactions checked. Variables considered in logistic model included location, age, seniority, hr spent typing at VDT, hr on the phone, 3 chair variables, and perceived adequacy of: (1) chair adjustment, VDT screen, (2) keyboard adjustment, VDT screen, (3) desk adjustment; job control, workload variability. Center B location had nonadjustable work stations and mostly nonadjustable chairs causing elevated arms, hunched shoulders and other undesirable postures. Linear regression also performed on psychosocial variables in separate models for health outcomes of job dissatisfaction and mental and physical exhaustion (not for shoulder MSDs). Did not include non-work-related variables in analyses.

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Hughes et al. 1997	Cross-sectional	104 male aluminum smelter workers: 62 carbon setters, 36 crand operators, 9 carbon plant workers. There were 14 workers who were not from selected jobs and were excluded.	Outcome: Symptoms occurring in the shoulder >once per month or lasting longer than 1 week in the previous year, no acute or traumatic onset; occurrence since working at the plant, no systemic disease. Physical examination: Active, passive, and resisted motions, pinch and grip strength, 128 Hz vibration sensitivity, two-point discrimination. Psychosocial scales from questionnaire based on Theorell and Karasek Job Stress Questionnaire, and on Work Apgar questionnaire used. Exposure: For carbon setters and crane operators (non-repetitive jobs) and modified job-surveillance checklist method was used. Job task analysis used a formula based on the relative frequency of occurrence of posture during tasks.	14.9% with positive symptoms and physical exam. 24% had symptoms in the elbow-forearm in the previous week.	õ	Model based on MSD defined by symptoms and physical exam		Participation rate: carbon setters: 65%; crane operators: 56%; carbon plant: 33%. Examiners blinded to exposure and health status: Not reported. Analysis controlled for age, smoking status, sports and/or hobbies. Psychosocial data collected individually; physical factors based on estimates of each job. Job risk factors entered into the model for hand/wrist included (1) the number of years of handling >2.7 kgs./hand, (2) push/pull, (3) lift/carry, (4) pinching, (5) wrist flexion/extension, 60 ulnar deviation, and (7) forearm twisting. Health interview included information about metabolic diseases, acute traumatic injuries, smoking, hobbies. Low participation rate limits interpretation.
						Age: OR=0.93	0.8-1.0	
						Good health: OR=0.35	0.1-0.87	
						Low decision latitude: OR=4.0	0.8-19	
						Years of forearm twist: OR=46	3.8-550	
						Model based on MSD defined by symptoms		
						Age: OR=0.96	0.8-0.98	
						Smoker: OR=0.41	0.1-1.4	
						Low decision latitude: OR=4.5	1.3-16	
						High Job demand: OR=3.0	0.7-13	
						Years forearm twist: 92	7.3-4	

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Ignatius et al. 1993	Cross-sectional	1,917 of 3,248 male postal employees completed an interviewer-administered questionnaire; 1,081 were letter delivery postmen compared to 836 other postal workers.	Outcome: history of symptoms and severity of recurrent joint pain as defined by Wells et al. [1983]. Exposure: work factors related to weight of letter bags, distance walked each day, use of transporting tools. Postmen carry/day an average load of 45 lbs; walked 4.5 km plus 1,300 steps for 3.7 hr/day.	Recurrent joint pain: 55.1% Severe joint pain: 12.0%	38.4% 6.2%	1.8 2.2	1.5 -2.2 1.5-3.1	Participation rate: 59% Severe shoulder pain associated with age, work experience, bag weight and walking time. Bags usually carried on one shoulder.

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Jonsson et al. 1988	Prospective	Electronics Workers (n=69 females) out of initial 96 workers. (See Kilbom et al. 1986 for initial study.)	Outcome: Three separate physical exams at yearly intervals (one initially) assessing tenderness on palpation, pain or restriction with active and passive movements; symptoms in previous 12 months with regard to character, frequency, duration, localization, and relation to work or other physical activities. Analyzed if score on any symptom of $2, on a 4 point scale; "severe" symptom score equals 4. Exposure: Carried out at outset of study: Maximum voluntary isometric contraction (MVC) of forearm flexors, shoulder strength, handgrip, heart rate using a bicycle ergometer and rating of perceived exertion. Videotaping performed for the analysis of working postures and movements. Reallocation tasks: Non sitting; no inspection of small details on printed circuit boards; standing and walking, occasionally sitting; caretaker work; surveillance of machinery; and assembling bigger and heavier equipment.	Severe shoulder disorders: 22% at 2nd exam After 1 year; 24%	Initially: 11% of subjects had shoulder MSDs 20% with unchanged working conditions	At 3rd exam during 3rd year of longitudinal study: 38 subjects reallocated to varied tasks had improved (16% of these had severe symptoms initially) significance at *p*<0.05 Those with unchanged working tasks deteriorated further (26%).		Participation rate: 72% of original group had 3 exams one year apart. 80% had 1st and 3rd year exams. Questionnaire included spare time physical activity, hobbies, perceived psychological stress at work, work satisfaction, number of breaks, rest pauses. Most of physiologic and ergonomic evaluations conducted only at outset of study. Low muscle strength not a risk factor for subsequent symptoms. Relative time spent with shoulder elevated negatively related to "remaining healthy" after both 1 and 2 years. Muscular strength and endurance not related to improvement nor remaining healthy. At 2nd and 3rd examination, there was a strong negative relationship between "remaining healthy" and satisfaction with colleagues. Predictors of remaining healthy were work without elevating the shoulders and satisfaction with work tasks. No mention of examiner being blinded to case status. Predictors of deterioration were previously physically heavy jobs, high productivity (after 1 year), and previous sick leave. Predictors of improvement were reallocation, physical activity in spare time, and high productivity (after 2 years).

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Kiken et al. 1990	Cross-sectional	294 Poultry Processors at 2 plants. Plant #1=174 Plant #2=120	Outcome: Period prevalence symptom in last 12 months by questionnaire. Case: Pain, aching, stiffness, burning, numbness or tingling in the shoulder, began after employment at the plant; not due to previous accident or injury outside work; lasted >8 hr and occurred 4 or more times in the past year.	Plant #1: Any symptom for shoulder case: 46%	28%	1.6	0.9-2.9	Participation rate: 98%. Examiners blinded to case and exposure status. Analysis stratified for gender and age.
				Period prevalence: 13%	3%	4.0	0.6-29	Higher exposure jobs (HE) were located in the receiving, evisceration, whole bird grading, cut up and deboning departments. Lower exposure jobs (LE) were located in the maintenance, sanitation, quality assurance and clerical departments.
			Point prevalence determined by physical exam. Rotator cuff defined as pain $3 on a 0 to 8 scale on active and resisted shoulder abduction. Case must fulfill symptom definition (listed above).	Point prevalence for shoulder case: 3%	0%	Indeterminate	ô	
				Plant #2: Any symptom for shoulder case: 50%	30%	1.7	0.8 -3.3	30% of workers involved in a job rotation program may have influenced associations made. Annual turnover rate close to 50% at plant 1 and 70% at plant 2 making survivor bias a strong possibility -- leading to underestimation of associations.
			Exposure: Determined by observation; level of exposure was based on exposure to repetitive and forceful hand motions, not shoulder.	Period prevalence: 14%	5%	2.8	0.4-19.6	
			Exposure measurements estimated for the hand and wrist region and *NOT* the shoulder area.	Point prevalence for shoulder case: 3%	0%	Indeterminate	ô	

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Kilbom et al. 1986	Cross-sectional	106 of 138 female assemblers in two electronic manufacturing companies agreed to participate; 10 excluded because of symptoms in past 12 months. 96 underwent medical, physiological, and ergonomic evaluation. (See Jonsson et al. 1988, earlier in this table, for follow-up.)	Outcome: Three separate physical exams at yearly intervals (one initially) assessing tenderness on palpation, pain or restriction with active and passive movements; symptoms in previous 12 months with regard to character, frequency, duration, localization, and relation to work or other physical activities. Analyzed if score on any symptom of $2, on a 4 point scale; "severe" symptom score equals 4. Exposure: Carried out at outset of study: Maximum voluntary isometric contraction (MVC) of forearm flexors, shoulder strength, handgrip, heart rate using a bicycle ergometer and rating of perceived exertion. Videotaping during the representative part of working day from rear and side. Upper arm studied at rest and in 0 to 30E, 30 to 60E, 60 to 90E, in extension and >90E abduction. The shoulder recorded as resting or elevated; also frequency of changes in posture between different angular sectors/hr, duration of postures. Work cycle time and number of cycles/hr, time at rest for arm, shoulder, head.	MSD symptoms in the shoulder using a four point severity scale: None: 84% Slight: 5% Moderate: 7% Severe: 3%		Logistic Regression model (all variables significant at the *p*<0.05 level). Shorter stature Years of employment in electronics. Fewer total number of upper arm flexions/hr. Greater percentage of work cycle time with upper arm abducted 0 to 30E.		Participation rate: 77%. See Jonsson et al. 1988 for follow-up. No relation between maximal static strength and symptoms. Examiner blinded to case status. Questions included spare time physical activities, hobbies, perceived psychosocial stress at work, work satisfaction, number of breaks, rest pauses. 59% had no symptoms or only slight ones. There were no cases of shoulder tendinitis. Age showed a weak positive correlation. Years of employment, productivity, muscle strength were not related to symptoms. There was large inter-worker variation in working posture and working techniques. The authors followed up on the non-participants and found no significant differences from participants. The more dynamic working technique, the less symptoms.

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Kvarnström 1983b	Cross-sectional and Case-control	112 cases of prolonged shoulder disorders identified in a workplace of 11,000 employees. The total number of employees was approximately half factory workers and half office workers. Case more than control study: Controls chosen at random from factory workers, matched for age and gender.	Outcome: Shoulder cases fulfilled the following: symptoms from shoulder was the main reason for inability to work, off work longer than 4 weeks, fatigue in one of both shoulders, pain in shoulder brought on by work and aching at rest were present, and Clinical examination demonstrated tenderness of the shoulder muscles, especially muscularis trapezius, levator scapulae, and/or infraspinatus and/or tenderness at the tendon insertions of the rotator cuff muscles. Muscle strength in shoulder assessed with regards to four functions Exposure: (1) Information obtained through interview: organization of work, physical work load, physical environment, psychosocial work environment, social and ethnic conditions, (2) detailed work history. Factors 0,1, or 2 given to different types of work depending on the workload borne by the shoulder. This factor multiplied by number of years spent at job, and products were added, (3) 2 company engineers graded the degree of monotony and repetitiveness in each job held by cases and controls.			Die casting machine operators (involved heavy work with repetitive movements of the shoulders): RR=5.4 Plastic workers: RR=2.2 Spray painters: RR=3.7 Surface treatment operators: RR=4.7 Assembly line workers: RR=5.2 Ergonomic experts' evaluation: cases had significantly more monotonous and repetitive work than controls.		Participation rate: Not reported. Examiners not blinded to exposure, but selection based on diagnosis of shoulder MSD. All 112 shoulder disorders occurred in laborers; none in office workers. RR for Swedish workers: 0.46; RR for immigrants: 3.1. All cases except one were paid piece rate. "Young persons significantly less ill than middled-aged." The following questionnaire responses were significantly different between cases and controls: Group piece rate, shift work, heavy work, monotonous, stressful, detrimental to health, heavy lifting, and unsuitable working conditions. 9 cases and 1 control cited poor relationship with supervisor. No difference in environmental condition, job content. Cases more likely to be married, have ill spouses, have children at home, work alternating shifts than controls. Work history showed no difference between points for cases and controls (see exposure column). Muscle strength bilaterally significantly lower in cases in four functions.

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	RR, OR, or PRR	95% CI	Comments
McCormack et al. 1990	Cross-sectional	Manufacturing workers: packaging or folding workers (41 males, 328 females); sewing workers (28 males, 534 females); boarding workers (19 males, 277 females) compared to knitting workers (203 males, 149 females); non-office workers (204 males, 264 females) compared with knitting workers (203 males, 149 females). These groups were compared to a referent group consisting of non-office workers maintaining machinery, involved in transportation, or worked as cleaners and sweepers. None of the referent group used rapid repetitive movements comparable to the employees in the other job categories. 21, 25 and 36 operators from each group and 25 of 55 auxiliary nurses and home helpers (controls) participated in the study.	Outcome: Questionnaire and physical examination initially by nurse screening; if employee answered affirmative to question regarding symptoms in upper extremity and/or had any positive physical findings, then had physician examination. The term "shoulder condition" used to define abnormalities of shoulder; consisted of bursitis, bicipital tendinitis and impingement syndrome. Exposure: Based on observation of job activities; only the boarding workers had activities requiring reaching overhead (from personal communication with first author).	Packaging/ folding workers: 2.7%	non-office workers: 2.1%	1.3	0.5-3.8	Participation rate: 91%. Examiners not blinded to exposure status (information obtained from personal communication). 11 Physician examiners; inter-examiner potential problem acknowledged by authors. Questionnaire asked types of jobs, length of time on job, production rate, nature and type of upper extremity complaint and general health history. Age, sex, race, job category and years of employment not statistically significant with "shoulder conditions." Patients with objective diagnostic shoulder findings: Of 45 cases diagnosed: 25 graded as “mild”, 19 graded as “moderate; 1 graded as severe.
				Sewing workers: 2.5%	2.1%	1.2	0.5-2.7	
				Boarding workers: 2.4%	2.1%	1.1	0.4-2.9	
				Knitting workers: 1.1%	2.1%	1.3	0.5-3.1	

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Milerad and Ekenvall 1990	Cross-sectional	99 Dentists randomly selected from Stockholm dentist registry who practiced $10 years compared to 100 pharmacists selected from all pharmacists in Stockholm.	Outcome: Based on telephone questionnaire: Shoulder symptoms at any time before the interview "lifetime prevalence." Further analyzed according to Nordic questionnaire as to duration during last 12 months and during last 7 days, effect on work performance and leisure activities, and sick leave.	Male: 36% Female: 67%	15% 28%	2.4 2.4	1.0 -5.4 1.5-3.7	Participation rate: 99%. Stratified analysis by gender.
				Neck and shoulder: 36%	17%	2.1	1.3-3.0	No difference in leisure time exposure, smoking, systemic disease, exposure to vibration. Symptoms increased with age in female dentists only.
			Exposure: Questionnaire included: (1) abduction of arm, particularly in sit-down dentistry, (2) static postures, (3) work hr/day.	Neck and shoulder and upper arm: 16%	3%	5.4	1.6-17.9	Duration of employment highly correlated with age (r=0.84, 0.89). No relation between symptoms and duration of employment. Equal problems dominant and nondominant sides.

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	RR, OR, or PRR	95% CI	Comments
Ohara et al. 1976	Cross-sectional and Prospective	For cross-sectional study: 399 cash register operators compared with 99 office machine operators and 410 other workers (clerks and saleswomen). All female. For prospective study: 56 workers employed <7 months had testing pre- and post-intervention using questionnaire and physical exam. 86 operators, newly hired after interventions, also had evaluation after 10 months of working.	Outcome: Assessed by standard health inventory and medical examination (used clinical classification according to the committee on cervicobrachial disorders of the Japan Association of Industrial Health, in Table 3 in the paper). Periodic physical exam performed twice a year from 1973. Primary exams performed on 371 operators. 130 (35%) received detailed exams. Exposure: To repetitive movements relocating merchandise across counter and bagging, involved muscle activity of the fingers, hands, and arms; extreme and sustained postures. Interventions: (1) a 2-operator system, 1 working the register, one packing articles, changing roles every hr; (2) continuous operating time <60 min; max. working hr/day 4.5 hr; (3) 15- min resting period every hr; (4) electronic cash registers with light touch keyboard substituted for half of previously used mechanical cash registers.	Shoulder stiffness: Cashiers: 81% Shoulder dullness and pain: Cashiers: 49%	Shoulder stiffness : Office Workers: 72% Shoulder dullness and pain: Other workers: 68% Office workers: 30%	1.7 2.0 2.2	1.0-2.8 1.4-2.8 1.4-3.5	Participation rate: for prospective study = 100%. Participation rate: for cross-sectional study, not reported. Unknown whether examiners blinded to case status. Interventions did not reduce complaints in the shoulder region, but did improve symptoms in the arms, hands, fingers, low back, and legs. The lack of improvement in the shoulder region was stated to be due to the use of the same narrow check stands, unsuitable counter height, and necessity of continuous lifting of the upper limbs. Operators hired after the interventions and then examined after 10 months had less Grade I, II , or III occupational cervicobrachial disorders in examination than those hired before intervention. Only 14.5% with >3 years employment at worksite. Narrow work space and counter height not adjusted for height of worker.

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Ohlsson et al. 1989	Cross-sectional	Electrical equipment and automobile assemblers (n=148), former female assembly workers who quit within 4 years (n=76) compared to randomly sampled females from general population (n=60).	Outcome: Based on questionnaire: Any shoulder pain, shoulder pain affecting work ability, and shoulder pain in the last 7 days. Exposure: Based on job category.	Shoulder pain in previous 12 months: 55%	45%	2.0	1.1-4.0	Participation rate: Not reported. Significant association for shoulder symptoms and medium and fast pace compared to slow pace but not very fast pace.
				Shoulder pain in previous 7 days: 38%	18%	3.4	1.6-7.1	Significant association with duration of employment (*p*=0.03), but much stronger for workers <35 years than workers >35 years.
				Work in auxiliary previous 12 months: 21%	10%	2.4	1.0-5.8	Significant interaction between age and employment. Older females employed for shorter periods had more symptoms than younger ones.

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

				MSD prevalence				
Study	**Study design**	**Study population**	**Outcome and exposure**	**Exposed workers**	**Referent group**	**RR, OR, or PRR**	**95% CI**	**Comments**
Ohlsson et al. 1994	Cross-sectional	Exposed Group: 206 of 247 females working in 13 fish processing plants participated. 322 females who left employment in the fish processing industry in the 10 years prior to the study. Comparison group: All 208 females employed in the same towns as the exposed; 71 were employed in day nurseries; 92 in offices; 42 caretakers of elderly; 3 gardeners.	Outcome: Defined by criteria from questionnaire and physical examination: standard diagnosis of frozen shoulder, supraspinatus tendinitis, infraspinatus tendinitis, bicipital tendinitis acromioclavicular syndrome. Exposure: Assessed by questionnaire (length of employment; psychosocial factors, physical factors) and by observational methods (Ergonomic Workplace Analysis) and NIOSH guidelines for lifting. Analyzed 10 items: work site, general physical activity, lifting, work postures and movements, job content, job restrictiveness, worker communication, difficulty of decision making, repetitiveness of the work, and attentiveness. 74 workers videotaped $10 min. from the back and sides. Average counts of two independent readers for frequencies, duration and critical angles of movement used.	Frozen shoulder: 2%	0.5%	4.1	0.5-37	Participation rate: 83%. No exposure information available to examiners, however, it was not possible to completely blind the study/referent group status. All activities (trimming of cod, packing fish and herring filleting) were found to be highly repetitive with poor working postures and fast movements by standardized "ergonomic workplace analysis" (EWA) methods; very few pauses in the work cycle; tasks not varied. Sports activities were highly associated with shoulder tendinitis (OR=4, 9) in multiple logistic regression analysis. In the control group, prevalences of upper limb disorders increased substantially with age. Among the exposed, the prevalence remained almost constant with age. Excess prevalence for exposed females most pronounced for females <45 years. There was a pronounced dose-response for disorders of the neck or shoulders vs. duration of exposure in the industry. No such associations seen in group >45 years. Authors explained as perhaps due to the "healthy worker effect," but, it would be more accurate to describe it as "survivor bias." Psychosocial work environment, stress and worry factors, tendencies towards muscular tension differed significantly between exposed and controls.
				Supraspinatus tendinitis: 15%	5%	3.4	1.6-7.2	
				Infraspinatus tendinitis: 12%	3%	4.7	1.4-15.2	
				Bicipital tendinitis: 10%	4%	2.4	1.1-5.4	
				Acromioclavicular syndrome: 17%	6%	3.1	1.6-6.0	
						PRR of shoulder disorders: 2.95	2.2-4.0	
						PRR for suprapinatus, infraspinatus and bicipial tendinitis: 3.03	2.0-4.6	
						PRR for suprapinatus and infraspinatus tendinitis alone: 3.5	2.0-5.9	

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	Referent group	RR, OR, or PRR	95% CI	Comments
Ohlsson et al. 1995	Cross-Sectional	Industrial Workers (n=82 females) exposed to repetitive tasks with short cycles mostly far <30 sec, usually with a flexed neck and arms elevated and abducted intermittently; 68 former workers (mean employment time 21 years) who had left the factory during the 7 years before the study; these workers were compared to 64 referents with no repetitive exposure at their current jobs (female residents of a nearby town currently employed as customer service, ordering and price marking in supermarkets, as office workers (no constant computer work) or as kitchen workers.	Outcome: Measured by physical exam and questionnaire. Frozen shoulder: Limited out-ward rotation and abduction. Infraspinatus, supraspinatus tendinitis: Local tenderness over tender insertion, pain with resisted abduction. Bicipital tendinitis: Pain with resisted elevation of arm, resisted flexion of elbow. Acromicoclavicular syndrome: Pain with horizontal adduction and/or outward rotation of arm. Exposure: Videotaping and observation. Analysis of elevation of the arm: 0E, 30E, 60E, and for abduction 30E, 60E, 90E. 74 workers videotaped $10 min. from back and sides. Average counts of two inde-pendent readers for frequencies, duration, and critical angles of movement used. Repetitive industrial work tasks divided into 3 groups: (a) fairly mobile work, (b) assembling or pressing items, and © sorting, polishing and packing items Weekly working time, work rotation, patterns of breaks, individual performance rate (piece rate). Only exposure readings from right arm were used. Muscle strength (maximum voluntary capacity) measured by hand dynamometer at elevation,	50% (n=82) Employment duration: <10 years (n=19): 53% 10 to 19 years (n=25): 48% >20 years (n=38): 50%	16% (n=64)	5.0 9.6 4.4 3.8	2.2-11.0 2.8-33.0 1.5-13.0 1.4-10.0	Participation rate: current workers: 96%; past workers: 86%; referents: 100%. Questionnaire included individual factors, work/environment, symptoms. No exposure information available to examiners, however, it was not possible to completely blind the study/referent group status. Psychosocial scales assessed: control over one's work, stimulation, psychological climate, work strain, fellowship at work and social network at work. Age, stress/worry tendency, subjective muscular tension tendency, social network outside of work, psychosomatic symptoms. Age and employment status (repetitive vs. referent) controlled for in logistic model. For continuous variables, OR are for 75th vs. 25th percentiles. Videotape analysis revealed considerable variation in posture even within groups performing similar assembling tasks. Logistic models replacing repetitive work with videotape variables found muscular tension tendency and neck flexion movements significantly associated with neck/shoulder diagnoses. Significant association between time spent with upper arm abducted >60° and neck/shoulder diagnoses.

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	Referent group	RR, OR, or PRR	95% CI	Comments
Onishi et al. 1976	Cross-sectional	Female industrial workers: 42 reservationists; 95 fluorescent lamp assemblers; 109 photographic film rollers; 46 teachers of handicapped children; 101 office workers.	Outcome: Based on (1) symptoms of shoulder stiffness, dullness, pain, numbness; (2) pressure (<1.5 kv/cm^2) measured by strain transducer at which subject felt pain. (3) physical exam: range of motion, tests, nerve compression tenderness. Exposure: Observation of job tasks, then job categorization. Reservations; Key 15,000 to 20,000 strokes/day or more on busy days 2 to 3 times/week. Assemblers inspect lamps once every 3.5 to 4.5 sec; all work 12 hr/day. Film rollers wind 1 roll of 35mm film every 2.5 to 5 sec over 7.5 hr/day. Prolonged contraction of trapezius noted in 2 film rollers. Teachers and nurses daily care of disabled children e.g., lifting. Office workers: Record keeping, copying, etc.	Shoulder Tenderness: Reserva-tionists: assemblers: 70% Film rollers: 84% Teachers: 58% Shoulder Stiffness: Reservatio-nists (N=45): 56.6% Assemblers (N=94): 66.6% Film Rollers (N=127): 59.1% Teachers (N=52): 65.4%	Office workers (n=101): 48% 34.7%	1.1 6.0 1.6 2.5 3.7 2.7 2.1	0.6-1.9 3.0-12.2 0.7-3.3 1.1-5.6 2.0-7.0 1.5-4.9 0.9-4.6	Participation rate: Not reported. Unknown whether examiners blinded to case status. Body height, weight skin fold thickness and muscle strength, grip strength, obtained. Body height and weight differences not significant. Significant difference between body fat in reservationists and office workers. Significant difference in grip strength in teachers and nurses compared with office workers. Those with habitual shoulder stiffness had lower threshold of local tenderness than those without stiffness. No difference between workers with tenderness threshold above 1.5 Kb/cm^2 and those below with respect to age, height, weight, skin fold thickness, grip strength, upper arm abduction strength, back muscle strength.

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Punnett et al. 1985	Cross-sectional	162 female garment workers, 85% were employed as sewing machine operators and sewing and trimming by hand. Comparison: 76 of 190 full or part-time workers on day shift in a hospital who worked as nurses or aids; lab techs or therapists; food service workers. Employees typing >4 hr/day excluded from comparison group.	Outcome: Self-administered questionnaire about pain and standardized physical exam. Cases defined as the presences of persistent shoulder pain (lasted for most days for one month or more within the past year); were not associated with previous injury, and, began after first employment in garment manufacturing or hospital employment. Key questions based on the arthritis supplement questionnaire of NHANES. Exposure: Self-administered questionnaire; number of years in the industry, job category, previous work history.	Garment workers: 19.6%	Hospital employees 8.8%	Shoulder MSDs in Garment workers vs. Hospital employees: OR= 2.2 Shoulder MSDs in Straight stitch workers vs. Hospital employees: OR=3.9 Shoulder MSDs in Top stitch workers vs. Hospital employees OR=5.0	1.0-4.9 *p*#0.05 *p*#0.05	Participation rate: 97% (garment workers), 40% (hospital workers). Analysis stratified for number of years employed, decade of age, native language. Age and length of employment not a predictor of risk of shoulder MSDs. Prevalence of pain not associated with years of employment in garment workers. Non-English speakers significantly less likely to report pain (RR 0.6 $p<0.05$). Native English speakers significantly older than non-native English speakers ($p<0.03$). Logistic regression model found garment work and language significantly related to shoulder pain.

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence				Comments
				Exposed workers	Referent group	RR, OR, or PRR	95% CI	
Rossignol et al. 1987	Cross-sectional	191 computer and data processing services, public utilities of Massachusetts State Department, 28 of whom did not use a keyboard with a VDT. Centers selected at random from 38 work sites with >50 employees.	Outcome: Self-administered questionnaire case defined as: "Almost always experienced" shoulder pain, stiffness or soreness or missed work due to shoulder pain, stiffness or soreness. Exposure: Self-reported number of hr/day working on a keyboard with a VDT. Subjects selected after observation of work sites.	0.5 to 3 hr of VDT use/day (n=31): 35% 4 to 6 hr of VDT use/day (n=28): 48% >7 hr of VDT use/day (n=104): 51%	Comparison group (with no computer use) (n=28): 18%	Up to 3 hr of VDT use compared to 0 hr of use. OR=2.5 4 to 6 hr of VDT use compared to 0 hr of use: OR=4.0 >7 hr of VDT use compared to 0 hr of use: OR=4.8	0.7-10.8 1.0-16.9 1.6-17.2	Participation rate: in six industry groups 67 to 100%. Participation rate: for individual clerical workers: 94 to 99%. "Assessed magnitude of confounding by age, cigarette smoking, industry, educational VDT training." The study was presented as "General health survey to avoid observation bias."

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

				MSD prevalence				
Study	**Study design**	**Study population**	**Outcome and exposure**	**Exposed workers**	**Referent group**	**RR, OR, or PRR**	**95% CI**	**Comments**
Sakakibara et al. 1987	Cross-sectional	48 Orchard workers (20 males and 20 females). Compared symptoms after completion of thinning of pears, bagging of pears and bagging of apples (covering fruit with paper bags while on the trees). Internal comparison using same study population.	Outcome: Shoulder pain described as the presence of stiffness and pain daily. Exposure: Observation of jobs. Angles of flexion of the shoulder on one subject were measured every 25 min. during a whole day doing each task. Farmers worked approximately 8 hr/day for 10.6 to 13.6 days each year bagging or thinning pears and bagging apples. Median shoulder flexion was 110E to 119E for thinning pears and bagging pears; 30E bagging apples.	Workers thinning pears (estimated from histograms): 46% Workers bagging pears (estimated from histograms): 29%	Workers bagging apples: 21%	Workers thinning pears vs. workers bagging apples: OR=2.2 Workers bagging pears vs. bagging apples: OR=1.4	1.2-4.1 0.7-2.8	Participation rate: 77%. Stratified by gender. General fatigue, gastric disturbances, appetite loss and headache showed no difference in frequency between tasks. Stiffness and pain in shoulders significantly higher from thinning and bagging pears than apples which authors attributed to working posture of elevated arms and neck extension. Exposure data based on measurement of one worker may not be generalized to others. The proportion of workers with >90E forward shoulder flexion was significantly higher for thinning out pears and bagging pears than for bagging apples.

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Sakakibara et al. 1995	Cross-sectional	Of 65 female Japanese farmers. 52 completed the questionnaire and physical exam in late June for bagging pears and late July for bagging apples.	Questionnaire: Stiffness and pain in shoulder region. Symptoms in past 12 months for $one day, or symptoms in past 12 months for $8 days. Exam: Muscular tenderness in shoulder region; maximal grasping power measured by dynamometer and back muscle power by myosphenometer. Exposure: Observation of tasks and measurements of representative workers (only two workers measured). Angle of arm elevation during bagging was measured in one subject. Angle of forward flexion of shoulder for bagging pears was 110 to 139º. 75% of angles were above 90º. For bagging apples the angle of forward flexion was 0 to 140º; 41% of the angles were >90º.	Pear bagging Muscle tenderness: 48.1% Pain in joint motion: 23.1%	Apple bagging Muscle tender-ness: 28.8% Pain in joint motion: 21.2% controls	Workers bagging pears with muscle tenderness vs. apple bagging with muscle tenderness: OR=1.7 Workers bagging pears with pain in joint motion vs. apple bagging with pain in joint motion: OR=1.1	1.1-2.9 0.53-2.3	Participation rate: 80%. Examiners not blinded to case status due to design of study. Same population examined two times. 2nd exam occurred one month after first. These results used in analyses for comparison of two tasks. Stiffness and pain during apple bagging may have been pain that was a residual of pear bagging operations. Number of fruit bagged/day was significantly more in pear bagging than in apple bagging. Exposure measurements only obtained on 2 workers and generalized to all workers.

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Schibye et al. 1995	Pro-spective	Follow-up of 303 sewing machine operators at nine factories representing different technology levels who completed questionnaire in 1985. In April 1991, 241 of 279 traced workers responded to same questionnaire.	Outcome: Cases defined by the Nordic questionnaire for symptoms as to duration during last 12 months and during last 7 days, effect on work performance and leisure activities, and sick leave. Exposure: Assessed by questions regarding type of machine operated, work organization, workplace design, units produced/day, and payment system, time of employment as a sewing machine operator.	Workers who delivered or collected their own materials: 18% shoulder symptoms; the rest 33%	õ	õ	õ	Participation Rate in 1985: 94%. Participation Rate in 1991: 86%. All participants were female. 77 of 241 workers still operated a sewing machine in 1991. 82 workers had another job in 1991. Among those 35 years or younger, 77% had left their jobs; among those above 35 years, 57% had left their jobs. 20% reported musculoskeletal symptoms as the reason for leaving job. No significant changes in prevalences among those employed as sewing machine operators from 1985 to 1991; significant decrease in those who changed employment.

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence				Comments
				Exposed workers	Referent group	RR, OR, or PRR	95% CI	
Stenlund et al. 1992	Cross-sectional	55 of 75 rockblastors, 54 of 75 bricklayers randomly selected from union records and 98 of 110 foremen selected from foremen employed in large construction firms.	Outcome: Based on a grading of acromioclavicular joints of shoulders. Grade 0 = normal Grade 1 = minimal changes Grade 2 = moderate changes Grade 3 = severe osteoarthritis Grade 4 = joint destroyed Exposure: Based on self-reported estimates of loads lifted, hr of exposure to vibration, job title, and years of employment. The weights of tools also obtained. Bricklayers lifted a mean of 29,439 tonnes; Rockblasters, a mean of 33,210 tonnes; Foremen, a mean of 2,261 tonnes.	Bricklayers Rt side: 59.3%	Foremen 36.7%	2.2	1.0-4.7	Participation rate: 80%. Classification of X-rays achieved with blinding of investigators to age, name or exposure status. Study looked at manual work and exposure to vibration and relationship to osteoarthritis in acromioclavicular joint using shoulder x-rays. Logistic regression models adjusted for age, smoking, dexterity, checked for interactions. Questionnaire included questions about smoking, dexterity, ethnicity, citizenship. Risks were elevated as length of employment increased and as exposure to vibration and amount lifted increased. X-ray grades 2 and 3 for analysis. Smoking significantly associated with osteoarthritis of right shoulder (OR=2, 2.4) but not left side. Significance found, but is it meaningful? Left handedness significantly associated with osteoarthritis of left side (OR=2.5). The age adjusted odds ratio for osteoarthrosis in the right acromioclavicular joint for brick layers and rock blasters as compared with foremen, was 2.16 on the right side 95%CI(1.14-4.09), and was 2.56 95% CI (1.33-4.93).
				Lt side: 40.7%	23.4%	1.8	0.8-3.9	
				Rockblasters Rt side: 61.8%	Foremen 36.7%	2.1	0.9-4.6	
				Lt side: 56.4%	23.4%	4.0	1.8-9.2	
						Years of manual work >28 years vs. <10 years Rt side: 2.9	1.2-7.4	
						Lt side: 2.5	1.0-5.9	
						10 to 28 years vs. <10 years Rt side: 1.1	1.1-4.7	
						Lt side: 2.3	1.0-5.3	
						Load lifted 725,000 vs. 710 tonnes Rt side: 3.2	1.1-9.2	
						Lt side:10.3	3.1-34.5	
						Vibration 725,000 hr vs <9001 hr Rt side: 2.2	1.0-4.6	
						Lt side: 3.1	1.4-6.9	

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Stenlund et al. 1993	Cross-sectional	55 of 75 rockblasters and 54 of 75 bricklayers selected randomly from union records, and 98 of 110 foremen randomly selected from foremen employed in large construction companies.	Outcome: Based on questionnaire of previous injuries and diseases of musculoskeletal system and previous shoulder pain, and physical exam. Case defined as "Signs of shoulder tendinitis" as palpable pain of the muscle attachment or pronounced pain reaction to isometric contraction in any of the 4 rotator cuff muscles or biceps muscles. "Clinical entity of tendinitis" defined as pain during the last year, pronounced pain reaction to palpation or isometric contraction. Exposure: Based on self-reported estimates of load lifted, hr of exposure to vibration, job title and years of employment. Load defined as 0 to 709 tonnes, 710 to 25,999 tonnes, >25,999 tonnes vibration defined as hr of exposure: 0 to 8,999, 9000 to 255,199, >255,999 hr to each tool multiplied by factor corresponding to vibration energy. Years of manual work: 0 to 9, 10 to 28, >28 years.	Bricklayers Rt. side: 11.1%; Lt. side: 14.8%	Foremen 8.2% 17.1%	 0.4 õ	 0.2-1.3 õ	Participation rate: 80%. Examiners blinded to exposure status or job title. Unconditional multiple regression analysis adjusted for age, handedness, smoking and sport activities. In all models left and right sides calculated separately. Vibration related to shoulder tendinitis although confounded by static loads and lifting. Interactions tested for. The study looked at manual work and exposure to vibration and their relationship to signs of tendinitis of the shoulder. Exposure-response found where comparison of high vibration exposure compared to low exposure.
				Rockblasters Rt. side: 32.7% Lt. side: 40.0%	 8.2% 17.1%	 1.7 3.3	 0.7-4 1.2-9.3	
						Clinical Entity Load Rt. side: 1.0 Lt. side: 1.6	 0.5-2.2 0.6-4.1	
						Vibration Rt. side: 1.9 Lt. side: 2.5	 1.0-3.4 1.1-5.9	
						Manual Work Rt. side: 0.9 Lt. side: 2.3	 0.5-1.8 0.9-6.3	
						Signs of Tendinitis Load Rt. side: 1.0 Lt. side: 1.8	 0.6-1.8 0.9-3.4	
						Vibration Rt. side: 1.7 Lt. side: 1.8	 1.1-2.6 1.1-3.1	
						Manual Work Rt side: 1.1 Lt side: 1.9	 0.7-1.8 1.0-3.4	

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Sweeney et al. 1994	Cross-sectional	105 of 164 sign language interpreters for the deaf, who attended a professional conference of sign language interpreters.	Outcome: Symptom questionnaire and physical exam: Symptom case defined as the presence of pain, aching, stiffness, burning, numbness or tingling in the shoulder lasting $ one week or once/month within the past 12 months; no previous injury and symptoms occurred after becoming a sign-language interpreter. Symptom-exam case: Defined as the presence of symptoms and a positive exam for the shoulder. Exposure: Based on questionnaire (years of employment as a sign language interpreter; numbers of hrs/week engaged in signing).	Symptom case: 22% Symptom case with moderate to severe shoulder discomfort: 50% Positive symptom + positive exam: 1%	>20 hr signing, compared to <10 hr/week ō	2.5 ō	0.8- 8.2 ō	Participation rate: 64%. Examiner blinded to exposure status. Generalizability of results to other sign language interpreters is limited.

(Continued)

Table 3-5 (Continued). Epidemiologic studies evaluating work-related shoulder musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Wells et al. 1983	Cross-sectional	Of 199 letter carriers, 196 were compared to 76 of 79 meter readers and 127 of 131 postal clerks.	Outcome: Telephone interview based on current pain; frequency, severity, interference with work, etc; score of 20 required to be a case. More points given to neck and shoulder problems that interfered with routine daily activities.	All letter carriers: 18%	Postal clerks: 5%	3.6	1.8-7.8	Participation rate: 99% among letter carriers, 92% meter readers, 97% postal clerks. Schooling and marital status asked.
				Letter carriers: increased weight: 23%	Postal clerks: 5%	5.7	2.1-17.8	Symptoms alone used for MSD definition.
			Exposure: Based on job category; based on self-reported information on weight carried, previous work involving lifting and work-related injuries.	Letter carriers: no weight increase: 13%	Postal clerks: 5%	3.3	1.1-11.1	Comparison group (gas meter readers) used because of similar "walking rate" without carrying weight compared to letter carriers. Postal clerks neither walk nor carry weight. During analysis, more weight was given to scoring neck and shoulder than other body regions. Outcome influenced results when ranking of body MSDs, though, would not influence group comparison. Adjusted for age, number of years on the job, quetlet ratio and previous work experience. 104 letter carriers had bag weight increased from 25 to 35 lbs in the year prior to the study. Letter carriers with increased bag weight walked on average 5.24 hr; those with no change in bag weight walked 4.83 hr. Letter bags usually carried on the shoulder.

CHAPTER 4

Elbow Musculoskeletal Disorders (Epicondylitis): Evidence for Work-Relatedness

SUMMARY

Over 20 epidemiologic studies have examined physical workplace factors and their relationship to epicondylitis. The majority of studies involved study populations exposed to some combination of work factors, but among these studies were also those that assessed specific work factors. Each of the studies examined (those with negative, positive, or equivocal findings) contributed to the overall pool of data to make our decision on the strength of work-relatedness. Using epidemiologic criteria to examine these studies, and taking into account issues of confounding, bias, and strengths and limitations of the studies, we conclude the following:

There is **insufficient evidence** for support of an association between repetitive work and elbow musculoskeletal disorders (MSDs) based on currently available epidemiologic data. No studies having repetitive work as the dominant exposure factor met the four epidemiologic criteria.

There is **evidence** for the association with forceful work and epicondylitis. Studies that base exposure assessment on quantitative or semiquantitative data tended to show a stronger relationship for epicondylitis and force. Eight studies fulfilling at least one criteria showed statistically significant relationships.

There is **insufficient evidence** to draw conclusions about the relationship of postural factors alone and epicondylitis at this time.

There is **strong evidence** for a relationship between exposure to a combination of risk factors (e.g., force and repetition, force and posture) and epicondylitis. Based on the epidemiologic studies reviewed above, especially those with some quantitative evaluation of the risk factors, the evidence is clear that an exposure to a combination of exposures, especially at higher exposure levels (as can be seen in, for example, meatpacking or construction work) increases risk for epicondylitis. The one prospective study which had a combination of exposure factors had a particularly high incidence rate (IR=6.7), and illustrated a temporal relationship between physical exposure factors and epicondylitis.

The strong evidence for a combination of factors is consistent with evidence found in the sports and biomechanical literature. Studies outside the field of epidemiology also suggest that forceful and repetitive contraction of the elbow flexors or extensors (which can be caused by flexion and extension of the wrist) increases the risk of epicondylitis.

Epidemiologic surveillance data, both nationally and internationally, have consistently reported that the highest incidence of epicondylitis occurs in occupations and job tasks which are manually intensive and require high work demands in dynamic environments—for example, in mechanics, butchers, construction workers, and boilermakers.

Epicondylar tenderness has also been found to be associated with a combination of higher levels of forceful exertions, repetition, and extreme postures of the elbow. This distinction may not be a true demarcation of different disease processes, but part of a continuum. Some data indicate that a high

percentage of individuals with severe elbow pain are not able to do their jobs, and they have a higher rate of sick leave than individuals with other upper extremity disorders.

INTRODUCTION

Epicondylitis is an uncommon disorder, with the overall prevalence in the general population reported to be from 1% to 5% [Allender 1974]. There are fewer epidemiologic studies addressing workplace risk factors for elbow MSDs than for other MSDs. Most of these studies compare the prevalence of epicondylitis in workers in jobs known to have highly repetitive, forceful tasks (such as meat processing) to workers in less repetitive, forceful work (such as office jobs); the majority of these studies were not designed to identify individual workplace risk factors.

The text of this section on epicondylitis is organized by work-related exposure factor. The discussion within each factor is organized according to the criteria for evaluating evidence for work-relatedness in epidemiologic studies using the strength of association, the consistency of association, temporal relationships, exposure-response relationship, and coherence of evidence. Conclusions are presented with respect to epicondylitis for each exposure factor. Summary information relevant to the criteria used to evaluate study quality is presented in Tables 4-1 to 4-4. A more extensive summary (Table 4-5) includes information on health outcomes, covariates, and exposure measures. All tables are presented at the end of this chapter. Not all the articles summarized in the tables are referenced in this narrative, but they have been reviewed and evaluated and are included for information.

There are 19 studies referenced in Tables 4-1 through 4-4, 18 cross-sectional studies and one cohort. Those studies using symptom and physical examination findings to define epicondylitis used consistent criteria—almost all studies using physical examination for diagnosis required pain with palpation of the epicondylar area and pain at the elbow with resisted movement of the wrist. However, studies using a definition based on symptom data alone used various criteria, some based on frequency and duration of symptoms [Burt et al.1990; Hoekstra et al. 1994; Fishbein et al. 1988] others based on elbow symptoms preventing work activities [Ohlsson et al. 1989].

REPETITION

Definition of Repetition for Elbow MSDs

For our review, we chose studies that addressed the physical factor of repetition and its relation to elbow MSDs, especially those studies that focused on epicondylitis. Studies usually defined repetition, or repetitive work, for the elbow as work activities that involved (1) cyclical flexion and extension of the elbow or (2) cyclical pronation, supination, extension, and flexion of the wrist that generates loads to the elbow/forearm region. Most of the studies that examined repetition as a risk factor for epicondylitis had several concurrent or interacting physical work load factors. We attempted to select those studies in which repetition was either the single risk factor or the dominant risk factor based on our review

of the study and our knowledge of the occupation. This method eliminated those studies in which a combination of high levels of repetition and high levels of force exist, or those studies which selected their exposure groups based on highly repetitive, forceful work.

Studies Reporting on the Association of Repetition and Epicondylitis

Seven studies reported results on the association between repetition and adverse elbow health outcomes including epicondylitis. The epidemiologic studies that address repetitive work and epicondylitis compare working groups by classifying them into categories based on some estimation of repetitive work, such as percent of time typing [Burt et al. 1990], number of items per hour [Ohlsson et al. 1989], or number of hand manipulations per hour [Baron et al. 1991]. Those studies which may have measured repetitive work but have exposure to higher levels of force will be discussed in the "Force" section.

Studies Meeting the Four Evaluation Criteria

None of the studies (see Table 4-1 and Figure 4-1) reviewed for the elbow summary section met all four evaluation criteria outlined in the Introduction Section.

Studies Meeting at Least One of the Criteria

The studies will be summarized in alphabetical order as they appear in
Table 4-1.

Andersen and Gaardboe [1993a] used a cross-sectional design to compare sewing machine operators with a random sample of women from the general population of the same region. Elbow pain, not epicondylitis, was the MSD of interest in this study. A case of elbow pain was based on self-reported symptoms lasting more than 1 month since starting career, or pain for more than 30 days. Exposure was based on the authors' experiences as occupational health physicians and involved crude assessment of exposure level and exposure repetitiveness. Analysis dealt with exposure as "duration of exposure as a sewing machine operator". Statistical modeling controlled for age, having children, not doing leisure exercise, smoking, and socioeconomic status. For this study, the exposure classification scheme does not allow separation of the effects of repetition from those of force, although repetition may be a more obvious exposure.

Baron et al. [1991] explored epicondylitis among grocery store workers, comparing the prevalence among grocery store cashiers to that among non-cashiers and identified work risk factors while controlling for covariates. Detailed ergonomic assessment of grocery checking and cashiering was completed using both on-site observational techniques and videotaped analyses. The majority of cashiers were categorized as having "medium" levels of repetition for the hand (defined in this study as making 1250 to 2500 hand movements per hour). Repetitive movements were not recorded directly for the elbow; however, the number of hand movements serve as an approximation for elbow repetitions. Age, hobbies, second jobs, systemic disease, and height were considered as covariates in the multivariate analyses. The diagnosis of epicondylitis required standard physical examination techniques of palpation and resisted extension and flexion of the elbow.

Burt et al. [1990] studied 834 employees using computers at a metropolitan newspaper, using a self-administered questionnaire for case ascertainment. Exposure assessment was based on self-reported typing time and observation of employees' job tasks, then categorization by job title. A separate job analysis using a checklist and observational techniques was carried out for validating questionnaire exposure data. Workers fulfilling the case definition for elbow/forearm pain were compared to those who did not fulfill the case definition. Prevalence of cases was associated with percent of time typing and typing speed. Logistic regression controlled for age, gender, metabolic disorders, and job satisfaction.

Automobile assembly line workers were compared to a randomly selected group from the general population in the study by Byström et al. [1995]. A case of epicondylitis required symptoms and physical examination. "Job title" was used as a surrogate for exposure in the analysis. No assessment of repetition or repetitive work was completed specifically for the elbow.

McCormack et al. [1990] had a randomly selected population of 2,261 textile workers from over 8,000 eligible workers. Workers were analyzed by job category, after observation of jobs. Epicondylitis case ascertainment was by clinical exam. Of the 37 cases of epicondylitis identified, 13 were categorized as mild, 22 were moderate, and 2 were severe. Eleven examiners may have introduced an interexaminer reliability problem. Age, gender, race, and years of employment were analyzed as confounders.

Ohlsson et al. [1989] studied electrical equipment and automobile assemblers, former assembly workers and compared these two groups to a random sample from the general population. A case of elbow pain was based on questionnaire responses; exposure was based on job categorization as well as questionnaire responses. Repetitive exposure was based on a self-reported frequency of task items completed per hour (work pace). Results showed no association with work pace and elbow symptoms, and no association between length of employment and elbow symptoms.

Punnett et al. [1985] compared neck/shoulder MSDs based on symptom reporting alone in 162 women garment workers and 76 women hospital workers such as nurses, laboratory technicians, and laundry workers. There was a low participation rate among the hospital workers. Eighty-six percent of the garment workers were sewing machine operators and finishers (sewing and trimming by hand). The sewing machine operators were described as using highly repetitive, low force wrist and finger motions, while the finishers had shoulder and elbow motions as well. The exposed garment workers likely had more repetitive jobs than most of the hospital workers.

Strength of Association—Repetition and Elbow MSDs

No studies met the four criteria to discuss strength of association.

Strength of Association—Studies Not Meeting the Four Criteria

For the other studies not fulfilling all the criteria, the odds ratio (OR) reported in the

Baron et al. [1991] study for epicondylitis overall was 2.3, but this was not statistically significant.

Anderson and Gaardboe [1993a] used years employed as a sewing machine operator as a surrogate for exposure and found no significant association with epicondylitis.
None of the other studies that looked at epicondylitis among working groups carried out independent exposure assessment of workers or representative workers that focused on the elbow.

Burt et al. [1990] found a statistically significant OR of 2.8 for elbow/forearm symptoms in newspaper employees who reported typing 80%–100% of their working day compared to those typing 0%–20%. (Typing hours has been used as a surrogate of both repetition and duration of exposure.)

Likewise, Punnett et al. [1985] found a significant prevalence rate ratio (PRR=2.4) of persistent elbow symptoms among garment workers performing repetitive, forceful work compared to hospital workers. Analysis by job title showed that underpressers, whose jobs consisted of ironing by hand, had a PRR of 6.0. Among stitchers (sewing machine operators), the significant PRR for the task of setting linings was 7.7. When standardized to the age distribution of the hospital workers, the rate ratio did not change.

McCormack et al. [1990] and Ohlsson et al. [1989] based exposure on job title and found no association between repetitive work and epicondylitis, with non-significant ORs between 0.5 and 2.8.

Temporal Relationship—Repetition and Epicondylitis

There were no prospective studies which addressed repetition as a physical factor alone; all the studies were cross-sectional, so a temporal relationship cannot be established. However, some cross-sectional studies allow us to infer causality by use of restrictive case definitions. Studies by the National Institute for Occupational Safety and Health (NIOSH) investigators [Burt et al. 1990; Baron et al. 1991] excluded from analysis those workers who reported symptoms experienced prior to their present job and those with acute injury to the elbow not related to the job.

Consistency in Association for Repetition and Epicondylitis

The studies were not consistent in showing an association between repetitive work and epicondylitis. In terms of strength of association, there were no studies that had statistically significant ORs greater than 3.0, four studies had ORs between 1.0 and 3.0, that were statistically significant; and two studies had nonsignificant ORs less than 1.0.

Coherence of Evidence for Repetition

The evidence for epicondylitis in the biomechanical and sports literature does not address repetition alone, but has consistent evidence with a combination of forceful exertion, awkward or extreme postures, and repetitive movements. Please refer to the discussion under Coherence of Evidence for Force.

Exposure-Response Relationship for Repetition

In Baron et al.'s [1991] study, there was a dose-response relationship for the elbow for the number of hours per week working as a checker, with ORs up to around 3.0, but not for the duration of employment (the average length of employment was 8 years).

Conclusions Regarding Repetition

There is insufficient evidence for support of an association between repetitive work and elbow MSDs based on currently available epidemiologic data. There were no studies that met the four criteria. Of the 7 studies examining repetitive work, no studies found ORs above 3.0, 5 studies found ORs from 1–3, and 2 studies found an OR less than one.

FORCE

Definition of Force for Elbow MSDs

For our review, we included studies that examined force or forceful work or heavy loads to the elbow, or described exposure as strenuous work involving the forearm extensors or flexors, which could generate loads to the elbow/forearm region. Most of the studies that examined force or forceful work as a risk factor for epicondylitis had several concurrent or interacting physical workload factors.

Studies Reporting on the Association of Force and Epicondylitis

Thirteen studies reported results on the association between force and adverse elbow health outcomes, including epicondylitis. The epidemiologic studies that addressed forceful work and epicondylitis compared working groups by classifying them into broad categories based on an estimated amount of resistance or force of exertion and a combination of estimated rate of repetition (e.g., Viikari-Juntura et al. [1991b]; Kurppa et al. [1991]; Chiang et al. [1993]) or in terms of overall elbow stress [Dimberg 1987; Ritz 1995].

Studies Meeting the Four Evaluation Criteria

Of the studies examining epicondylitis and forceful exertion, three studies [Chiang et al. 1993; Luopajärvi et al. 1979; Moore and Garg 1994] fulfilled all four criteria. Most of these studies used combinations of risk factors in their analysis, of which forceful exertion was one.

Chiang et al. [1993] assessed exposure though observational methods, recording of tasks and biomechanical movements of representative workers. With these methods, they categorized fish processing workers into three exposure groups according to the ergonomic risks to the shoulders and upper limbs: (1) those with low force and low repetition (the comparison group), (2) those with high force or high repetition, and (3) those with both high force and high repetition. The diagnosis of epicondylitis included standard physical examination techniques of palpation and resisted extension and flexion of the elbow. Examination-defined cases were about one-half the number of cases defined by symptom alone. The analysis was stratified by gender, and those with metabolic diseases associated with MSDs were excluded. There was no significant difference in age between the comparison groups. Multivariate analysis was not carried out for the elbow in this study.

Luopajärvi et al. [1979] determined MSDs differences between female assembly line workers and shop assistants in a department store (cashiers were excluded from the comparison group). Exposure assessment involved on-site observation, video analysis and interviews. The assembly work was found to be repetitive, with up to 25,000 cycles per workday involving hand and finger motions. Specific cycles were not recorded for elbow motions; however, motions involving the hands and fingers involve tendons and muscles from the flexors and extensors that have their origin at the elbow. Static muscle loading of the forearm muscles, deviations of the wrist, and lifting were also found. The diagnosis of epicondylitis included standard physical examination techniques of palpation and resisted extension and flexion of the elbow. Subjects with previous trauma, arthritis, and other pathologies associated with MSDs were excluded. All participants were female. Covariates considered in the analysis included age, social background, hobbies, and the amount of housework performed. Duration of employment was not an issue because the factory had only been open a short time.

Moore and Garg [1994] carried out a medical records review using an epicondylitis case definition based on symptoms and physical examination and a semi-quantitative ergonomic assessment of 32 jobs at a meatpacking plant. The authors used their “Strain Index” to categorize jobs as “hazardous” or “safe” based on a number of factors: observation, video analysis, and judgements based on force, repetition, posture, and grasp. Force was estimated as percent of maximal strength by comparing the reported weight of the pertinent object with estimated average maximal strength of the worker for different types of pinches and grasps, then categorized into five levels.

These values were derived from population-based data stratified according to age, gender, and hand dominance. Repetition was recorded as cycle-time and exertions per minute. The exposure assessment in this study gave more weight to the factor of “force” than to repetition or posture (the force variable could increase to a higher categorization level if the job was repetitive, involved jerky motions, or extreme postures). Work histories, demographics, and pre-existing morbidity data were not collected on each participant. The diagnosis of epicondylitis extracted from the medical records included standard physical examination techniques of palpation and resisted extension and flexion of the elbow. Analyses were based on “full-time equivalents” for jobs, not individual workers. This analysis did not control for potential confounders; there was a slight preponderance of morbidity of all MSDs among females.

Studies Meeting at Least One Criteria

The Andersen and Gaardboe study [1993a], which did not carry out ergonomic assessment pertaining to the elbow, found a non-significant association between repetitive, forceful work and symptoms or physical findings consistent with epicondylitis. In the Andersen and Gaardboe study [1993a], the exposed group consisted of sewing machine operators.

Baron et al.’s [1991] measure of force was based on estimated assessment of exertion by experienced ergonomists through observation of tasks and video analysis, as well as weight of scanned items. Average forces for the grocery checkers were categorized as "low" and peak forces "medium" on a three-tiered scale ("low, medium, and high").

Byström et al.'s [1995] study of automobile assembly workers is reviewed in the Repetition section.

Dimberg's studies [1987] fulfilled three of the criteria but did not mention if examiners were blinded to exposure status. In the 1987 study, exposure was assessed by observational methods, jobs were categorized according to the amount of elbow stress in a particular job, but no individual measurements were made. Numerical results from the logistic regression model were not given in the paper, although employee category (blue collar versus white collar), gender, and degree of elbow stress were said not to be significant predictors of having any one of the three types of epicondylitis. The author classified epicondylitis into three types: leisure-related, no known cause, and work-related groups based on history. When the author specifically looked at "work-related" epicondylitis (criteria for such designation was not given) with respect to elbow stress, he found a significant trend with increasing levels of elbow stress.

The exposure assessment approach was different for the 1989 study by Dimberg et al. In the 1987 study by Dimberg, the exposure classification scheme was focused principally on the elbow and identified jobs with heavy elbow-straining work. In the 1989 study, the author focused on multiple health outcomes in the upper extremity and used an exposure classification scheme that was more broadly focused on the stress to the hand/wrist, elbow, and shoulder areas.

One study by Kurppa et al. [1991] was prospective. Here, workers in meat processing were categorized into strenuous and nonstrenuous jobs based on repetitive and forceful work. The strenuous tasks for the meatcutters consisted of cutting approximately 1,200 kg of veal or 3,000 kg of pork per day; the nonstrenuous tasks consisted primarily of office work. Workers had to have a physician visit and diagnosis in order to be considered a case—a restrictive definition requiring significant enough symptoms to seek out medical care.

Twenty-five percent of cases were diagnosed by physicians outside the plant, so examination techniques may not have been the same as those for the other 75%. The nonstrenuous group was similar to the strenuous group with regards to age, gender, and duration of employment, except for the small number of male sausage makers and male meatpackers—these were excluded from calculation of individual IRs.

Punnett et al.'s [1985] study of garment workers is reviewed in the Repetition section.

Ritz [1995] did not mention the participation rate in their study of welders and pipefitters but fulfilled the other three criteria. Workers studied were likely to be a representative sample, however, since all male employees who were taking their annual examinations during a three month period were enrolled in the study. The multiple logistic model analysis considered age and a variety of confounding factors. Among these public gas and water work employees, the welders and pipefitters who installed and repaired pipes were considered to have high exposure.

Roto and Kivi [1984] based their exposure on job title alone, but fulfilled the other three criteria. They compared meatcutters who had forceful, repetitive work to construction workers who had more varied tasks. The authors stratified the analysis by age and found the majority of cases in the older age groups. They also found that the meatcutters with epicondylitis had been exposed, on the average, five years longer than the other meatcutters. All the meatcutters had more than 15 years in their current occupation, which the authors attributed to support of the work-relatedness of the condition, although increasing age may have been a confounder or effect modifier.

Viikari-Juntura et al. [1991b] studied subjects at the same meat processing plant as Kurppa et al. [1991] using 3 cross-sectional examinations covering a period of 31 months. The same exposure assessment scheme used in the Kurppa et al. [1991] study mentioned above was used comparing workers in strenuous and nonstrenuous work. This study compared the prevalence of all cases of epicondylitis; cases due to injury or known non-occupational causes were not excluded. The diagnosis of epicondylitis included standard physical examination techniques of palpation and resisted extension and flexion of the elbow; the authors stated that palpation pressure increased on the second of the three cross-sectional examinations and may have influenced results. The investigators stated the comparison group was selected similar to the study group in gender, age, and duration of employment.

In conclusion, for the studies with less than our four criteria, four are supportive [Kurppa et al. 1991; Ritz 1995; Dimberg 1987; and Roto and Kivi 1984], two are non-supportive [Dimberg et al. 1989; Byström et al. 1995], and one is not very informative [Andersen and Gaardboe 1993a]. The results from the positive studies are unlikely to be due to confounding or selection bias. Overall, these studies provide limited support for the association of forceful repetitive work and epicondylitis.

Strength of Association—Force and Epicondylitis

Chiang et al. [1993] did not find an association between hand-intensive work (categorized based on forceful exertion and repetition) and epicondylitis when analyzing all workers at six fish processing plants. However, in examining the highest level of exposure (we calculated the odd ratios for men and women separately, which was not done in the article), we found a significant difference between males in the highest exposed group (Group III) and males in the lowest exposed group (Group I) (OR= 6.75) and a non-significant OR of 1.44 for women. Exposure in Group III was based on a combination of high-force exertion and high repetition; analysis of working techniques by gender was not performed, so the reason for the difference in the groups by gender is not known. The Chiang et al. [1993] study provides limited support for the association between high levels of forceful repetitive elbow work and epicondylitis.

Luopajärvi et al. [1979] found a non-significant difference overall in the prevalence of epicondylitis and pronator teres syndrome (3 versus 11 cases, OR 3.35 [95% confidence interval (CI) 0.86–19.1]); for lateral epicondylitis only, an OR of 2.73 (95% CI 0.66–15.94). There were five cases of medial epicondylitis in the assembly workers and none in the shop assistants. The increase in medial epicondylitis (an indeterminate OR because of "zero" cases in the shop assistants) was attributed to the difficult grasping movements involved in the assembly line work. They found that their female assembly workers tended to have physically light work, but this work required highly repetitive movements of the wrists and fingers and static muscle loading of the forearm muscles.

Using the Strain Index, Moore and Garg [1994] found a significant relationship between hazardous jobs (of which force was a major component) and upper extremity MSDs (of which epicondylitis was an important component). The results found a significant OR of 5.5 for a case of epicondylitis to occur in a hazardous job. When approximating the classification scheme for low and high force used by Silverstein et al. [1987] and then by Kurppa et al. [1991], Viikari-Juntura et al. [1991b], and Chiang et al. [1993], the association between forcefulness and the overall upper extremity morbidity in the study was again statistically significant ($p<0.02$).

The overall conclusion from the three studies that met our four criteria is that there is evidence for association between force and epicondylitis based on strength of association.

Strength of Association—Studies Not Meeting the Four Criteria: Force and Elbow MSDs

Baron et al. [1991] found an OR of 2.3 for the combination of factors, but this was not statistically significant. The authors mention that ergonomic analysis of the non-checkers showed that they also performed work requiring repetitive motions and awkward postures; therefore, the comparison probably resulted in a lower OR than had the referent group been truly unexposed to the ergonomic stressors.

Kurppa et al. [1991] found a strong significant relationship between strenuous jobs and epicondylitis (IR= 6.7), while Viikari-Juntura et al. [1991b] did not (OR=0.88, nonsignificant). These results may have been influenced by allowing "cases" who had recurrence in the same elbow to be counted as new cases (12 out of 57 employees with epicondylitis had more than one episode, and were counted twice). There was a median of 184 days between the episodes. In examining this study, it is important to see if the odds of having epicondylitis would be elevated if these workers with recurrences were only counted once. We recalculated the OR using only "persons" and not "single episodes of epicondylitis" in order to obtain a more conservative estimate. We counted, only once, the employees with recurrence, as well as the four employees mentioned with simultaneous occurrence in both elbows and subtracted these from the strenuous job cases. This gave a total of 44 cases of epicondylitis among the strenuous group.

Using this estimate, more restrictive than that found in the article, gives an OR of 5.5 (2.4, 12.7) for epicondylitis among the workers with strenuous jobs versus those with nonstrenuous jobs. The Kurppa et al. [1991] prospective study also found the IR of epicondylitis in nonstrenuous jobs to be similar to Allender's [1974] population background prevalence rate (1%) for epicondylitis.

Ritz [1995] found a significant OR for 10 years of high exposure to elbow straining work: 1.7 for currently held jobs and 2.2 for formerly held jobs. The significant OR for moderate exposure in the current job was 1.4 for 10 years of exposure. This study provides support for the association of forceful work with epicondylitis.

We calculated odd ratios from data in Dimberg's [1987] study and found an OR for moderate stress versus none or light elbow stress of 2.9, and for heavy versus none or light stress of 7.4. Heavy stress in the elbows was assigned to job titles like blaster, driller, or grinder. The major limitation of this analysis of the work-related cases is that it did not consider age, a likely confounder. Overall, this study provides support for the association between forceful work and epicondylitis, particularly in older workers.

The 1989 Dimberg et al. study was not supportive of an association between lateral epicondylitis and forceful repetitive work, but was positive for "mental stress at work" at the onset of symptoms for lateral epicondylitis ($p<0.001$). As a result of the specific elbow exposure assessment, we believe that with regards to stressful or

forceful elbow exertions that the 1987 study is more informative.

The study conducted by Roto and Kivi [1984] found an OR of 6.4 (95% CI 0.99–40.9) using an exposure assessment based on job title alone (meatcutters were assumed to have more forceful jobs than construction workers). Only one referent had epicondylitis.

In the paper by Viikari-Juntura et al. [1991b], the cases of epicondylitis not listed as insidious all involved forceful, repetitive tasks (although some of these tasks were not related to work). Prevalences of "epicondylar pain" and "sick leave due to epicondylar pain" were significantly different between the two groups (OR 1.9 and 2.1). There was no significant difference in the prevalence of epicondylitis (combined work and non-work related) between workers in strenuous versus nonstrenuous jobs (OR=0.88). In 95 women sausage makers, there were four cases with insidious onset, while among 160 women referents there were two cases, one with insidious onset, the other related to an "exceptional task of cutting cheese." The resulting OR was 6.9 (95% CI 0.74–171). This study also found that rates of "epicondylar pain" and "sick leave due to epicondylar pain" differed significantly between the two groups (OR 1.9 and 2.1, respectively). Rates of medically diagnosed cases of epicondylitis were not statistically different between the two groups, but the results for epicondylar pain (causing sick leave in the two groups), and the fact that the majority of cases in both groups were due to events involving strenuous, repetitive tasks, give some support to forceful, repetitive work as
a cause.

Byström et al. [1995] noted that the low frequency could not be attributed to selected subjects being absent, as all persons on leave participated in the investigation. The authors also stated that "exposure to repetitiveness and force in automobile assembly line work may be less than in other investigated work situations." Because the authors did not give quantitative or qualitative information on the forcefulness or repetitiveness of jobs included in the study group, it is difficult to know whether these jobs were appropriate to use to study epicondylitis.

Temporal Relationship: Force and Epicondylitis

See temporal relationship above in Repetition and Epicondylitis.

Consistency of Association

The studies that met the four criteria were fairly consistent in their strength of association between force and epicondylitis, with most ORs between 2.5 and 7.0. Focusing on those studies that compared workers exposed to force that was documented to be at a high level, to those exposed to a low level, all studies [Chiang et al. 1993; Kurppa et al. 1991; Moore and Garg 1994] were consistent.

Of those 10 studies that examined force but did not fulfill the four criteria, two studies had a significant OR greater than 3.0, three studies had significant ORs between 1.0 and 3.0, one had a nonsignificant OR between 1.0 and 3.0, and two had an OR less than 1.0. Two had statistically significant findings but did not report ORs. Most of these studies examined workers in repetitive, forceful job tasks and did not separate out the independent effect of repetition through any analytic method.

Viikari-Juntura et al.'s [1991b] study did not exclude workers with elbow symptoms or physical findings that were due to acute injury not related to the job, which may account for the contrasting result. In fact, in that study, four workers with acute non-work-related epicondylitis in the nonstrenuous group were noted in the journal article. Another consideration for inconsistency is due to grouping of studies, which may all fulfill good epidemiologic criteria, may all examine the same risk factor, but may compare groups that do not have similar contrasting levels of exposure. For example, the Chiang et al. [1993] study found statistically significant results in men when comparing high force/high repetition jobs to low force/low repetition jobs. Baron et al. [1991], on the other hand, compared checkers in low force, medium repetition jobs to noncheckers in low force, low repetition jobs.

Two factors explain the difficulty in determining the reasons for the apparent inconsistencies among the studies on forceful and repetitive work. First, very few of the exposure assessments were quantitative—this is due to existing limitations in directly measuring exposure in detail in most field studies. As a result, there is likely to be frequent non-differential misclassification of exposure. Second, most of the studies completed have been cross-sectional, and therefore subject to survivor bias.

As an example, Chiang et al. [1993] found that epicondylitis was significantly associated with increasing repetitiveness and forcefulness among fish processors employed less than 12 months. For those working for 12 to 60 months, a similar trend was found, but a reverse trend was found in those workers employed for over 60 months. The authors stated that because most of the workers were semi-skilled, they were likely to leave their job if they felt frequent muscle pain because of it. They went further to say that the selection mechanism may explain the lack of significant associations between the disorders and the duration of employment. There was no indication that the authors pursued this hypothesis by trying to identify former workers who may have left. Turnover rate was not discussed. This example highlights two important factors concerning the cross-sectional studies examining work-related epicondylitis: there is some evidence that older workers may be at higher risk of epicondylitis [Dimberg 1987; Ritz 1995], and there is also a "survivor" effect, which results in the loss to the study of affected workers. These two factors make the interpretation of duration of disease relationships complex and may affect the estimate of the risk of disease.

There were studies that used more accurate exposure assessment or had comparison groups with marked differences in levels of exposure to forceful and repetitive work that were positive, such as the Kurppa et al. [1991] study of meatcutters, sausage makers, and packers, Moore and Garg's [1994] study of pork processors; Dimberg's [1987] study of blasters, drillers, grinders, and others in an engineering industry; Ritz's [1995] study of pipefitters and welders in a public utility; and Roto and Kivi's [1984] study of meatcutters. There were studies with these characteristics that were negative, such as the Viikari-Juntura et al. [1991b] study of meatcutters, sausage makers, and packers; and the study by Dimberg et al. [1989] of blue- and white-collar workers in the automobile industry. In both of these studies, those cases of epicondylitis listed in the comparison groups were due to highly repetitive, forceful activities. The lack of a significant difference in the prevalence of the disorder between the two groups may be because the referent, "low" exposure groups had a higher incidence of non-work-related lateral epicondylitis.

Coherence of Evidence

The epidemiologic results of finding the majority of cases occurring in highly repetitive, forceful work [Moore and Garg 1994; Chiang et al. 1993; Kurppa et al. 1991; Kopf et al.1988] are consistent with the evidence from biomechanical and physiologic findings, as well as from sports medicine literature and older medical clinical case series. In cases of lateral epicondylitis occurring in workplaces as well as in sports, the forearm extensors are repetitively contracted and produce a force that is transmitted via the muscles to their origin on the lateral epicondyle. These repetitive contractions produce chronic overload of the bone-tendon junction, which in turn leads to changes at this junction. The most common hypothesis is that microruptures occur at the attachment of the muscle to bone (usually at the origin of the extensor carpi radialis brevis muscle), which causes inflammation. Peƒina et al. [1991] did not agree with the microrupture theory; they theorized that overuse leads to avascularization of the affected muscle origin, which leads to overstimulation of the free nerve endings and results in aseptic inflammation. Further repetition of the offending movements causes angiofibroblastic hyperplasia of the origin. Nirschl [1975] stated that the degree of angiofibroblastic hyperplasia is correlated to the duration and severity of symptoms. On histologic analysis of severe cases of epicondylitis, one can see the characteristic invasion of fibroblasts and vascular tissue, the typical picture of angiofibroblastic hyperplasia.

Prior to many of the epidemiologic studies, there were numerous reports in the medical literature of clinical case series that suggest a relationship between epicondylitis and repetitive, forceful work. For example, as early as 1936 Cyriax reported that with regard to patients with lateral epicondylitis, "those patients who remember no special overexertion will be found to be working at screwing, lifting, hammering, ironing, etc., or to be violinists, surgeons, masseurs, etc." Cyriax had designated a "Chronic Occupational" variety of tennis elbow, in which he stated that "often no history of an injury is obtainable, but the patient's occupation at once provides the clue." He cited "work which entails repeated pronation and supination movements with elbow almost fully extended" to be responsible for epicondylitis [Cyriax 1936]. Feldman et al. [1987] reported that occupations with work tasks requiring repeated pronation and internal/external rotation of the forearm are at high risk of pronator teres syndrome (compression of the median nerve as it courses through the pronator teres muscle in the forearm). A number of case series have reported similar findings [Hartz et al. 1981; Morris and Peters 1976].

Sinclair [1965] reported 2 case series of patients with tennis elbow (lateral epicondylitis), 44 patients treated between 1959-1961 and 38 patients treated between 1961-1963. In the first group of 267, the 130 (48%) whose onset occurred spontaneously had occupations that included gripping tools with consequent forearm extensor muscle contraction and repetitive supination/ pronation of the forearm. In the second group of 26, the 23 (88%) who had spontaneous onset worked in jobs with constant gripping or repetitive movements.

Many case studies of professional athletes have documented that forceful, repeated dorsiflexion, pronation, and supination movements with the elbow extended can cause epicondylitis. [Ollivierre et al. 1995; Priest et al. 1977; King et al. 1969]. Most cases have occurred in baseball pitchers and tennis players. Occupations involving movements described above have also been found to have increases in rates of elbow MSDs. This literature has also referred to increased occurrence in occupations requiring force, awkward postures, and repetitive use of the elbow and forearm [Lapidus and Guidotti 1970; Mintz and Fraga 1973; Berkeley 1985]. These reports, though mainly case series, have lead to further studies that examined the links between exposure and epicondylitis.

An example of an early occupational study is one by Mintz and Fraga [1973], who found that foundry workers (with an average of 14 years of employment) who used tongs requiring twisting and bending of the elbows/forearms for eight hours per day had decreased elbow flexion and extension and pain on physical examination, as well as severe radiographically documented osteoarthritis localized to the elbows. In the studies that are reviewed in Tables 4-1 through 4-4, the occupations with the highest rates of epicondylitis, such as drillers, packers, meatcutters, and pipefitters, are consistent with the force-repetition model of the causation of epicondylitis. The development of epicondylitis in these workers is consistent with proposed biological mechanisms and is plausible.

The lack of elbow MSDs and work factors in some of the studies with occupations like sewing workers [McCormack et al. 1990] or automobile assembly line workers [Byström et al. 1995], most likely reflects the interplay of two factors. The movement of affected workers out of high exposure jobs limits the ability of cross-sectional studies to accurately determine associations between work factors and epicondylitis. Our ability to accurately identify working conditions with an elevated risk for epicondylitis may require an exposure assessment of each job to a degree that has been beyond the limits of current epidemiological methods. As a result, misclassification of exposure may be common. Overall, the majority of the epidemiologic studies are supportive of the hypothesis of an increase risk of epicondylitis for occupations that involve forceful and repetitive work, frequent extension, flexion, supination, and pronation of the hand and the forearm. The surveillance data are also supportive of this hypothesis [Roto and Kivi 1984; Washington State Department of Labor and Industry 1996]. The highest relative risks for epicondylitis in Finland were with mechanics, butchers, food industry workers, and packers; the highest industries in Washington State for 1987-1995 [Silverstein et al. *In Press*] were construction workers, meat dealers, and foundry workers—all occupations with repetitive, forceful work involving the arms and hands and requiring pronation and supination.

Evidence of a Dose-Response

Relationship for Force

The Baron et al. [1991] study is mentioned above in the Repetition Section as showing a dose-response relationship for number of hours of work per week. Chiang et al. [1993] found that among men the prevalence of epicondylitis increased with increasing force and repetition in fish processors. In several studies, only dichotomous divisions were made, so conclusions concerning an exposure-response relationship cannot be drawn. However, we can see significantly contrasting rates of elbow MSDs between high- and low-exposure groups. Moore and Garg [1994] found a higher risk in workers with high-strain jobs compared to those with low-strain jobs. Kurppa et al. [1991] found higher risk in workers with strenuous jobs compared to those with nonstrenuous jobs, and that female sausage makers had an increase in epicondylar tenderness with increasing duration of employment. While Dimberg [1987] found no difference in epicondylitis between blue- and white-collar workers, he found that workers with elbow pain severe enough to require a physician consult were significantly more often in those jobs identified independently as having high elbow stress. Dimberg also found a statistically significant correlation coefficient for lateral epicondylitis and time spent in the present job. Luopajärvi et al. [1979] found a higher rate of epicondylitis and pronator teres syndromes in a high-exposure group of assembly line packers compared to the referent group of shop assistants. Overall, these studies provide considerable evidence for a difference in level of risk for epicondylitis when there are marked differences in the level of exposure to forceful and repetitive tasks.

Ritz [1995] reported a positive dose-response relationship between duration of exposure to gas and waterworks jobs regarded as moderately and highly stressful to the elbow and epicondylitis. Roto and Kivi [1984] reported that all workers with epicondylitis in their meat-packing facility worked for more than 15 years in the strenuous job category and had been exposed an average of 5 years longer than non-diseased workers. Kopf et al. [1988] reported that in their study of brick layers, with increasing levels of job demands (defined as either heavy physical work, awkward working postures, repetitive movements, or restriction in standing position), the OR increased from 1.8 to 3.4. These studies, with less clear contrasts in exposure, provide support for the exposure-response relationship between epicondylitis and forceful, repetitive work.

POSTURE

Definition of Postures for Elbow MSDs

We chose to include those studies that addressed posture or examined workers in those activities or occupations that require repeated pronation and supination, flexion/ extension of the wrist, either singly or in combination with extension and flexion of the elbow.

Studies Reporting on the Association of Posture and Epicondylitis

The six studies in Table 4-3 addressed posture variables. Of these, only the studies by Moore and Garg [1994] and Luopajärvi et al. [1979] fulfilled all four criteria. The details of these studies are discussed in the Repetition and Force sections.

Strength of Association—Posture and Epicondylitis

Studies Meeting the Four Evaluation Criteria

The Moore and Garg [1994] study (also discussed above) recorded wrist posture using a classification similar to Armstrong et al. [1982] and Stetson et al. [1991]. Pinch grasp was also noted to be present or absent. In this study, posture was not found to be significantly associated with "hazardous" jobs. This may be due to the heavier weighting given the force rating system than the posture or repetition scale. For example, if a job required extreme posture, the authors increased the force rating instead of the posture rating. If a combination of extreme posture and high-speed movement was required, then the force rating was raised by two levels, but not the posture rating. Data that would allow analysis of the incidence of epicondylitis and the exposure to extreme posture were not presented.

Luopajärvi et al.'s [1979] assessment was focused on the extreme work position of the hands but not the elbow; it included extension, flexion and deviation of the wrists. Although there was a non-significant association between assembly line work and the presence of either epicondylitis or pronator teres syndrome in shop assistants (11 cases versus 3), there were 5 cases of medial epicondylitis and 2 cases of pronator teres syndrome in the assembly workers and none in the shop assistants. The greater prevalence of medial epicondylitis in assembly workers was attributed to the difficult grasping movements involved in the assembly line work. The authors stated that the overall prevalence may have been "connected with the constant overstrain of flexors in work."

Studies Not Meeting the Four Evaluation Criteria

The Dimberg [1987] study stated that over-exertion of the extensor muscles of the wrist due to gripping and twisting movements prior to the onset of symptoms was verified in 28 of the 40 (70%) of the cases, of which 14 were considered to be caused by work. In the study by Dimberg et al. [1989], the guidelines for classification include repeated rotation of the forearms and wrists in Group 1, large and frequent rotations in extreme positions in Group 2, but fail to include work involving frequent rotations in the highest exposed group, Group 3. The difference in exposure classification scheme may explain why there was no relationship between prevalence of epicondylitis and increasing work strain.

Hughes and Silverstein [1997] found a strong, statistically significant association (OR 37) between elbow/forearm disorders and "the number of years of forearm twisting" in their study of aluminum workers. However, this study had an overall low participation rate (55%), which limits the interpretation of its result.

The other study that may be interpreted as related to a posture variable is the one by Hoekstra et al. [1994]. This study evaluated video display terminal users at two work sites differing only in whether adjustable office equipment was present. By self-reported symptoms and exposure

observations, the Hoekstra et al. [1994] study found that having a "non-optimally adjusted" chair was associated with elbow MSDs. This improper chair adjustment was thought to increase shoulder and elbow flexion, as well as wrist deviation, thus producing more symptoms. These conclusions should be considered to be hypothesis generating and not definitive.

Temporal Relationship

There are no prospective studies that address posture and epicondylitis. The one prospective study concerning epicondylitis did not address posture.

Consistency in Association

There are too few occupational epidemiologic studies that address posture and epicondylitis to meaningfully discuss consistency of association.

Coherence of Evidence

Please refer to the "Repetition Section and Coherence of Evidence" for a discussion of the sports literature, and the combination of factors, including extreme postures that have been documented concerning epicondylitis.

Exposure-Response Relationship

There is little evidence on which to base a discussion exposure response relationship in the epidemiologic studies. Once again, the reader is referred to the biomechanical sports literature.

EPICONDYLITIS AND THE ROLE OF CONFOUNDERS

The model for epicondylitis clearly implies that both occupational and non-occupational activities can cause the disorder. Several studies [Ritz 1995; Andersen and Gaardboe 1993a; Dimberg 1987] directly address the issue of work-related versus non-work-related exposures by assessing both. Two of the most important potential confounders or effect modifiers are age and duration of employment. In Dimberg's [1987] and Ritz's [1995] studies, older workers had high rates of epicondylitis. Nevertheless, in both studies the increase in the risk for epicondylitis in the high-exposure group does not seem related primarily to age, independent of intensity and duration of exposure. Furthermore, the incidence of elbow MSDs unlike most MSDs, has been found to decrease after retirement age, after peaking during the fourth and fifth decades.

Many of the studies controlled for several possible confounders in their analyses. In general, for epicondylitis, psychosocial factors or gender do not appear to be important confounders in occupational studies.

CONCLUSIONS

The epidemiologic studies reviewed in this section focused principally on the risk of epicondylitis in workers performing repetitive job tasks requiring forceful movements. These forceful movements included, but were not limited to, repeated dorsiflexion, flexion, pronation, and supination, sometimes with the arm extended. Clinical case series of occupationally-related epicondylitis and studies of epicondylitis among athletes had suggested that repeated forceful dorsiflexion, flexion, pronation, and supination, especially with the arm extended, increased the risk of epicondylitis. In general, the epidemiologic studies have not quantitatively measured the fraction of forceful hand motions most likely to contribute to epicondylitis; rather, they have used as a surrogate qualitative estimation the presence or absence of these types of hand movements [Viikari-Juntura et al. 1991b]. Although we recognize this limitation of the epidemiologic studies, there is value in assessing where we are in regards to the epidemiologic evidence of causal inference.

There is epidemiologic evidence for the relationship between forceful work and epicondylitis. Those studies that base their exposure assessment on quantitative or semiquantitative data have shown a solid relationship. We conclude that there is insufficient evidence for the association of repetitive work and epicondylitis. For extreme posture in the workplace, the epidemiologic evidence thus far is also insufficient, and we turn to the sports medicine literature to assist us in evaluating the risk of the single factors of repetition and posture. The strongest evidence by far when examining the relationship between work factors and epicondylitis is the combination of factors, especially at higher levels of exposure. This is consistent with the evidence that is found in the biomechanical and sports literature.

Most of the relevant occupational studies were cross-sectional; the current estimates of the level of exposure were used to estimate past and current exposure. Despite the cross-sectional nature of the studies, it is likely, in our opinion, that the exposures predated the onset of disorders in most cases.

When we examine all of the studies, a majority of studies are positive. The association between forceful and repetitive work involving dorsiflexion, flexion, supination, and pronation of the hand is definitely biologically plausible. These motions can cause the contraction of the muscle-tendon units that attach in the area of the medial and lateral epicondyles of the elbow.

The evidence for a qualitative exposure-response relationship overall was considerable for the combination of exposures, with studies examining differences in levels of exposure for the elbow, and corresponding evidence for greater risk in the highly exposed group. In contrast, we found one study with clear differences in exposure and no evidence of an increase in risk [Viikari-Juntura et al. 1991b].

In summary, the combination of the biological plausibility, the studies with more quantitative evaluation of exposure factors finding strong associations, and the considerable evidence for the occurrence with combinations of factors at higher levels of exposure provide evidence for the association between repetitive, forceful work and epicondylitis. There are several important qualifications to this conclusion. Forceful and repetitive work is most likely a surrogate for repetitive, forceful hand motions that cause contractions of the muscles whose tendons insert in the area of the lateral and medial epicondyles of the elbow. While the studies do not identify the number or intensity of forceful contractions needed to increase the risk of epicondylitis, the levels are likely to be substantial. Future studies should focus on the types of forceful and repetitive hand motions such as forceful dorsiflexion, pronation, and supination that result in forceful contractions of the muscle tendon units that insert in the area of the lateral and medial epicondyles. Common non-occupational activities, such as sport activities, which cause epicondylitis should be considered. Older workers may be at some increased risk. Finally, even though the epidemiologic literature shows that many affected workers continue to work with definite symptoms and physical findings of epicondylitis, survivor bias should be addressed.

Table 4-1. Epidemiologic criteria used to examine studies of elbow MSDs associated with repetition

Study (first author and year)	Risk indicator (OR, PRR, IR or *p*-value)*,†	Participation rate ≥70%	Physical examination	Investigator blinded to case and/or exposure status	Basis for assessing elbow exposure to repetition
Met at least one criterion:					
Andersen 1993a	1.7	Yes	No	Yes	Job titles or self-reports
Baron 1991	2.3	No	Yes	Yes	Observation or measurements
Burt 1990	2.8[†]	Yes	No	Yes	Job titles or self-reports
Byström 1995	0.74	Yes	Yes	No	Job titles or self-reports
McCormack 1990	0.5–1.2	Yes	Yes	NR[‡]	Job titles or self-reports
Met none of the criteria:					
Ohlsson 1989	1.5–2.8	NR	No	NR	Job titles or self-reports
Punnett 1985	2.4[†]	No	No	NR	Job titles or self-reports

[*]Some risk indicators are based on a combination of risk factors—not on repetition alone (i.e., repetition plus force, posture, or vibration). Odds ratio (OR), prevalence rate ratio (PRR), or incidence ratio (IR).

[†]Indicates statistical significance.

[‡]Not reported.

Figure 4-1. **Risk Indicator for "Repetition" and Elbow Musculoskeletal Disorders**

(Odds Ratios and Confidence Intervals)

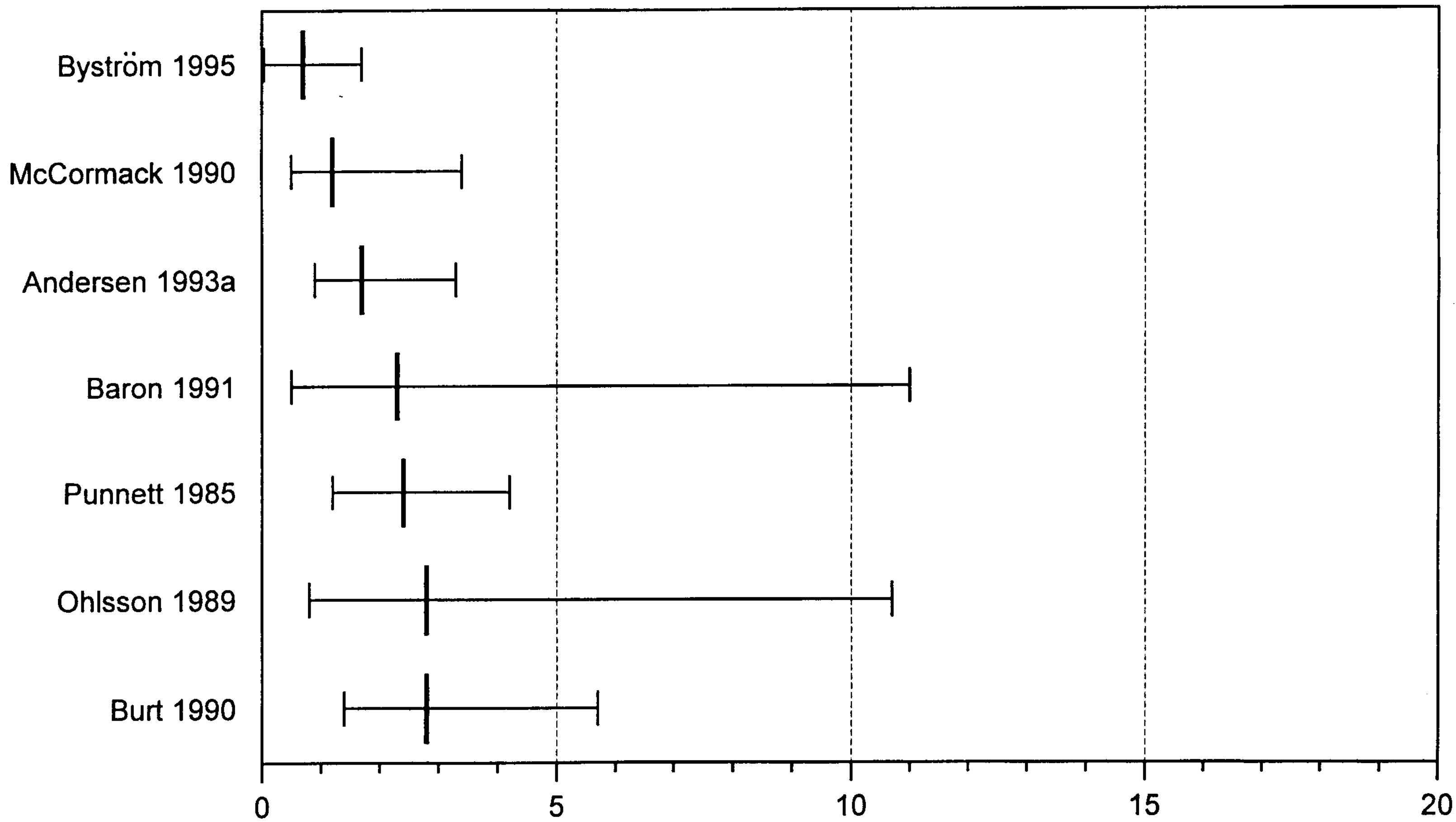


Table 4-2. Epidemiologic criteria used to examine studies of elbow MSDs associated with force

Study (first author and year)	Risk indicator (OR, PRR, IR or *p*-value)[*,†]	Participation rate $70%	Physical examination	Investigator blinded to case and/or exposure status	Basis for assessing elbow exposure to force
Met all four criteria:					
Chiang 1993	6.75[†] (males) 1.44 (females)	Yes	Yes	Yes	Observation or measurements
Luopajärvi 1979	2.7	Yes	Yes	Yes	Observation or measurements
Moore 1994	5.5[†]	Yes	Yes	Yes	Observation or measurements
Met at least one criterion:					
Andersen 1993a	1.7	Yes	No	Yes	Job titles or self-reports
Baron 1991	2.3	No	Yes	Yes	Observation or measurements
Byström 1995	0.74	Yes	Yes	No	Job titles or self-reports
Dimberg 1987	NR[†,‡]	Yes	Yes	NR	Observation or measurements
Dimberg 1989	NR	Yes	Yes	NR	Observation or measurements
Kurppa 1991	6.7[†]	Yes	Yes	NR	Observation or measurements
Punnett 1985	2.4[†]	Yes	No	NR	Job titles or self-reports
Ritz 1995	1.4–1.7[†]	NR	Yes	Yes	Observation or measurements
Roto 1984	6.4[†]	Yes	Yes	Yes	Job titles or self-reports
Viikari-Juntura 1991b	0.88	Yes	Yes	NR	Observation or measurements

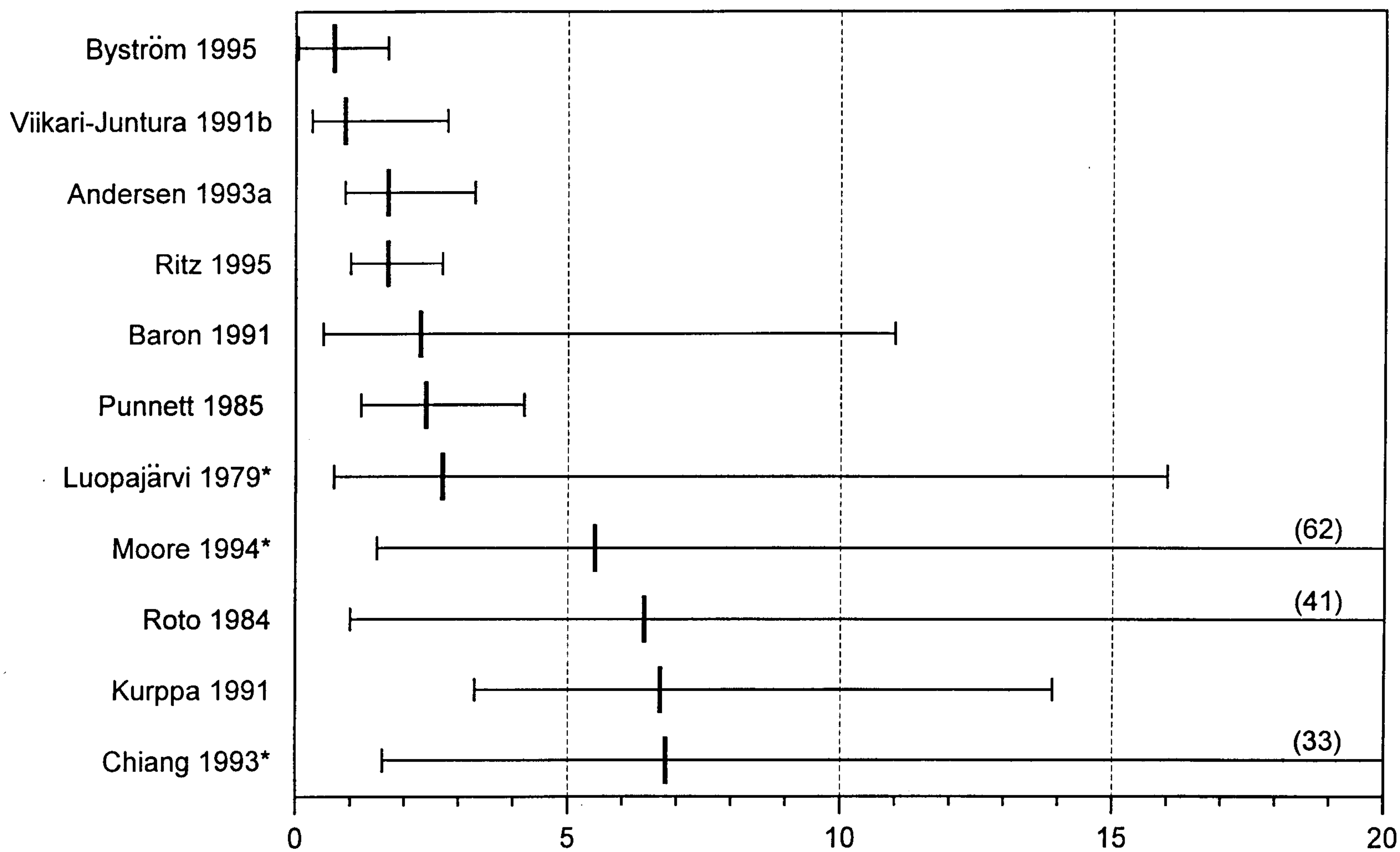
[*]Some risk indicators are based on a combination of risk factors—not on force alone (i.e., force plus repetition, posture, or vibration). Odds ratio (OR), prevalence rate ratio (PRR), or incidence ratio (IR).

[†]Indicates statistical significance. If combined with NR, a significant association was reported without a numerical value.

[‡]Not reported.

Figure 4-2. **Risk Indicator for "Force" and Elbow Musculoskeletal Disorders**

(Odds Ratios and Confidence Intervals)



* Studies which met all four criteria.

Note: Two studies indicated statistically significant associations without reporting odds ratios. See Table 4-2.

Table 4-3. Epidemiologic criteria used to examine studies of elbow MSDs associated with posture

Study (first author and year)	Risk indicator (OR, PRR, IR or *p*-value)*,†	Participation rate $70%	Physical examination or medical records	Investigator blinded to case and/or exposure status	Basis for assessing elbow exposure to posture
Met all four criteria:					
Luopajärvi 1979	2.7	Yes	Yes	Yes	Observation or measurements
Moore 1994	NR‡	Yes	Yes	Yes	Observation or measurements
Met at least one criterion:					
Dimberg 1987	NR†	Yes	Yes	NR	Observation or measurements
Dimberg 1989	NR	Yes	Yes	NR	Observation or measurements
Hoekstra 1994	4.0†	Yes	No	Yes	Job titles or self-reports
Hughes 1997	37.0†	No	Yes	NR	Observation or measurements

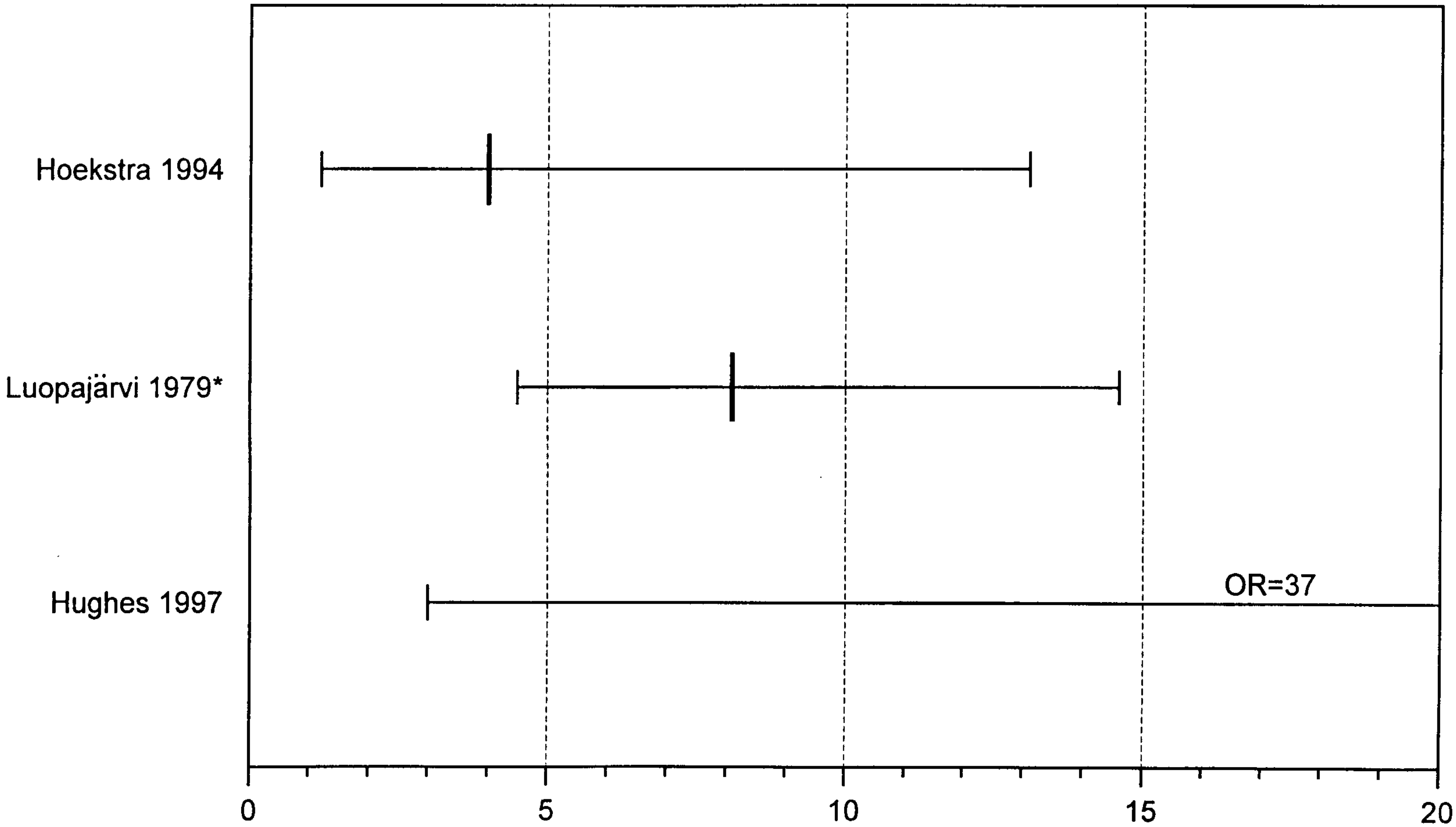
*Some risk indicators are based on a combination of risk indicators—not on posture alone (e.g., posture plus repetition, force, or vibration). Odds ratio (OR), prevalence rate ratio (PRR), or incidence ratio (IR).

†Indicates statistical significance. If combined with NR, a significant association was reported without a numerical value.

‡Not reported.

Figure 4-3. **Risk Indicator for "Posture" and Elbow Musculoskeletal Disorders**

(Odds Ratios and Confidence Intervals)



* Studies which met all four criteria.

Note: Some studies indicate a statistical significant association without a risk indicator. See Table 4-1.

Table 4-4. Epidemiologic criteria used to examine studies of elbow MSDs associated with vibration

Study (first author and year)	Risk indicator (OR, PRR, IR or *p*-value)*,†	Participation rate $70%	Physical examination or medical records	Investigator blinded to case and/or exposure status	Basis of assessing elbow exposure to vibration
Met at least one criterion:					
Bovenzi 1991	4.9†	NR‡	Yes	Yes	Observation or measurements

*Some risk indicators are based on a combination of risk indicators—not on vibration alone (e.g., vibration plus repetition, force, or posture). Odds ratio (OR), prevalence rate ratio (PRR), or incidence ratio (IR).

† Indicates statistical significance.

‡ Not reported.

Table 4–5. Epidemiologic studies evaluating elbow musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Andersen and Gaardboe 1993a	Cross-sectional	424 female sewing machine operators, compared to 781 females from the general population of the region and an internal referent group of 89 females from the garment industry.	Outcome: Questionnaire: continuous pain lasting > 1 month since starting career; pain for > 30 days. Exposure: Job categorization based on "authors' experiences" as occupational health physicians and involved crude assessment of exposure level and exposure repetitiveness. Jobs involving high repetitiveness (several times/min) and low or high force, and jobs with medium repetitiveness (many times/hr) combined with high force were classified as high exposed jobs; jobs with medium repetitiveness and low force and jobs with more variation and high force were classified as medium exposed. Job titles such as teachers, self-employed, trained nurses, and the academic professions were "low exposed." Exposure also measured as years as sewing machine operator.	4.5%	2.6%	1.7	0.9-3.3	Participation rate: 78.2%. Examiners blinded to control/subject status. Adjusted for age, number of children, exercising, smoking, socioeconomic status.

(Continued)

Table 4–5 (Continued). Epidemiologic studies evaluating elbow musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Baron et al. 1991	Cross-sectional; case-referent	Grocery checkers using laser scanners (n=124, 119 females, 5 males) compared to other grocery store workers (n=157, 56 females, 101 males); excluded 18 workers in meat, fish, and deli departments, workers under 18, and pregnant workers.	Outcome: Self-administered questionnaire and physical exam. Case defined as the presence of pain, numbness, tingling, aching, stiffness or burning in the elbow region as previous non-occupational injury; symptoms must have begun after employment at the supermarket of employment and in the current job, and last >1 week or occurred once a month within the past year. Physical Exam: Tenderness at the lateral/medial epicondyle and pain with palpation and resisted motion. Exposure: Based on job category, estimates of repetitiveness, average and peak forces based on observed and videotaped postures, weight of scanned items, and subjective assessment of exertion. The majority of cashiers were categorized as having “medium” levels of repetition for the hand (defined in this study as making 1250 to 2500 hand movements/hr).	8% among checkers	õ	2.3	0.5-11	Participation rate: 85% checkers; 55% non-checkers in field study. Following telephone survey 91% checkers and 85% non-checkers. Examiners blinded to worker’s job and health status. Age, hobbies, second jobs, systemic disease and height were considered as covariates in the multivariate analyses. Total repetitions/hr ranged from 1,432 to 1,782 for right hand and 882 to 1,260 for left hand. Average forces were low and peak forces medium. No statistical significance associated between duration of employment as a checker and elbow MSDs. Multiple awkward postures of all upper extremities recorded but not analyzed in models. Statistically significant increase in elbow MSD with increase in hr/week “checking.”

(Continued)

Table 4–5 (Continued). Epidemiologic studies evaluating elbow musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Bovenzi et al. 1991	Cross-sectional	Vibration-exposed forestry operators using chain-saws (n=65) and maintenance workers (n=31, control group).	Outcome: Epicondylitis syndrome: Pain at the epicondyle either during rest or motion, local tenderness at the lateral or medial epicondyle; pain during resisted flexion/extension of the fingers and wrist with the elbow flexed, palpated local tenderness at the lateral/medial epicondyle. Exposure: Direct observation of awkward postures, manual forces and repetitiveness evaluated via checklist. Vibration measured from two chain saws.	29.3	6.4%	For vibration exposed group >7.5 m/s^2: OR=4.9 (adjusted) OR=5.99 (unadjusted)	1.27-56	Participation rate: Not reported. Analysis controlled for age and ponderal index. Controls found to have several risk factors for MSDs at work-static arm and hand overload, overhead work, stressful postures, non-vibrating hand tool use. Controls actually had a greater proportion of the time in work cycles shorter than 30 sec than forestry workers.

(Continued)

Table 4–5 (Continued). Epidemiologic studies evaluating elbow musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	95% CI	Comments
Burt et al. 1990	Cross-sectional	Newspaper employees (n=836, females=55%). Workers fulfilling case definitions compared to those who did not fulfill case definition.	Outcome: Self administered questionnaire. Case defined as the presence of pain, numbness, tingling, aching, stiffness, or burning in the elbow region as previous non-occupational injury. Symptoms began after starting the job, last > 1 week or occurred once a month within the past year; reported as "moderate" (3) or greater on a 5-point scale. Exposure: Based on observation of job tasks, then categorized by job title. A separate job analysis using a checklist and observational techniques was carried out for validating questionnaire exposure data.	Male: 11% Female: 14%	õ	80% to 100% time typing compared to 0% to 19%: OR=2.8 Reporters compared to others: OR=2.5	1.4-5.7 1.5-4.0	Participation rate: 81%. Analysis controlled for age, gender, years on the job. Psychosocial factors dealing with job control and job satisfaction were addressed in questionnaire. Job analysis found significant correlation (0.56) between reported average typing time/day and observed 8 hr period of typing ($p < 0.0001$). Reporters were characterized by high, periodic demands (deadlines), although they had high control and high job satisfaction. Number of workers in some non- typing jobs not reported. Case definition based on symptoms alone.

(Continued)

Table 4–5 (Continued). Epidemiologic studies evaluating elbow musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Byström et al. 1995	Cross-sectional	Automobile assembly line workers (n=199) compared to a randomly selected group from the general population (n=186). The automobile assembly line workers were randomly selected from a primary group of 700 assembly line workers. These original 700 workers had been randomly selected from the 2,334 assembly workers of a Swedish automobile factory.	Outcome: Epicondylitis was defined as tenderness to palpation of the lateral or medial epicondyle and pain at the same epicondyle or in the forearm extensors or flexors on resisted wrist extension or flexion. Exposure: No evaluation of repetition, force, posture, or vibration occurred in this study to evaluate risk factors for epicondylitis. “Assembly line worker” vs. “Population referent” was used. Hand grip strength was evaluated. Forearm muscular load and wrist angle were evaluated for a subgroup in this population but were not used in this analysis [Hägg et al 1996].	Tender lateral epicondyle: 4.3% Epicondy-litis: 0 cases	Tender lateral epicondyle: 12.4% Epicondy-litis: 1%	PRR for tender lateral epicondyle: 0.74	0.04-1.7	Participation rate: 96%. Comparison group is from the MUSIC study (Hagberg and Hogstedt, 1991). Examiners were blinded to questionnaire responses but not exposure status. Analysis stratified by gender and age <40 years. Psychosocial variables and other potential confounders or effect modifiers were addressed by Fransson-Hall et al. [1995]. Pain-pressure threshold (PTT) was evaluated. PTT was not related to age. It was higher among women with short employment compared to those who had been employed for a long time. No correlation was found between low MCV and subjective or objective signs.

(Continued)

Table 4–5 (Continued). Epidemiologic studies evaluating elbow musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Chiang et al. 1993	Cross-sectional	207 fish processing workers, 67 males and 140 females, divided in 3 groups: (I) low force, low repetition (comparison group, n=61); (II) high force or high repetition (n=118); (III) high force and high repetition (n=28).	Outcome: Prevalence of lateral or medial epicondylitis (local tenderness, pain in resisted extension or flexion of the wrist and fingers, decreased hand grip strength compared to the opposite hand). Exposure: Assessed by observation and recording of tasks and biomechanical movements of three workers, each representing one of 3 study groups. Highly repetitive jobs with cycle time <30 sec or >50% of cycle-time performing the same fundamental cycles. Hand force from EMG recordings of forearm flexor muscles. Classification of workers into 3 groups according to the ergonomic risks of the shoulders and upper limbs: Group I: low rep. and low force; Group II: high repetition or high force; Group III: high repetition and high force.	Group II: 15% Male: 10%; Female: 17% Group III: 21% Male: 33%; Female: 18% Physician observed epicondy-litis, all cases: 14.5 %	Group I: 10% Male: 6%; Female: 14%	Crude ORs calculated from data presented: Group II vs. Group I, males: OR=1.7 Group II vs. Group I, females: OR=1.2 Group III vs. Group I, males: OR=6.75 Group III vs. Group I, females: OR=1.44	0.3-9.2 0.4-3.4 1.6-32.7 0.3-5.6	Participation rate: Authors reported: "In order to prvent selective bias all employees in the fatories were observed initially." Workers examined in random sequence to prevent observer bias, examiners blinded to case status. Analysis stratified by gender. No significant age difference in exposure groups. Logistic regression not performed for epicondylitis because of lack of significant trend with increasing exposure. Workers with hypertension, diabetes, history of traumatic injuries to upper limbs, arthritis, or collagen diseases excluded from study group. Physician observed cases had about ½ the prevalence of symptoms of elbow pain (9.8 vs. 18.0; 5.3 vs. 19.5; 35.7 vs. 17.9). No dose-response for elbow pain or physician observed epicondylitis.

(Continued)

Table 4–5 (Continued). Epidemiologic studies evaluating elbow musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Dimberg 1987	Cross-sectional	A questionnaire was distributed to every fifth person in the automobile company's personnel file selected by random numbers. Final sample consisted of 546 workers, 494 males and 52 females. (25 were excluded due to military service, pregnancy, or study away).	Outcome: Only workers reporting elbow problems were examined by the physician. Physical exam: case defined as physical findings of lateral elbow pain and pain with palpation over lateral epicondyle and pain increase with dorsiflexion of wrist with resistance. Exposure: Observation of the work site then categorization of jobs "with respect to elbow stress" by a Physical Work Stress Group composed of a physician, physiotherapist, and safety engineer. Table 2 in the article lists types of jobs with respect to subjects's elbow stress.	Lateral humeral epicondylitis among all subjects: 7.4% Blue collar workers: 5.3% White collar workers: 11% Blue collar: under age 40 years: 4.6% Blue collar: over age 40 years: 8.9% White collar: under age 40 years: 6.1% White collar: over age 40 years: 13.9%	♁	Epicondylitis, blue vs. white collar workers: 0.7 Distribution of epicondylitis cases by type of work stress: Leisure related epicondylitis: low work stress: 85%; medium work stress: 15%; high work stress: 0% No-known-cause group: epicondylitis: low work stress: 75%; medium work stress: 25%; high work stress: 0% Work-related epicondylitis: low work stress: 14%; medium work stress: 36%; high work stress: 50%	0.3-1.2	Participation rate: 98.9%. Physician blinded to exposure status: not reported. Results age stratified. Physician-consulted elbow pain significantly greater in jobs with increased elbow stress. Work considered to be the cause in 35%. Authors found that work-related group had work defined by high stress (categorized by low, moderate, and high) compared to leisure-related epicondylitis and epicondylitis of no-known-cause. Authors reported that proportion of workers who consulted a physician for their elbow problems was significantly greater with increasing elbow stress ($p < 0.05$). Multiple regression analyses included gender, employee category, age, and degree of stress as independent variables—only age significantly related to prevalence. Overexertion of the extensor muscles of the wrist due to gripping and twisting movements prior to onset was verified in 28 (70%) of those with epicondylitis. Tennis players among "sufferers": 15% total population: 12%. All racquet sports: 20% among sufferers, 15% among total population.

(Continued)

Table 4–5 (Continued). Epidemiologic studies evaluating elbow musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Dimberg et al. 1989	Cross-sectional	2,814 automotive workers, both blue- and white-collar workers: 2,423 males, 382 females.	Outcome: Questionnaire results of elbow trouble (pain, ache, discomfort) preventing normal work in last 12 months. Physical exam performed on 615 of 641 symptomatic workers. Epicondylitis: tenderness at the lateral/medial epicondyle and pain with resistance. Exposure: Observation of jobs, then classification into 3 Physical Work Stress Groups by physician, physiotherapist, and safety engineer. Guidelines for classification with respect to the strain on the subject's neck and upper extremities listed for light, moderately heavy, and heavy work included in article.	Blue collar	White collar	Univariate Results: *p*<0.001: higher age; longer time in present job; ponderal index, more symptoms; more mental stress at the onset of symptoms. *p*<0.05: salaried staff vs. others; heavy weight; less racquet sports, more symptoms. *p*<0.01: vibrating hand tools, more symptoms; time in present job, more symptoms. *p*>0.05: gender; strain group; full time; hrs/week; piece-work; fixed pay; smoking, house-owner.		Participation rate: 96%. Not stated whether examiner blinded to exposure status. Multivariate analysis performed, although the confounders controlled for were not stated by authors, nor were ORs presented. Vibrating tools, ponderal index, and mental stress at work listed as significant. Guidelines for classification of jobs as listed in the article do not seem to reflect increasing elbow stress. Group 1 includes "repeated rotation of the forearms and wrists occurs sporadically"; Group 2 includes less specifically "large and frequent rotations in extreme positions"; Group 3 does not include any reference to repeated rotation or extreme position of the forearms or wrists. The classification used seems unlikely to pick up increased elbow stress that would reflect higher strain and risk of epicondylitis. Increased ponderal index correlated with elbow symptoms in multivariate analysis. Mental stress at work with the onset of symptoms correlated with right-sided lateral epicondylitis. Mental stress variables not uniformly collected, so this may impact interpretation.

(Continued)

Table 4–5 (Continued). Epidemiologic studies evaluating elbow musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	95% CI	Comments
Fishbein et al. 1988	Cross-sectional (mailed survey)	2212 musicians performing on a regular basis with one or more of the International Conference of Symphony and Opera Musicians (ICSOM). Total population of the membership was 4,025 musicians in 48 ICSOM orchestras. One orchestra did not participate.	Outcome: Outcome based on self-reported responses from survey. Self-reported elbow pain, with severity defined in terms of the effect of the problem on the musician's performance. Exposure: Questionnaire responses to orchestral instrument, age they began playing, age they joined the orchestra, number of weeks each year spent playing professionally.	10% right elbow: 6 % severe 8% left elbow: 4% severe	õ	Severe medical problem and its affect on performance, females vs. males: OR=2.04	1.6-2.6	Participation rate: 55%. Low response rate due to the fact that many orchestras were not in season at the time of the survey. Statistical weighting performed; "severe" pain was defined as pain that affects performance. Health habits, such as extent of exercise, use of cigarettes, alcohol, beta blockers, and other drugs. Average age beginning playing instrument is 10 years. Average age joining a professional orchestra is 23 years. Average age: male musicians–43 years, female musicians–40 years. Severe problems were more likely in ages under 35 than over 45 years. Authors speculated that musicians with severe problems leave the orchestra. Low participation rate limits interpretation.

(Continued)

Table 4–5 (Continued). Epidemiologic studies evaluating elbow musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Hales et al. 1994	Cross-sectional	518 telecommunication workers (416 females and 117 males). Workers fulfilling outcome definition compared to those not fulfilling outcome definition.	Outcome: Pain, aching, stiffness, burning, numbness, or tingling >1 week or >12 times a year; occurring after employment on current job within the last year and positive physical examination (PE): Moderate to worst pain experienced with medial or lateral epicondyle palpation. Exposure: Assessed by questionnaire. Questions addressed number of overtime hr, co-worker use of same workstation, task rotation, hr spent at the (VDT) workstation, hr spent typing, number and types of work breaks, length of time sitting, frequency of arising from a chair, number of keystrokes estimated for each directory assistance operator.	7%	ð	Fear of being replaced by computers: OR=2.9 Lack of decision-making opportunities: OR=2.8 Surges in workload: OR=2.4 Race (non-white) OR=2.4	1.4-6.1 1.4-5.7 1.2-5.0 1.2-5.0	Participation rate: 93%. ORs for psychosocial represent risk at scores one standard deviation (SD) above the mean compared to risk at scores one SD below mean. May be a problem with non-normal distribution. Analysis controlled for age, gender, individual factors, and number of keystrokes/day. Physician examiners blinded to case and exposure status. Although keystrokes/day was not significant–workers only typed average of 8 words/min over 8-hr period. 97% of workers "used" VDTs $ 6 hr/day–not enough variance to adequately evaluate hr typing. Number of hr on hobbies and recreation not significant. Over 70 variables analyzed in models–may have multiple comparison problem.

(Continued)

Table 4–5 (Continued). Epidemiologic studies evaluating elbow musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Hoekstra et al. 1994	Cross-sectional	108 of 114 teleservice representatives working at 2 government administration centers: A and B.	Outcome: Self administered questionnaire. Case defined as the presence of pain, numbness, tingling, aching, stiffness, or burning in the elbow region as previous non-occupational injury; symptoms began after starting the job, last > 1 week or occurred once a month within the past year; reported as “moderate” (3) or greater on a 5-point scale. Exposure: Measurement and evaluation of work station; observation of postures to provide descriptive differences between the two locations.	Center A Center B	19% 21%	"Non-optimally" adjusted chair: 4.0	õ 1.2-13.1	Participation rate: 95%. Analysis controlled for gender. Interactions evaluated. Variables considered in logistic model included location, age, seniority, hr spent typing at VDT, hr on the phone, 3 chair variables: (1) Perceived adequacy of chair adjustment, VDT screen, (2) Perceived adequacy of keyboard adjustment, VDT screen, (3) Perceived adequacy of desk adjustment, job control, workload variability. Linear regression also performed on psychosocial variables in separate models for job dissatisfaction and exhaustion. Center B generally had nonadjustable chairs and work stations. Authors noted elevated arms, hunched shoulders and other "undesirable" postures. Did not include non-work-related variables in analyses.

(Continued)

Table 4–5 (Continued). Epidemiologic studies evaluating elbow musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	95% CI	Comments
Hughes and Silverstein 1997	Cross-sectional	104 male aluminum smelter workers: 62 carbon setters, 36 crane operators, 9 carbon plant workers. There were 14 workers who were not from selected jobs and were excluded.	Outcome: Symptoms occurring in the elbow/forearm > once/month or lasting longer than one week in the previous year, no acute or traumatic onset; occurrence since working at the plant, no systemic disease. Physical examination: Active, passive, and resisted motions, pinch and grip strength, 128 Hz vibration sensitivity, two-point discrimination. Psychosocial scales from questionnaire based on Theorell and Karasek Job Stress Questionnaire, and on Work Apgar Questionnaire. Exposure: For carbon setters and crane operators (non-repetitive jobs) a modified job-surveillance checklist method was used. Job task analysis used a formula based on the relative frequency of occurrence of postures during (a) task(s).	11.6% with positive symptoms and physical exam 24% had symptoms in the elbow/forearm in the previous week	õ	Model based on MSD defined by symptoms and physical exam Age: OR=0.96 Low decision latitude: OR=3.5 Years of forearm twist: OR=37 Model based on MSD defined by symptoms Age: OR=0.96 Years of ulnar deviation: OR=0.005 Years forearm twist: OR=4	 0.9-1.2 0.6-19 3.0-470 0.9-1.2 0.0-16 0.18- 4	Participation rate: Carbon setters: 65%; crane operators: 56%; carbon plant: 33%. Examiners blinded to exposure and health status: not stated. Analysis controlled for age, smoking status, sports, and/or hobbies. Psychosocial data collected individually; physical factors based on estimates of each job. Job risk factors entered into the model for hand/wrist included: (1) the number of years handling > 2.7 kg/hand, (2) push/pull, (3) lift/carry, (4) pinching, (5) wrist flexion/extension, (6) ulnar deviation, and (7) forearm twisting. Health interview included information about metabolic diseases, acute traumatic injuries, smoking, hobbies. Low participation rate limits interpretation.

(Continued)

Table 4–5 (Continued). Epidemiologic studies evaluating elbow musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Kopf et al. 1988	Cross-sectional	Bricklayers (n=163) compared to other manual workers (n=144) employed by state agencies in Hamburg, Germany.	Outcome: Questionnaire based, self-reported symptoms. Self-reported pain in the elbow. Exposure: Based on job categories, bricklayer vs. other manual laborers. Physical stress of bricklayers described as lifting and carrying bricks weighing 5 to 24 kg up to 100 times/hr with the left hand and handling the bricklayer's trowel with the right hand.	Not reported	Not reported	Painful left elbow, bricklayers vs. other manual workers: OR=2.8	Not reported	Participation rate: bricklayers: 65%, manual workers: 69%. Controlled for confounders: age, job satisfaction, job security, vibration, moistness, Scheuerman's disease. Karasek's model of job latitude and job demands were included in the questionnaire. Physically demanding previous tasks, medical disposition for MSD, being a member of a trade union included in analysis. 64% attributable risk proportion of elbow pain is explained by being a bricklayer. For increasing levels of job demands (heavy physical work, awkward working positions, repetitive movements, and restriction in standing position), OR increased from 1.8 to 3.4.

(Continued)

Table 4–5 (Continued). Epidemiologic studies evaluating elbow musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	95% CI	Comments
Kurppa et al. 1991	Cohort; 31 month follow-up	Sausage makers (107 females) compared to nonstrenuous jobs (197 females). Meatcutters (102 males) compared to nonstrenuous jobs (n=141). Packers (118 females) compared to nonstrenuous jobs (197 females).	Outcome: Tenderness to palpation of the epicondyle and epicondylar pain provoked by resisted extension or flexion of the wrist and fingers with the elbow extended. Incidence based on visits to doctor during 31 month visit. Disease considered "new" episode if new sick leave with same diagnosis occurred at same anatomic site within 60 days after end of former sick leave. Exposure: Data obtained from "previous published literature" and walkthrough. "Cutting of veal (appx. 1,200 kg/day) or pork (appx. 3,000 kg/day) (meatcutters); spraying the sausages and hanging them on bars (sausage makers); peeling sausages, inserting them into slicing machine, setting the slices into packages, setting packages on a conveyor belt, collecting finished packages into bags; room temperature 8E to 10E (packers); nonstrenuous tasks included primarily office work."	Sausage makers (females): 11.1 cases/100 person-years Meatcutters (males): 6.4 cases/100 person-years Packers (males): 7.0 cases/100 person-years	Workers in Non-strenuous jobs: 1.1 cases /100 person-years Workers in non-strenuous jobs: 0.9 cases/100 person-years Workers in Nonstrenu-ous jobs: 1.1 cases/100 person-years	IR of males in strenuous jobs vs. nonstrenuous jobs: 5.7 IR of females in strenuous jobs vs. nonstrenuous jobs: 8.1 IR of total number of cases of epicondylitis in strenuous jobs vs. nonstrenuous jobs: 6.7	3.3-13.9	Participation rate: 93% of strenuous workers retained during study; 90% of nonstrenuous workers. Examiners blinded to exposure or past episodes: not reported. Diagnoses made by different physicians at different locations. Plant physicians agreed to the diagnostic criteria and made 75% of diagnoses. 25% of physicians were not involved in agreement of diagnostic criteria. 13% of epicondylitis diagnosed by consulting specialists at the nearby medical center, 12% elsewhere, usually at municipal health centers. No adjustment for confounders, but referent group selected similar to strenuous group with regards to age, gender, and duration of employment, except for male sausage makers and male packers who were younger than the rest of the study population–these were excluded from calculations of incidence rates. "New" episode of epicondylitis may be recurrence of same disease. 12 employees reafflicted with epicondylitis with median of 184 days between episodes. There were 68 diagnoses of epicondylitis among 57 individuals.

(Continued)

Table 4–5 (Continued). Epidemiologic studies evaluating elbow musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Luopajärvi et al. 1979	Cross-sectional	Female assembly line workers (n=152) compared to female shop assistants in a department store (n=133). Cashiers excluded from comparison group.	Outcome: Epicondylitis diagnosed by interview and physical exam. Symptoms include muscle pain during effort, local swelling, and local ache at rest. Signs include tenderness at the ateral or medial epicondyle on palpation, pain during resisted extension/flexion of the wrist and fingers with the elbow extended. Physiotherapist examined workers, diagnoses were from pre-determined criteria (Waris 1979). In problem cases orthopedic and physiatric teams handled cases. Exposure: Exposure to repetitive work, awkward hand/arm postures, and static work assessed by observation, video analysis and interviews. Video recordings showed repetitive motins of the hands and fingers up to 25,000 cycles/day, static muscle loading of the forearm muscles, and deviations of the wrist, lifting.	5.9%	2.3%	2.7	0.66-15.9	Participation rate: 84%. Workers excluded from participation for previous trauma, arthritis and other pathologies. Examiner blinded to case status: yes, according to the Waris et al. 1979, epidemiologic screening procedure, which was used in study. No association between age and MSDs or length of employment and MSDs. Gender not an issue because study population was all female. Factory opened only short time so no association between duration of employment and MSDs possible. Social background, hobbies, amount of housework not significant.

(Continued)

Table 4–5 (Continued). Epidemiologic studies evaluating elbow musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
McCormack et al. 1990	Cross-sectional	Randomly selected population of 2,261 textile workers from 8,539 eligible workers; 4 groups compared with 468 non-office workers Manufacturing workers: A. Packaging/folding workers (41 males, 238 females). B. Sewing workers (28 males, 534 females). C. Non-office workers (204 males, 264 females). D. Boarding workers (19 males, 277 females).	Outcome: Based on physician administered physical exams. Reproducible tenderness with direct pressure on the lateral epicondyle. Severity graded as mild, moderate, and severe. Exposure: Assessment by observation of jobs. Exposure to repetitive finger, wrist and elbow motions assumed from job title; no objective measurements performed.	Boarding workers: 1.0% Sewing workers: 2.1% Packaging/ folding workers: 2.2% Knitting: 1.4%	Non-office workers: 1.9%	Boarding vs. non-office: OR=0.5 Sewing vs. non-office: OR=1.1 Packaging vs. non-office: OR=1.1 Knitting vs. non-office: OR=1.2	0.09-2.1 0.4-2.9 0.4-3.2 0.5-3.4	Participation rate: 91%. Physician or nurse examiners not blinded to case or exposure status (personal communication). Age, gender, race, and years of employment analyzed. Prevalence higher in workers with < 3 years of employment. Questionnaire asked types of jobs, length of time on job, production rate, nature and type of upper extremity complaint, and general health history. 11 physician examiners; interexaminer reliability potential problem acknowledged by authors. Epicondylitis significantly associated with years of employment, age, race. Job category not related to epicondylitis, however no measurement of force, repetition, posture analysis, etc. Of 37 cases of epicondylitis identified: 13 were categorized as mild, 22 were moderate, and 2 were severe.

(Continued)

Table 4–5 (Continued). Epidemiologic studies evaluating elbow musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	Referent group	RR, OR, or PRR	95% CI	Comments
Moore and Garg 1994	Cross-sectional	Workers employed in 32 jobs at a pork processing plant (n=230). Workers in jobs classified as "hazardous" compared to those in "safe" jobs.	Outcome: OSHA logs verified by medical records data for 20 months. Epicondylitis: localized elbow pain that increased with tension of muscle-tendon unit and direct palpation. A case required that a physical examination specific to epicondylitis was performed. Exposure: Observation and video analysis, semi-quantitative methods using motion and time methods (MTM), force estimated as % maximal strength (5 levels), wrist posture (3 levels), type of grasp (2 levels), high speed work (yes or no), localized mechanical compression (yes or no), vibration (yes or no), and cold (yes or no). Observed videotaped representative worker in each job. Repetition as cycle-time and exertions/min measures. Jobs classified as "hazardous" or "safe" based on data, experience of authors, and judgements. Work histories, demographic, pre-existing morbidity data not collected on each participant.	Workers in "hazardous jobs": 23%	Workers in "safe jobs": 3%	Odds of epicondylitis in workers in "hazardous jobs" compared to workers in "safe jobs": OR=5.5 (based on personal communi-cation)	1.5-62	Participation rate: Cases identified from medical records. Jobs analyzed from observational methods. Investigators blinded to exposure, case outcome status, and personal identifiers on medical records. Repetitiveness and "type of grasp" were not significant factors between hazardous- and safe-job categories. No pattern of morbidity accord-ing to date of clinic visits. Strength demands significantly greater for hazardous job categories compared to safe. IR based on full-time equivalents and not individual workers, may have influenced overall results. Workers had a maximum of 32 months of exposure at plant–duration of employment analysis limited. Duration of exposure not collected on study sample. Average maximal strength derived from population-based data stratified for age, gender, and hand dominance. Using estimates of Silverstein's classification, association between forcefulness, and overall observed morbidity was statistically significant; repetition was not. 31 of 32 jobs were in high repetitive category–no variance to find difference.

(Continued)

Table 4–5 (Continued). Epidemiologic studies evaluating elbow musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	RR, OR, or PRR	95% CI	Comments
Ohlsson et al. 1989	Cross-sectional	Electrical equipment and automobile assemblers (n=148), former female assembly workers who quit within 4 years (n=76) compared to randomly sampled females from general population (n=60).	Outcome: Questionnaire: Any elbow pain, elbow pain affecting work ability, and elbow pain in the last seven days and the last 12 months. Exposure: No exposure measurements; based on job categorization. Work pace divided into 4 classes: (1) Slow <100 items/hr; (2) Medium 100 to 199 items/hr; (3) Fast 200 to 700 items/hr; (4) Very Fast >700 items/hr.	Elbow pain in last 12 months: 21%	Elbow pain in last 12 months: 17%	1.5	0.6-3.4	Participation rate: Not reported. Work pace assessed by questionnaire, the number of items completed/hr. No association between length of employment and elbow symptoms. No statistical significance associated with work pace (data not present). Logistic models evaluated for interaction and controlled for age. Study group consisted of females only.
				Elbow pain in last 7 days: 14%	Elbow pain in last 7 days: 11%	1.9	0.7-5.3	
				Work inability in last 12 months: 10%	Work inability in last 12 months: 3%	2.8	0.8-10.7	

(Continued)

Table 4–5 (Continued). Epidemiologic studies evaluating elbow musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Punnett et al. 1985	Cross-sectional	162 female garment workers, 85% were employed as sewing machine operators and sewing and trimming by hand. Comparison: 76 of 190 full or part-time workers on day shift in a hospital who worked as nurses or aids; lab technicians or therapists; food service workers. Employees typing >4 hr/day excluded from comparison group.	Outcome: Self-administered questionnaire concerning symptoms Cases defined as the presences of persistent elbow pain, numbness or tingling (lasted for most days for one month or more within the past year); were not associated with previous injury; and, began after first employment in garment manufacturing or hospital employment. Key questions based on the arthritis supplement questionnaire of National Health and Nutrition Examination Survey (NHANES). Exposure: Self-administered questionnaire; # of years in the industry, job category, previous work history.	Garment workers: 6.5%	Hospital employees: 2.8%	Elbow Symptoms in Garment workers vs. Hospital employees: OR= 2.4 Persistent elbow pain in finishers vs. hospital employees: OR=5.6 Persistent elbow pain in underpresser vs. hospital employees: OR=5.0	1.2-4.2	Participation rate: 97% (garment workers), 40% (hospital workers). Analysis stratified for number of years employed, decade of age, native language. Health outcome based on symptoms alone for elbow MSDs. Age and length of employment not a predictor of risk of elbow MSDs. Prevalence of pain not associated with years of employment in garment workers. Non-English speakers significantly less likely to report pain (RR 0.6 ; p<0.05). Native English speakers significantly older than non-native English speakers (p<0.03).

(Continued)

Table 4–5 (Continued). Epidemiologic studies evaluating elbow musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Ritz 1995	Cross-sectional	290 males from the public gas and water works of Hamburg, Germany examined during routine medical check-up at the company occupational health center. Employees, excluded if on sick leave, came for medical treatment, pre-employment checkups, or to file a worker's compensation claim.	Outcome: Physician diagnosed; required local tenderness to palpation at the epicondyle and pain during resisted movement of the wrist and fingers (extension or flexion of the wrist or fingers with an extended elbow) AND elbow pain during the lifting of a chair. Epicondylitis was categorized as severe (Grade II and Grade III) if both functional tests were positive and as moderate (Grade I) if only symptom was a severe tenderness to palpation or a moderate pain in the resistance test. Clinical signs of epicondylitis > Grade 0 at one or more of the four anatomical sites was considered sufficient for the diagnosis. Exposure: All current and former job titles evaluated by members of the team according to possible bio-mechanical strain to the elbow and grouped into categories of high, moderate, and non work-related exposure. Exposure categorization was based on company job descriptions, interviews with employees, and workplace observations. Exposure duration was defined for all subjects as the	41 employees: 14% had epicondylitis 11% fulfilled Waris's criteria for epicondylitis (Waris, 1979)		10 years of high exposure to elbow straining work for currently held job: OR=1.7 High exposure to elbow straining work for formerly held job: OR= 2.16 10 years of high exposure to elbow straining work for currently held job using diagnostic criteria for epicondylitis [Waris et al. 1979]: OR=1.89	1.0-2.7 1.1-4.3 1.2-3.1	Participation rate: Not reported. Examiner blinded to exposure status. Logistic regression model controlled for age, age-squared, and an indicator term for "history of cervical spine symptoms" (yes, no). The following variables tested for confounding: having ever played tennis, squash, other racquet sports, rowing, bowling, the duration of having played these sports, injuries involving the elbow joint, ponderal index, handedness, and former surgical treatment for epicondylitis. The variable "time in years since retiring from a job with high or moderate exposure" was retained in the model for workers formerly employed in high exposure jobs when duration of exposure was tricotomized. Mean length of employment was not significantly different between cases and non-cases. Increasing duration of current exposure increased the risk of being diagnosed with epicondylitis.

(Continued)

Table 4–5 (Continued). Epidemiologic studies evaluating elbow musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Roto and Kivi 1984	Cross-sectional	Meatcutters, (n=90) compared to construction workers (n=72) not exposed to repetitive movements.	Outcome: Defined by physical exam: local tenderness, pain during resisted extension/flexion of the wrist and fingers, and decreased hand grip power in comparison to other hand. Exposure: Based on job title (meatcutter vs. construction worker).	Meatcutters: 8.9%	Construction workers: 1.4%	6.4	0.99-40.9 p= 0.05	Participation rate: 100% for meat cutters, 94% for construction workers. Authors state that examiners were blinded to occupation of subjects because part of larger group of meat processing workers examined, but it is unclear whether construction foremen (referents) were examined separately. Serologic testing for rheumatoid arthritis was done to control for potential confounding (none detected). 7 additional meatcutters had local tenderness in epicondylar region. All with epicondylitis had > 15 years of employment. Authors stated that on average, meatcutters with epicondylitis had been exposed five years longer than other meatcutters, supporting the association with meatcutting.

(Continued)

Table 4–5 (Continued). Epidemiologic studies evaluating elbow musculoskeletal disorders

				MSD prevalence				
Study	**Study design**	**Study population**	**Outcome and exposure**	**Exposed workers**	**Referent group**	**RR, OR, or PRR**	**95% CI**	**Comments**
Viikari-Juntura 1991b	Cross-sectional	All permanent workers exposed to repetitive and manually stressful tasks in a meatpacking plant (102 meatcutters, 150 packers, and 125 sausage makers) were compared to 332 workers in nonstrenuous jobs (supervisors, maintenance men, accountants, and office workers).	Outcome: Elbow trouble (pain, ache, discomfort) preventing normal work in last 12 months and physical exam: tenderness at the lateral/medial epicondyle and pain with resistance. Exposure: Based on observation: Meatcutters: High force/high repetition. Sausage makers: High repetition/low force with high force tasks. Packers: High repetition/low force with high force jobs. Nonstrenuous jobs, mainly office jobs. "Cutting of veal (appx. 1,200 kg/day) or pork (appx. 3,000 kg/day) (meatcutters); spraying the sausages and hanging them on bars (sausage makers); peeling sausages, inserting them into slicing machine, setting the slices into packages, setting packages on a conveyor belt, collecting finished packages into bags; room temperature 8E to 10E (packers); nonstrenuous tasks included primarily office work."	Epicondylitis: 0.8% Lateral: 0.6% Medial: 0.2%	Epicondylitis: 0.8% Lateral: 0.6% Medial: 0.3%	The Odds Ratio of epicondylitis in strenuous jobs vs. non-strenuous jobs: 0.88 Elbow Pain (without the physical exam): Male: 1.8 Female: 1.6	0.27-2.8 1.1-2.8 1.2-2.3	Participation rate: 94%. No adjustment for confounders in analysis. Authors stated that the comparison group was selected similar to the study group to sex, age, and duration of employment. Examiners blinded to case and exposure status. Male packers and male sausage makers younger and length of employment shorter than other groups. Palpation pressure increased on 2nd of cross-sectional examinations–may have influenced results. For female sausage makers, elbow pain for preceding 12 months increased with age and duration of employment. No such associations in other groups. Age and current occupational correlated (r=0.52) for female sausage makers. Cases were not excluded due to direct trauma.

CHAPTER 5
Hand/Wrist Musculoskeletal Disorders (Carpal Tunnel Syndrome, Hand/Wrist Tendinitis, and Hand-Arm Vibration Syndrome): Evidence for Work-Relatedness

Musculoskeletal disorders (MSDs) of the hand/wrist region have been separated into three components for the purpose of this review: (a) Carpal Tunnel Syndrome (CTS), (b) Hand/Wrist Tendinitis, and (c) Hand-Arm Vibration Syndrome (HAVS). Each of these are described with regard to the evidence for causality between workplace risk factors and development of MSDs.

CHAPTER 5a
Carpal Tunnel Syndrome

SUMMARY

Over 30 epidemiologic studies have examined physical workplace factors and their relationship to carpal tunnel syndrome (CTS). Several studies fulfill the four epidemiologic criteria that were used in this review, and appropriately address important methodologic issues. The studies generally involved populations exposed to a combination of work factors, but a few assessed single work factors such as repetitive motions of the hand. We examined each of these studies, whether the findings were positive, negative, or equivocal, to evaluate the strength of work-relatedness using causal inference.

There is **evidence** of a positive association between highly repetitive work alone or in combination with other factors and CTS based on currently available epidemiologic data. There is also **evidence** of a positive association between forceful work and CTS. There is **insufficient evidence** of an association between CTS and extreme postures. Individual variability in work methods among workers in similar jobs and the influence of differing anthropometry on posture are among the difficulties noted in measuring postural characteristics of jobs in field studies. Findings from laboratory-based studies of extreme postural factors support a positive association with CTS. There is **evidence** of a positive association between work involving hand/wrist vibration and CTS.

There is **strong evidence** of a positive association between exposure to a combination of risk factors (e.g., force and repetition, force and posture) and CTS. Based on the epidemiologic studies reviewed above, especially those with quantitative evaluation of the risk factors, the evidence is clear that exposure to a combination of the job factors studied (repetition, force, posture, etc.) increases the risk for CTS. This is consistent with the evidence that is found in the biomechanical, physiological, and psychosocial literature. Epidemiologic surveillance data, both nationally and internationally, have also consistently indicated that the highest rates of CTS occur in occupations and job tasks with high work demands for intensive manual exertion–for example, in meatpackers, poultry processors, and automobile assembly workers.

INTRODUCTION

In 1988, CTS had an estimated population prevalence of 53 cases per 10,000 current workers [Tanaka et al. (in press)]. Twenty percent of these individuals reported absence from work because of CTS. In 1994, the Bureau of Labor Statistics (BLS) reported that the rate of CTS cases that result in “days away from work” was 4.8 cases per 10,000 workers. The agency also reported that the median number of days away from work for CTS was 30, which is even greater than the median reported for back pain cases [BLS 1995]. In 1993, the incidence rate (IR) for CTS workers’ compensation cases was 31.7 cases per 10,000 workers; only a minority of these cases involved time off of work [Washington State Department of Labor and Industry 1996]. These data suggest that about 5 to 10 workers per 10,000 workers will miss work each year due to work-related CTS.

In recent years, the literature relating occupational factors to the development of CTS has been extensively reviewed by numerous authors [Moore 1992; Stock 1991; Gerr et al. 1991; Hagberg et al. 1992; Armstrong et al. 1993; Kuorinka and Forcier 1995; Viikari-Juntura 1995]. Most of these reviews reach a similar conclusion—work factors are one of the important causes of CTS. One review [Moore 1992] found the evidence more equivocal, but stated that the epidemiologic studies revealed a fairly consistent pattern of observations regarding the spectrum and relative frequency of CTS [among other musculoskeletal disorders (MSDs)] among jobs believed to be hazardous. The epidemiologic studies which form the basis for these reviews are outlined in Tables 5a–1 to 5a–4 of this chapter.

Thirty studies of occupational CTS are listed on Tables 5a–5. Twenty-one are cross-sectional studies, six are case-control, and three involve a longitudinal phase; all have been published since 1979. We included one surveillance study [Franklin et al. 1991] because it has been included in many of the earlier reviews. The few earlier studies of CTS identified were clinical case series, or did not identify work place risk factors and were not included in the tables related to CTS.

OUTCOME AND EXPOSURE MEASURES

In four of 30 studies listed in Tables 5a–1 to 5a–4, CTS was assessed based on symptoms alone; in another nine studies, the case definition was based on a combination of symptoms and physical findings. Electrophysiological tests of nerve function were completed in 14 studies. Electrodiagnostic testing (nerve conduction studies) has been considered by some to be a requirement for a valid case definition of CTS, as is similarly used for a clinical diagnosis in individuals with CTS. A few studies which have looked at the relationship of occupational factors to CTS have used a health outcome based on electrodiagnostic testing alone [Nathan et al. 1988; Schottland et al. 1991; Radecki 1995.] However, some authors [Nilsson 1995; Werner et al. 1997] have discouraged the use of labeling workers as having “CTS” or “median nerve mononeuropathy” based on abnormal sensory nerve conduction alone (without symptoms). The reason for this view is illustrated in a recent prospective study by Werner et al. [1997]. On follow-up six to eighteen months after initial evaluation, they found that asymptomatic active workers with abnormal sensory median nerve function (by Nerve Conduction Studies [NCS]) were no more likely to develop symptoms consistent with CTS than those with normal nerve function. Studies which have used nerve conduction tests for epidemiologic field studies have employed a variety of evaluation methods and techniques [Nathan et al. 1988, 1994b; Bernard et al. 1993; Osorio et al. 1994]. Normal values for nerve conduction studies have also varied from laboratory to laboratory. NCS results have been found to vary with electrode placement, temperature, as well as age, height, finger circumference and wrist ratio [Stetson 1993], suggesting that “normal” values may need to be corrected for those factors.

Several epidemiologic studies have used a surveillance case definition of CTS based on symptoms in the median nerve distribution and abnormal physical examination findings using Phalen’s test and Tinel’s sign, and have not included NCS. Two recent studies [Bernard et al. 1993; Atterbury et al. 1996] looked at CTS diagnosis based on questionnaire and physical examination findings and its association with the “gold standard” of nerve conduction diagnosed median mononeuropathy. Both studies found statistically significant evidence to support the use of an epidemiologic CTS case definition based on symptoms and physical examination (not requiring NCS) for epidemiologic surveillance studies. Nathan

[1992a] also found a strong relationship between symptoms and prolonged sensory median nerve conduction. (It is important to note here that a case definition used for epidemiologic purposes usually differs from one used for medical diagnosis and therapeutic intervention.)

Researchers have relied on a variety of methods to assess exposure to suspected occupational risk factors for CTS. These methods include direct measurement, observation, self-reports, and categorization by job titles. Most investigators agree that use of observational or direct measurement methods increases the quality (both the precision and accuracy) of ergonomic exposure assessments, but these methods also tend to be costly and time consuming. In general, misclassification errors tend to dilute the observed associations between disease and physical workload [Viikari-Juntura 1995].

REPETITION

Definition of Repetition for CTS

For our review, we identified studies that examined repetition or repetitive work for the hand and wrist for CTS as cyclical or repetitive work activities that involved either 1) repetitive hand/finger or wrist movements such as hand gripping or wrist extension/flexion, ulnar/radial deviation, and supination or pronation. Most of the studies that examined repetition or repetitive work as a risk factor for CTS had several concurrent or interacting physical workload factors. Therefore, repetitive work should be considered in this context, with repetition as only one exposure factor, accompanied by others such as force, extreme posture, and, less commonly, vibration.

Studies Reporting on the Association of Repetition and CTS

Nineteen studies reported on the results of the association between repetition and CTS. Several studies in Table 5a-1 quantitatively measured [Moore 1992; Chiang et al. 1990, 1993; Silverstein et al. 1987] or observed [Stetson et al. 1993; Nathan et al. 1988, 1992a; Barnhart et al. 1991; Osorio et al. 1994] and categorized repetitive hand and wrist movements in terms of: a) the frequency or duration of tasks pertaining to the hand/wrist, b) the ratio of work-time to recovery time, c) the percentage of the workday spent on repetitive activities, or d) the quantity of work performed in a given time. The rest of the studies generally used job titles or questionnaires to characterize exposure.

Studies Meeting the Four Evaluation Criteria

Five epidemiologic studies of the hand/wrist area addressing repetitiveness and CTS [Chiang et al. 1990, 1993; Moore and Garg 1994; Osorio et al. 1994; Silverstein et al. 1987] met the four criteria. Chiang et al. [1990] studied 207 workers from 2 frozen food processing plants. Investigators observed job tasks and divided them into low or high repetitiveness categories of wrist movement based on cycle time, as previously described by Silverstein et al. [1987]. Jobs were also classified according to whether or not workers' hands were exposed to cold work conditions. The resulting exposure groups were:
Group 1–Not Cold, Low Repetitiveness (mainly office staff and technicians);
Group 2–Cold Exposure or High Repetitiveness; and Group 3–Cold Exposure and High Repetitiveness. CTS diagnosis was based on abnormal clinical examination and nerve conduction studies. Prevalence of CTS

was 3% in Group 1, 15% in Group 2, and 37% in Group 3. Statistical modeling that also included gender, age, length of employment, and cold resulted in an odds ratio (OR) of 1.87 (p=0.02) for CTS among those with highly repetitive jobs. The OR for CTS among those exposed to cold conditions and high repetitiveness was 3.32 (p=0.03). The authors cautioned that cold exposure may have at least partially acted as a proxy for forceful hand/wrist exertion in this study group.

Chiang et al. [1993] studied 207 workers from 8 fish processing factories in Taiwan. Jobs were divided into 3 groups based on levels of repetitiveness and force. The comparison group (low force/low repetitiveness) was comprised of managers, office staff, and skilled craftsmen (group 1). The fish-processing workers were divided into high repetitiveness or high force (group 2), and high force and high repetitiveness (group 3). Repetition of upper limb movements (not specifically the wrist) was defined based on observed cycle time [Silverstein et al. 1987]. CTS was defined on the basis of symptoms and positive physical examination findings, ruling out systemic diseases and injury. CTS prevalence for the overall study group was 14.5%. CTS prevalence increased from group 1, to group 2, and to group 3 (8.2%, 15.3%, and 28.6%, respectively), a statistically significant trend (p<0.01). Repetitiveness alone was not a significant predictor of CTS (OR 1.1). Statistical modeling showed that women in this study group had a higher prevalence of CTS than men (OR 2.6, 95% confidence interval [CI] 1.3–5.2). Because the proportion of women varied by exposure group (48%, 75%, and 79% from group 1 to 3), further analyses were limited to females. The OR for repet-itiveness was 1.5 (95% CI 0.8–2.8), con-trolling for oral contraceptive use and force.

Moore and Garg [1994] evaluated 32 jobs in a pork processing plant and then reviewed past OSHA illness and injury logs and plant medical records for CTS cases in these job categories. A CTS case required the recording of suggestive symptoms (numbness and tingling) combined with electrodiagnostic confirmation (as reported by the attending electromyographers) of a case. Incidence ratios (IRs) were calculated using the full-time equivalent number of hours worked reported on the logs. The exact number of workers was not reported. Exposure assessment included videotape analysis of job tasks for repetitiveness and awkward postures. The force measure was an estimate of the percent maximum voluntary contraction (%MVC) based on weight of tools, and parts and population strength data adjusted for extreme posture or speed. Jobs were then categorized as hazardous or safe (for all upper extremity MSDs, not for CTS), based on exposure data and the judgment of the investigators. The hazardous jobs had a relative risk (RR) for CTS of 2.8 (95% CI 0.2–36.7) compared to the safe jobs. Due to the lack of data from individual workers, the study was unable to control for common confounders. Potential for survivor effect (79% of the workforce was laid off the year prior to the study), a limited latency period (8–32 months), and the potential for incomplete case ascertainment (underreporting is known to be a problem with OSHA illness and injury logs) limit confidence in this estimate. This study did not specifically address the relationship between repetitiveness and CTS. No significant association was identified between repetitiveness and the grouped "upper extremity musculoskeletal disorders," but there was very little variability in repetitiveness (31 of the 32 jobs had a cycle time less than 30 seconds).

Osorio et al. [1994] studied 56 supermarket workers. Exposure to repetitive and forceful wrist motions was rated as high, moderate, or low, following observation of job tasks. The CTS case definition was based on symptoms and nerve conduction studies. CTS-like symptoms occurred more often (OR 8.3, 95% CI 2.6–26.4) among workers in the high exposure group compared to the low exposed group. The odds of meeting the symptom and NCS-based CTS case definition among the high exposure group were 6.7 (95% CI 0.8–52.9), compared to the low exposure group.

Silverstein et al. [1987] studied 652 workers in 39 jobs from 7 different plants (electronics, appliance, apparel, and bearing manufacturing; metal casting, and an iron foundry). Investigators divided jobs into high or low repetitiveness categories, based on analysis of videotaped job tasks of 3 representative workers in each job. High repetitiveness was defined as cycle time less than 30 seconds or at least 50% of the work cycle spent performing the same fundamental movements. Jobs were also divided into high or low force categories based on EMGs of representative workers' forearm flexor muscles while they performed their usual tasks. EMG measurements were averaged within each work group to characterize the force requirements of the job. High force was defined as a mean adjusted force >6 kg. Jobs were then classified into 4 groups: low force/low repetitiveness, high force/low repetitiveness, low force/high repetitiveness, and high force/high repetitiveness. Fourteen cases (2.1% prevalence) of CTS were diagnosed based on standardized physical examinations and structured interviews.

The OR for CTS in highly repetitive jobs compared to low repetitive jobs, irrespective of force, was 5.5 ($p<0.05$) in a statistical model that also included age, gender, years on the job, and plant. The OR for CTS in jobs with combined exposures to high force and high repetition was 15.5 ($p<0.05$), compared to jobs with low force and low repetition. Age, gender, plant, years on the job, hormonal status, prior health history, and recreational activities were analyzed and determined not to confound the associations identified.

Studies Meeting at Least One Criterion

Fourteen additional studies met at least one of the criteria.

Barnhart et al. [1991] studied ski manufacturing workers categorized as having repetitive or nonrepetitive jobs based on observational exposure methods for hand/wrist exposure. The participation rate for this study was below 70%. Three different case definitions were used for CTS based on symptoms, physical exam findings, and NCS using the mean median-ulnar difference in each group. Each case definition used the NCS results. The authors reported a significant prevalence ratio (PR) of 2.3 for the mean median-ulnar sensory latency nerve difference among those in repetitive jobs compared to those in non-repetitive jobs. However, the difference was found in the ulnar rather than in the median nerve. The median nerve latencies were not statistically different between the two groups.

Baron et al. [1991] studied CTS in 124 grocery store checkers and 157 other grocery store workers who were not checkers. The CTS case definition required symptoms that met pre-determined criteria on a standardized questionnaire and physical examinations. The OR for CTS among checkers was 3.7 (95% CI 0.7–16.7), in a model that included age, hobbies, second jobs, systemic disease, and obesity. Participation rates at the work sites were higher among the exposed group (checkers: 85% participation, non-checkers: 55% participation). After telephone interviews in which 85% of the non-checkers completed questionnaires, investigators reported that the proportion of non-checkers meeting the case definition did not increase.

Cannon et al. [1981] in a case-control study of aircraft engine workers did not find a significant association with the performance of repetitive motion tasks (OR 2.1, 95%CI 0.9–5.3), but found a significant association with self-reported use of vibrating hand tools, history of gynecologic surgery, and an inverse relationship with years on the job. One must assume from the article that "repetitive motion tasks" were defined by job title. The diagnosis of CTS was based on medical and workers' compensation records.

In English et al.'s [1995] case-control study of upper limb disorders diagnosed in orthopedic clinics, the case series included 171 cases of CTS and 996 controls. Exposure was based on self-reports; repetitiveness was defined as a motion occurring more than once per minute. The logistic regression model of CTS found significant associations with height (negative), weight (positive), presentation at the clinic as a result of an accident (negative), and two occupational factors:
1) uninterrupted shoulder rotation with elevated arm (OR 1.8, 95% CI 1.2–2.8) and 2) protection from repeated finger tapping (OR 0.4, 95% CI 0.2–0.7). The authors note that the latter observation presented "difficulties of interpretation." Limitations of this study concern the lack of exposure assessment for repetition, and the questionable reliability for reported limb movements as an accurate measure of repetition.

Feldman et al. [1987] studied electronic workers at a large manufacturing firm using a questionnaire survey and biomechanical job analysis. Four work areas with 84 workers were identified as "high risk" with highly repetitive and forceful tasks. Workers in these high risk areas had physical examinations and NCS. Sixty-two workers from the high risk area had repeat NCS one year later. Comparing these high risk workers to the others, one can calculate ORs for symptoms of numbness and tingling [OR 2.26 ($p<0.05$)] and a positive Phalen's sign [2.7 ($p<0.05$)]. Longitudinal NCS of workers in the high risk area showed significant worsening in the median motor latency and sensory conduction velocity in the left hand, and motor changes over a year's period, which the authors attributed to work exposure. A limitation of this study concerns inadequate exposure information about the extent of worker exposure to repetitive and forceful work.

McCormack et al. [1990] studied 1,579 textile production workers and compared them to 468 other nonoffice workers, a comparison group that included machine maintenance workers, transportation workers, cleaners, and sweepers. The textile production workers were divided into four broad job categories based on similarity of upper extremity exertions. No formal exposure assessment was conducted. Health assessment included a questionnaire and screening physical examination followed by a diagnostic physical examination. CTS was diagnosed using predetermined clinical criteria. The severity of cases was also reported as mild, moderate, or severe. The overall prevalence for CTS was 1.1%, with 0.7% in boarding, 1.2% in sewing, 0.9% in knitting, 0.5% in packaging/folding, and 1.3% in the comparison group. None of the differences were statistically significant. A statistical model that also included age, gender, race, and years of employment showed that CTS occurred more often among women in this study ($p<0.05$). Interpretation of these data, especially with a low prevalence disorder like CTS, is difficult since gender varied with job (94% of boarding workers were female, compared to 56% in the comparison group), and the comparison group (machine maintenance workers, transportation workers, cleaners and sweepers) may have also been exposed to upper extremity exertions. Interactions among potential confounders were not addressed, but they are suspected because of significant associations between race and three MSDs.

Morgenstern et al. [1991] mailed questionnaires to 1,345 union grocery checkers and a general population group. Exposure was based on self-reported time working as a checker. Symptoms of CTS were significantly associated with age and the use of diuretics, and nonsignificantly associated with average hours worked per week, and years worked as a checker. A positive CTS outcome was based on the presence of all four symptoms: pain in the hands or wrist, nocturnal pain, tingling in the hands or fingers, or numbness. The estimated attributable fraction of CTS symptoms to working as a checker was about 60%, using both a general population comparison group and a low exposed checker group. The limitations of this study are: 1) the use of an overly sensitive health outcome measure, for example, 32% of the surveyed population reported numbness; and 2) the use of self-reported exposure.

Nathan et al. [1988] studied median nerve conduction of 471 randomly selected workers from four industries (steel mill, meat/food packaging, electronics, and plastics manufacturing). Median nerve sensory latency values were adjusted for age for statistical analyses. Thirty-nine percent of the study subjects had impaired sensory nerve conduction, or “slowing” of the median nerve. The five exposure groups were defined as follows: Group 1 is very low force, low repetition (VLF/LR); Group 2 is low force, very high repetition (LF/VHR); Group 3 is moderate force, moderate repetition (MF/MR); Group 4 is high force/moderate repetition (HF/MR); and Group 5 is very high force/high repetition (VHF/HR). There was no significant difference between Group 1 and Group 2, the groups that had the greatest differences in repetition. The authors reported a significantly higher number of subjects with median nerve slowing in Group 5 (VHF/HR) compared to Group 1 (VLF/LR), but not in other groups, using a statistical method described as a “pairwise unplanned simultaneous test procedure” [Sokal and Rohlf 1981]. The authors also reported that when individual hands were the basis of calculations rather than subjects, Group 3 had a significantly higher prevalence of median nerve slowing. Calculations of the data using PRs and chi-squares [Kleinbaum et al. 1982] resulted in significantly higher prevalences of median nerve slowing in each of Groups 3, 4, and 5 (moderate to high repetition, with moderate to very high force) compared to Group 1 (VLR/LF). PRs are 1.9 (95% CI 1.3–2.7), 1.7 (95% CI 1.1–2.5), and 2.0 (95% CI 1.1–3.4) for Groups 3, 4, and 5, respectively. A conservative (Bonferroni) adjustment of the significance level to 0.0125 for multiple comparisons [Kleinbaum et al. 1982] would result in Group 5 no longer being statistically significantly different from Group 1 (p=0.019), but Group 4 (p=0.009), and Group 3 (p=0.000) remain statistically significantly higher than Group 1 in prevalence of median nerve slowing.

In 1992, Nathan et al. [1992a] reported on a follow-up evaluation in the same study group. Sixty-seven percent of the original study subjects were included. Hands (630), rather than subjects, were the basis of analysis in this study. Novice workers (those employed less than 2 years in 1984) were less likely to return than non-novice workers (56% compared to 69%, p=.004). Maximum latency differences in median nerve sensory conduction were determined as in the Nathan et al. [1988] study. The authors state that there was no significant difference in the prevalence of median nerve slowing between any of the exposure categories in Nathan et al. [1988] using the same statistical method described in the Nathan et al. 1988 study. However, calculations using common statistical methods result in the following PRs for slowing: Group 3–1.5 (95% CI 1.0–2.2), Group 4–1.4 (95% CI 0.9–2.1), and Group 5–1.0 (95% CI 0.5–2.2), compared to Group 1. Group 5 had the same prevalence of slowing (18%) as Group 1 in 1989. In 1984 the prevalence of slowing was 29% in Group 5, and 15% in Group 1. The drop in prevalence of median nerve slowing in Group 5 between 1984 and 1989 might be explained by the higher drop-out rate among cases in Group 5 compared to Group 1 (PR 2.9, 95% CI 1.3–6.6). This was not addressed by the authors.

Punnett et al. [1985] compared the symptoms and physical findings of CTS in 162 women garment workers and 76 women hospital workers such as nurses, laboratory technicians, and laundry workers. Eighty-six percent of the garment workers were sewing machine operators and finishers (sewing and trimming by hand). The sewing machine operators were described as using highly repetitive, low force wrist and finger motions, whereas finishing work also involved shoulder and elbow motions. The exposed garment workers probably had more repetitive jobs than most of the hospital workers. CTS symptoms occurred more often among the garment workers (OR 2.7, 95% CI 1.2–7.6) compared to the hospital workers. There was a low participation rate (40%) among the hospital workers.

Schottland et al. [1991] carried out a comparison of NCS findings in poultry workers and job applicants as referents. No exposure assessment was performed, and applicants were not excluded if they had prior employment in the plant. Results indicated that the right median nerve sensory latency was significantly longer in 66 female poultry workers compared to 41 female job applicants. In these two groups of women there were less pronounced differences in the left median sensory latency. The latencies in the 27 male poultry workers did not differ significantly from the 44 male job applicants, although the power calculations presented in the paper noted limited power to detect differences among male participants. The OR for percentage of female poultry workers who exceeded the criteria value for the right median sensory latency is 2.86 (95% CI 1.1–7.9). The major limitations of this study are the absence of detailed information on exposure and the inclusion of former poultry workers into the applicant group, as well as the inadequate sample size, and the personal characteristics of these workers. This study found a significant association between highly repetitive, highly forceful work and abnormal NSC consistent with CTS. It does not allow analysis of repetition alone.

Stetson et al. [1993] used measurements of sensory nerve conduction velocity of the median nerve as indicators of nerve impairment or CTS; clinical examination results were not reported in this article. Three groups were studied: a reference group of 105 workers without occupational exposure to highly forceful or repetitive hand exertions, 103 industrial workers with hand/wrist symptoms, and 137 asymptomatic industrial workers. Exposure was assessed with a checklist by trained workers. Factors considered included repetitiveness (Silverstein criteria), force defined by the weight of an object that is carried or held, localized mechanical stress, and posture. Exposure assessments were available on 80% of the industrial workers. Most of the industrial workers were on repetitive jobs (76%), a minority carried more than ten pounds some of the time (32%), and gripped more than six pounds at least some of the time (44%). The analysis controlled for several confounders including age, gender, finger circumference, height, weight, and a square-shaped wrist. In the comparison of the asymptomatic to symptomatic industrial workers, the mean exposure for the symptomatic industrial workers was nonsignificantly slightly greater for all exposure factors except for repetitiveness. The median sensory amplitudes were significantly smaller ($p<0.01$) and latencies longer ($p<0.05$) for industrial workers with exposure to high grip forces compared to those without. Mean sensory amplitudes were significantly smaller ($p<0.05$) and motor and sensory latencies were significantly longer ($p<0.01$) in the industrial asymptomatic workers compared to the control group. These findings for the motor latencies are similar to Feldman et al. [1987]. Since most of the industrial workers were exposed to repetitive work, it is not clear whether this study population allowed a comparison between repetitive and non-repetitive work. Overall this study suggests that repetitive work combined with other risk factors is associated with slowing of median nerve conduction.

The Wieslander et al. [1989] case-control study used self-reported information collected via telephone interview about the duration of exposure (number of years and hours per week) to several work attributes including repetitive work. Definitions for these work attributes were not provided. Three categories of duration of exposure were defined for each attribute (<1 year, 1–20 years, and >20 years), but the asymmetry of the categories was not explained. A significant OR for reporting repetitive movements of the wrist comparing CTS patients to hospital referents (OR 4.6) and general population referents (OR 9.6) was reported, but only among those employed greater than 20 years. Those employed from 1–20 years compared to the referent population had elevated ORs for repetitive movements of the wrist (1.5 for CTS patients compared to hospital referents, and 2.3 compared to population referents), but these were not significant. Jobs with increasing numbers of work risk factors gave increasing ORs (from 1.7 to 7.1) among CTS cases when compared to referents; these were statistically significant when there were two or more risk factors. Given the limited quality of the exposure data and findings (repetition is a significant risk factor only after 20 years of exposure), this is only suggestive of a relationship between repetition alone and CTS.

Studies Not Meeting Any of the Criteria

Liss et al. [1995] conducted a mail survey concerning CTS among 2,124 Ontario dental hygienists compared to 305 dental assistants who do not scale teeth. Both groups had a low response rate (50%). The age adjusted OR was 5.2 (95% CI 0.9–32) for being told by a physician that you had CTS and 3.7 (95% CI 1.1–1.9) using a questionnaire-based definition of CTS. The major limitations of this study are the low participation rate, the lack of a detailed exposure assessment for repetitiveness, and self-reported health outcome.

Strength of Association—Repetition and CTS

Three of the five studies that met all four criteria evaluated the effect of repetitiveness alone on CTS: Chiang et al. [1990], Silverstein et al. [1987], and Chiang et al. [1993].

Chiang et al. [1990] reported an OR of 1.9 ($p<0.05$) for CTS among those with highly repetitive jobs. The OR for CTS among those exposed to high repetitiveness and cold was 3.32 ($p<0.05$). The additional effect attributed to cold may be at least partially explained by forceful motions among workers who were also exposed to cold. Force was not evaluated in this study.

Silverstein et al. [1987] reported an OR of 5.5 ($p<0.05$) for repetition as a single predictor of CTS. Among workers exposed to high repetition and high force, the OR was 15.5 ($p<0.05$).

Chiang et al. [1993] reported a significant trend of increasing prevalence of CTS with increasing exposure to repetition and/or force (8.2%, 15.3%, and 28.6%, $p<0.05$). Repetition (of the whole upper limb, not the wrist) alone did not significantly predict CTS (OR 1.1).

In summary, three studies that met all four criteria reported ORs for CTS associated with repetition. The statistically significant ORs for CTS attributed to repetition alone ranged from 1.9 to 5.5. The statistically significant ORs for CTS attributed to repetition in combination with force or cold ranged from 3.3 to 15.5. Gender, age, and other potential confounders were addressed and are unlikely to account for the associations reported.

Five other studies observed job tasks, then grouped them into categories according to estimated levels of repetitiveness combined with other risk factors [Feldman et al. 1987; Moore and Garg 1994; Nathan et al. 1988, 1992a; and Osorio et al. 1994]. CTS case definitions reported here required more than symptom-defined criteria. Moore and Garg [1994] reviewed medical records; Nathan et al. [1988] and Osorio et al. [1994] performed nerve conduction studies.

Feldman et al. [1987] reported an OR of 2.7 (*p*<0.05) for a positive Phalen's test among workers in high exposure jobs, compared to low exposure jobs.

Moore and Garg [1994] reported an OR of 2.8 (0.2, 36.7) for CTS among workers in "hazardous" jobs compared to workers in "nonhazardous" jobs.

Nathan et al.'s [1988] data result in PRs for four groups with varying levels of repetitiveness and force from very low (VL) to very high (VH), compared to a very low force, low repetition group (VLF/LR):
LF/VHR versus VLF/LR: 1.0 (95% CI 0.5–2.0)
MF/MR versus VLF/LR: 1.9 (95% CI 1.3–2.7)
HF/MR versus VLF/LR: 1.7 (95% CI 1.1–2.5)
VHF/HR versus VLF/LR: 2.0 (95% CI 1.1–3.4).

Nathan et al. [1992a] data, a 5-year follow-up of the 1988 study, result in PRs for the following groups:
LF/VHR versus VLF/LR: 1.0 (95% CI 0.6–1.9)
MF/MR versus VLF/LR: 1.5 (95% CI 1.0–2.2)
HF/MR versus VLF/LR: 1.4 (95% CI 0.9–2.1)
VHF/HR versus VLF/LR: 1.0 (95% CI 0.5–2.2).

Osorio et al. [1994] reported an OR of 6.7 (95% CI 0.8–52.9) for CTS among workers in high exposure jobs, compared to workers in low exposure jobs. Using a symptom-based case definition, the OR for the same comparison groups was 8.3 (95% CI 2.6–26.4).

To summarize, three of the five studies reviewed resulted in statistically significant positive findings for CTS associated with combined exposures. Feldman et al. [1987] reported an elevated OR for CTS with high combined exposure. Nathan et al.'s [1988] data resulted in elevated PRs for CTS among the three highest combined exposure groups. Nathan et al.'s [1992a] data resulted in an elevated PR for CTS among one of the high combined exposure groups. There was evidence of survivor bias in the highest exposure group.

The following studies used job title or job category to represent exposure to repetitiveness combined with other exposures and defined CTS based on physical examination [Baron et al. 1991, McCormack et al. 1990, Punnett et al. 1985] or nerve conduction studies [Schottland et al. 1991].

Baron et al. [1991] reported an OR of 3.7 (95% CI 0.7–16.7) for CTS, defined by symptoms and physical examination, among grocery checkers compared to other grocery workers.

McCormack et al. [1990] reported the following ORs for CTS among workers in each of four broad job categories that were considered exposed, compared to a comparison group of maintenance workers and cleaners that was considered to have low exposure:
Boarding versus Low: 0.5 (95% CI 0.1–2.9)
Sewing versus Low: 0.9 (95% CI 0.3–2.9)

Packaging versus Low: 0.4 (95% CI 0.0–2.4)
Knitting versus Low: 0.6 (95% CI 0.1–3.1)

Punnett et al. [1985] reported an OR of 2.7 (95% CI 1.2–7.6) for CTS among garment workers versus hospital workers.

Schottland et al. [1991] reported an OR of 2.86 (95% CI 1.1–7.9) for prolonged right median sensory latency among female poultry workers, compared to female applicants for the same jobs. No significant differences were identified among males.

In summary, two of the four studies reviewed above reported significantly elevated ORs for CTS or median sensory nerve conduction slowing.

Wieslander et al. [1989] reported an OR for CTS (surgical cases, confirmed by NCS) of 2.7 (95% CI 1.3–5.4) among those with self-reported exposure to repetitive wrist movement >20 years, compared to hospital referents, and 4.5 (95% CI 2.0–10.4), compared to population referents. Significant OR s for CTS among those with combined job risk factors ranged from 3.3 to 7.1.

The remaining two studies relied on self-reported symptoms and self-reported exposures from mail [Morgenstern et al. 1991] or telephone surveys [Liss et al. 1995]. Data quality and response rates limit interpretation of findings.

In conclusion, among the studies that measured repetition alone, there is evidence that repetition is positively associated with CTS. The majority of studies provide evidence of a stronger positive association between repetition combined with other job risk factors and CTS.

Temporal Relationship: Repetition and CTS

The question of which occurs first, exposure or disease, can be addressed most directly in prospective studies. However, study limitations such as survivor bias can cloud the interpretation of findings. In our analysis of Nathan et al.'s [1992a] data, 2 of 3 groups that were exposed to forceful hand/wrist exertions were more likely to have median nerve slowing when nerve conduction testing was repeated 5 years later. The highest exposure group had the same prevalence of slowing as the lowest exposure group in 1989, whereas they had a higher prevalence rate in 1984. As discussed above, this apparent decrease in prevalence over 5 years can probably be explained by a higher drop-out rate among cases in the highest exposure group, compared to the lowest exposure group. These interpretations of the data differ from those of the authors. Further study is needed to clarify these issues. However, to our knowledge, there is no evidence demonstrating that those with CTS would be more likely to be hired in jobs that involve high exposure to repetitive hand/wrist exertions and combined job risk factors, compared to those without CTS. In fact, employment practices tend to exclude new workers with CTS from jobs that require repetitive and intensive hand/wrist exertion.

Feldman et al. [1987] reported longer median motor (but not sensory) latencies among workers with combined exposure to hand/wrist exertion, compared to nerve conduction findings in the same group one year earlier.

Cross-sectional studies provide evidence that exposure occurred before CTS, by using case definitions that exclude pre-existing cases, and by excluding recently hired workers from the study. The studies that provide evidence that repetitive and combined job exposures are associated with CTS followed these practices, therefore the associations identified cannot be explained by disease occurring before exposure.

Consistency in Association for Repetition and CTS

One study [English et al. 1995] reported a statistically significant negative association between repetitive work and CTS. The specific exposure was self-reported repeated finger tapping; the investigators stated that they had difficulty interpreting this finding. All of the other statistically significant findings pointed to a positive association between repetitive work and CTS. The non-significant estimates of RR were also mostly greater than one.

Coherence of Evidence for Repetition

One of the most plausible ways that repetitive hand activities may be associated with CTS is thorough causing a substantial increase in the pressure in the carpal tunnel. This in turn can initiate a process which results in either reversible or irreversible damage to the median nerve [Rempel 1995]. The increase in pressure, if it is of sufficient duration and intensity, may reduce the flow of blood in the epineural venules. If prolonged, this reduction in flow may affect flow in the capillary circulation, resulting in greater vascular permeability and endoneural and synovial edema. Because of the structure of the median nerve and the carpal tunnel, this increase in fluid and resulting increase in pressure may persist for a long period of time. If the edema becomes chronic, then it may trigger a fibrosis which damages the function of the nerve. The interplay between acute increases in pressure and chronic changes to the nerve could partially explain why there is not a stronger correlation between symptoms of CTS and slowing of the median nerve. Both symptoms and slowing of the median nerve are likely to have both acute and chronic components in many cases of CTS.

The work determinants of pressure in the carpal tunnel are wrist posture and load on the tendons in the carpal tunnel. For example, the normal resting pressure in the carpal tunnel with the wrist in a neutral posture is about 5 millimeters of mercury (mmHg), and typing with the wrist in 45E of extension can result in an acute pressure of 60 mmHg. Substantial load on the fingertip with the wrist in a neutral posture can increase the pressure to 50 mmHg. A parabolic relationship between wrist posture and pressure in the carpal tunnel has been found. In laboratory studies of normal subjects, elevated carpal tunnel pressures quickly return to normal once the repetitive activity stops; patients with CTS take a long time for the pressure to return to their baseline values. One of the supporting observations for this model is that at surgery for CTS, edema and vascular sclerosis (fibrosis due to ischemia) are common [Rempel 1995].

This model of the etiology of work-related CTS is consistent with two observations from the epidemiological literature. First, it illustrates why both work and nonwork factors such as obesity may be important because anything that increases pressure in the carpal tunnel may contribute to CTS. Second, it explains why repetitiveness independent of wrist posture and load on the flexor tendons may not be a major risk factor for CTS.

Exposure-Response Relationship for Repetition

Evidence of an exposure-response relationship is provided by studies that show a correlation between the level or duration of exposure and either the number of cases, the illness severity, or the time to onset of the illness. Silverstein et al. [1987] showed an increasing prevalence of CTS signs and symptoms among industrial workers exposed to increasing levels of repetition and forceful exertion. This relationship was not seen when repetition alone was assessed. Similar findings on an exposure-response relationship were reported by Chiang et al. [1993], Osorio et al. [1994], Wieslander et al. [1989], and by Stock [1991] in her reanalysis of the Nathan et al. [1988] data.

Morgenstern et al. [1991] and Baron et al. [1991] reported increased prevalence of CTS with increasing length of time working as a grocery cashier.

Conclusions Regarding Repetition

Based on the epidemiologic studies noted above, especially those with quantitative evaluation of repetitive work, the strength of association for CTS and repetition has been shown to range from an OR of 2 to 15. The higher ORs are found when contrasting highly repetitive jobs to low repetitive jobs, and when repetition occurred in combination with high levels of forceful exertion. Those studies with certain epidemiologic limitations have also been fairly consistent in showing a relationship between repetition and CTS. The evidence from those studies which defined CTS based on symptoms, physical findings, and NCS is limited, due to the variety of methods used [Nathan et al. 1988; Stetson et al. 1993; Barnhart et al. 1991].

There is **evidence** of a positive association between highly repetitive work alone and CTS. There is **strong evidence** of a positive association between highly repetitive work in combination with other job factors and CTS, based on currently available epidemiologic data.

FORCE AND CTS

Definition of force for CTS

The studies reviewed in this section determined hand/wrist force exposure by a variety of methods. Some investigators [Armstrong and Chaffin 1979; Chiang et al. 1993; Silverstein et al. 1987] measured force by EMGs of representative workers' forearm flexor muscles while they performed their usual tasks. EMG measurements were averaged within each work group to characterize the force requirements of the job; jobs were then divided into low or high categories if the average force was above or below a cutoff point. Moore and Garg [1994] estimated force as %MVC, based on weight of tools and parts and population strength data, adjusted for extreme posture or speed. Jobs were then predicted to be either hazardous or safe (for any upper extremity musculoskeletal disorder), based on exposure data and judgment. Stetson et al. [1993] estimated manipulation forces based on weights of tools and parts and systematically recorded observations of one or more workers on each job. Jobs were then ranked according to grip force cutoffs. Nathan et al. [1988, 1992a] and Osorio et al. [1994] estimated relative levels of force (e.g., low, moderate, high) after observation of job tasks. McCormack et al. [1990] grouped jobs into broad job categories based on similarity of observed job tasks; one job group (boarding) required forceful hand/wrist exertions. Baron et al. [1991] and Punnett et al. [1985] used job title as a surrogate for exposure to forceful hand/wrist exertions.

Much of the epidemiologic data on CTS and force overlaps with those studies discussed in the above section on repetition. Repetitive work is frequently performed in combination with external forces, and much of the epidemiologic literature has combined these two factors when determining association with CTS.

Studies Reporting on the Association of Force and CTS

Eleven studies reported results on the association between force and CTS. The epidemiologic studies that addressed forceful work and CTS tended to compare working groups by classifying them into broad categories based on estimates of the forcefulness of hand/wrist exertions in combination with estimated repetitiveness. In most studies the exposure classification was an ordinal rating (e.g., low, moderate, or high); in some studies job categories or titles were used as surrogates for exposure to force exertions.

Studies Meeting the Four Evaluation Criteria

Four studies that evaluated the relationship between forceful hand/wrist exertion and CTS met all four criteria: Chiang et al. [1993], Moore and Garg [1994], Osorio et al. [1994], Silverstein et al. [1987]. Chiang et al. [1993] studied 207 workers from 8 fish-processing factories in Taiwan. Jobs were divided into 3 groups based on levels of force and repetitiveness. The comparison group (low force/low repetitiveness) was managers, office staff, and skilled craftsmen. The fish-processing workers were divided into high force or high repetitiveness (group 2), and high force and high repetitiveness (group 3). Hand force requirements of jobs were estimated by electromyographs of forearm flexor muscles of a representative worker from each group performing usual job tasks. High force was defined as an average hand force of >3 kg repetition of the upper limb (not specifically the wrist) was defined based on observed cycle time [Silverstein et al. 1987]. CTS was defined on the basis of symptoms and positive physical examination findings, ruling out systemic diseases and injury. CTS prevalence for the overall study group was 14.5%. CTS prevalence increased from group 1 to group 3 (8.2%, 15.3%, and 28.6%), a statistically significant trend $p<0.01$). Statistical modeling showed that women in this study group had a higher prevalence of CTS than men (OR 2.6, 95% CI 1.3–5.2). Force also significantly predicted CTS (OR 1.8, 95% CI 1.1–2.9), but not repetitiveness. Because the proportion of women varied by exposure group (48%, 75%, and 79% from groups 1 to 3), the possibility of an interaction between gender and job exposure exists, but this was not statistically examined. In an analysis limited to females, the 2 significant predictors of CTS were oral contraceptive use (OR 2.0, 95% CI 1.2–5.4), and force (OR 1.6, 95% CI 1.1–3.0). Concern over interpretation of these findings is raised because oral contraceptive use varies with age, and age may vary with job exposures.

These potential interactions were not examined, and women's ages by job group were not reported.

Moore and Garg [1994] evaluated 32 jobs in a pork processing plant and then reviewed past OSHA 200 logs and plant medical records for CTS cases in these job categories. IRs were calculated using the full-time equivalent (FTE) number of hours worked as reported on the logs. The exact number of workers was not reported. Exposure assessment included videotape analysis of job tasks for repetitiveness and awkward postures. The force measure was an estimate of the %MVC, based on weight of tools and parts and population strength data, adjusted for extreme posture or speed. Jobs were then predicted to be either hazardous or safe (for all Upper Extremity MSDs), based on exposure data and judgment. CTS was determined by reviewing OSHA 200 logs and plant medical records. The proportion of CTS in the overall study group during the 20 months of case ascertainment was 17.5 per 100 FTEs. If the occurrence of CTS did not vary over this period, the proportion of CTS in a 12-month period would be 10.5 per 100 FTEs. The hazardous jobs had a RR for CTS of 2.8 (0.2, 36.7) compared to the safe jobs. Potential for survivor effect (79% of the workforce was laid off the year before the study), limited latency period (8-32 months), and the potential for incomplete case ascertainment (underreporting is common on OSHA 200 logs, and logs were not reviewed for the first 12 months of the study) limit confidence in this estimate. One of the more hazardous jobs, the Ham Loaders, required extreme wrist, shoulder and elbow posture and was rated 4 on a 5-point scale for force, yet there was no observed morbidity. Since this job did not start until 1989, the period of observation for musculoskeletal disorders for this job was only 8 months. Other jobs studied allowed for up to a 32-month latency period. The possibility of differential case ascertainment between exposed and unexposed jobs exists, both because of different observation periods, as well as the likelihood that turnover may have been greater in the exposed jobs. It is also unclear whether employees worked full-time or part-time hours.

Osorio et al. [1994] studied 56 supermarket workers. Exposure to repetitive and forceful wrist motions was rated as high, moderate, or low, following observation of job tasks (97% initial concordance with 2 independent observers). The CTS case definition was based on symptoms and nerve conduction studies. CTS-like symptoms occurred more often (OR 8.3, 95% CI 2.6–26.4) among workers in the high exposure group compared to the low exposed group. The odds of meeting the symptom and NCS-based CTS case definition among the high exposure group were 6.7 (95% CI 0.8–52.9), compared to the low exposure group.

Silverstein et al. [1987] measured force by electromyographs of representative workers' forearm flexor muscles while they performed their usual tasks. EMG measurements were averaged within each work group to characterize the force requirements of the job; jobs were then divided into high or low categories if the mean adjusted force was above or below
4 kg. Jobs were then classified into 4 groups that also accounted for repetitiveness: low force/low repetitiveness, high force/low repetitiveness, low force/high repetitiveness, and high force/high repetitiveness. Fourteen cases (2.1% prevalence) of CTS were

diagnosed based on standardized physical examinations and structured interviews.

The OR for CTS in high force jobs compared to low force jobs, irrespective of repetitiveness, was 2.9 ($p>0.05$). The plant- adjusted OR for CTS in jobs with combined exposures to high force and high repetition was 14.3 ($p<0.05$), compared to jobs with low force and low repetition. Age, gender, plant, years on the job, hormonal status, prior health history, and recreational activities were analyzed and determined not to confound the associations identified. The OR for CTS in jobs with combined exposure from the multiple logistic analysis was 15.5 (95% CI 1.7–142.)

Studies Meeting at Least One Criterion

Baron et al. [1991] studied CTS in 124 grocery store checkers and 157 other grocery store workers who were not checkers. The CTS case definition required symptoms that met pre-determined criteria on a standardized questionnaire. Physical examinations were also performed, but participation rates at the work sites were higher among the exposed group (checkers: 85% participation, non-checkers: 55% participation). Telephone interviews to non-checkers resulted in questionnaire completion by 85% of the non-checkers. Based on a questionnaire case definition, the OR for CTS among checkers was 3.7 (95% CI 0.7–16.7), in a model that included age, hobbies, second jobs, systemic disease, and obesity.

McCormack et al. [1990] studied 1,579 textile production workers compared to 468 other nonoffice workers, a comparison group that included machine maintenance workers, transportation workers, cleaners, and sweepers. The textile production workers were divided into four broad job categories based on similarity of upper extremity exertions. The Boarding group required the most physical exertion. No formal exposure assessment was conducted. Health assessment included a questionnaire and screening physical examination followed by a diagnostic physical examination. CTS was diagnosed using predetermined clinical criteria. The severity of cases was also reported as mild, moderate or severe. The overall prevalence for CTS was 1.1%, with 0.7% in Boarding, 1.2% in Sewing, 0.9% in Knitting, 0.5% in Packaging/Folding, and 1.3% in the comparison group. None of the differences were statistically significant. A statistical model that also included age, gender, race, and years of employment showed that CTS occurred more often among women in this study ($p<0.05$). Interpretation of these data, especially with a low prevalence disorder like carpal tunnel syndrome, is difficult since gender varied with job (e.g., 94% of Boarding workers were female, compared to 56% in the comparison group), and the comparison group may have also been exposed to upper extremity exertions (machine maintenance workers, transportation workers, cleaners and sweepers). Interactions among potential confounders were not addressed, but they are suspected because of significant associations between race and three musculoskeletal disorders.

Nathan et al. [1988] studied median nerve conduction of 471 randomly selected workers from four industries (steel mill, meat/food packaging, electronics, and plastics manufacturing). Jobs were grouped into 5 relative levels of force (from very light to very high) after observation of job tasks. Jobs were also rated for repetitiveness (5 levels). Thirty-nine percent of the study subjects had impaired sensory conduction, or "slowing" of the median nerve. The 5 exposure groups were defined as follows: Group 1 is very low force, low repetition (VLF/LR); Group 2 is low force, very high repetition (LF/VHR); Group 3 is moderate force, moderate repetition (MF/MR); Group 4 is high force/moderate repetition (HF/MR); and Group 5 is very high force/high repetition (VHF/HR). The most logical comparisons to evaluate the effect of force would be Groups 3, 4, and 5 (moderate, high, and very high force) compared to Group 1 (low force). Group 2 jobs are not a good comparison because they are very highly repetitive, which may confound the comparisons. The authors reported a significantly higher number of subjects with median nerve slowing in Group 5 (VHF/HR) compared to Group 1 (VLF/LR), but not in other groups, using an uncommon statistical method (pairwise unplanned simultaneous test procedure [Sokal and Rohlf 1981]). The authors also reported that when individual hands were the basis of calculations rather than subjects, Group 3 had a significantly higher prevalence of median nerve slowing. Calculations of the more familiar PRs and chi-squares [Kleinbaum et al. 1982], using the published data, result in higher prevalences of median nerve slowing in each of Groups 3, 4, and 5, compared to Group 1 (PRs: 1.9, 95% CI 1.3–2.7; 1.7, 95% CI 1.1–2.5; and 2.0, 95% CI 1.1–3.4, respectively). A conservative adjustment (Bonferroni) of the significance level to 0.0125 for multiple comparisons [Kleinbaum et al. 1982] would result in Group 5 no longer being statistically significantly different from Group 1 (p=0.019), but Group 4 (p=0.009) and Group 3 (p=0.000) remain statistically significantly higher than Group 1 in prevalence of median nerve slowing.

In 1992 Nathan et al. [1992a] reported on a follow-up evaluation in the same study group. Sixty-seven per cent of the original study subjects were included. Hands (630), rather than subjects, were the basis of analysis in this study. Novice workers (those employed less than 2 years in 1984) were less likely to return than non-novice workers (56% compared to 69%, p=0.004). Probable CTS was defined on the basis of symptoms reported during a structured interview and a positive Phalen's or Tinel's test. Maximum latency differences in median nerve sensory conduction were determined as in the 1984 study. The authors state that there was no significant difference in the prevalence of slowing between any of the exposure categories in 1989. However, calculations using common statistical methods show significantly higher prevalences of slowing in Group 4 (PR 1.4, 95% CI 0.9–2.1) compared to Group 1. Group 3's prevalence of slowing was 26% compared to Group 1's 18%, but this difference was not statistically significant (p=0.07). Group 5 had the same prevalence of slowing (18%) as Group 1 in 1989; the prevalence of slowing in Group 5 was 29% in 1984. The drop in prevalence of slowing in Group 5 between 1984 and 1989 might be explained by the higher drop-out rate among cases in Group 5 compared to Group 1 (PR 2.9, 95% CI 1.3–6.6). This was not addressed by the authors.

Punnett et al. [1985] compared the symptoms and physical findings of CTS in 162 women garment workers and 76 women hospital workers such as nurses, laboratory technicians, and laundry workers. Eighty-six percent of the garment workers were sewing machine operators and finishers (sewing and trimming by hand). The sewing machine operators were described as using highly repetitive, low force wrist and finger motions, whereas finishing work also involved shoulder and elbow motions. The exposed garment workers likely had more repetitive jobs than most of the hospital workers. CTS symptoms occurred more often among the garment workers (OR 2.7, 95% CI 1.2–7.6) compared to the hospital workers. There was a low participation rate (40%) among the hospital workers.

Stetson et al. [1993] conducted nerve conduction studies on 105 administrative and professional workers, and 240 automotive workers. Hand/wrist forces were estimated based on weights of tools and parts and systematically recorded observations of one or more workers on each job. Jobs were then ranked according to grip force cutoffs: <6 lb, >6 lb, >10 lb. Median nerve measures differed among the groups: index finger sensory amplitudes were lower and distal sensory latencies were longer among automotive workers in jobs requiring grip force >6 lb and >10 lb, compared to those requiring less than 6 lb ($p<0.05$ for all). At the wrist, median sensory amplitudes were also lower and distal median sensory latencies were also longer among the >6 lb, and the >10 lb exposure groups ($p<0.05$ for 3 of 4 differences). Age, height, and finger circumference were included in statistical models. The automotive workers were then divided into two groups, symptomatic (n=103) and asymptomatic (n=137), based on whether or not they met standard interview criteria for CTS symptoms. When comparisons were made to the administrative and professional workers, 15 of 16 measures of median and ulnar nerve function showed lower amplitudes and longer latencies ($p<0.05$) among the asymptomatic automotive workers; differences were greater between the symptomatic automotive workers and the white collar workers. The symptomatic automotive workers had lower amplitudes and longer latencies for 5 of 6 median sensory measures ($p<0.05$), compared to the asymptomatic automotive workers; there were no significant differences in ulnar nerve function between these two groups. Asymptomatic automotive workers had "healthier" median nerves than automotive workers with CTS symptoms, but there were no differences between these 2 groups in ulnar nerve function, suggesting that the case definition was specific for CTS.

Of the studies that addressed CTS, almost all examined occupations and jobs in which force was combined with another exposure factor (such as repetition or awkward postures). Chiang et al. [1993] estimated exposure to hand/wrist force independent of repetitiveness and found statistically significant RRs for CTS ranging from 1.6 to 1.8. Estimates of RR that were not statistically significant ranged from 0.4 to 6.7 [McCormack et al. 1990; Osorio et al. 1994]. Relative risk estimates for CTS among workers exposed to a combination of forceful and repetitive hand/wrist exertions ranged from 1.0 to 15.5 [Nathan et al. 1988, 1992a; Silverstein et al. 1987].

Study limitations may impact the interpretation of findings. One limitation to consider is gender effect. Of the studies listed above reporting statistically significant associations between forceful hand/wrist exertions and CTS, gender effect was controlled for in the analyses. Other potential limitations such as selection factors impact the interpretation of the studies reviewed. Survivor bias can be a concern. If workers with CTS are more likely to leave jobs that require forceful and repetitive hand/wrist exertions than jobs without those demands, then the workers in the highest risk jobs may be "survivors" (those who did not get CTS). Our analysis of Nathan's [1992a] data from a follow-up of industrial workers shows that cases (with median nerve slowing) were more likely to drop out of the most highly exposed group than the unexposed group, which might explain why the RR for high exposure decreased from 2.0 to 1.0 over a 5-year period. Survivor bias results in an underestimate of the RR.

Refined or exact measures of exposure to forceful hand/wrist exertions are not always used in epidemiologic studies (e.g., sometimes exposure is based on job category and not actual forceful measurements); this can result in some study subjects being assigned to the wrong exposure category. When this occurs, the usual effect is again to underestimate the RR between exposure groups.

Stetson et al. [1993] did not report RR estimates for exposure variables, but they reported that median sensory amplitudes were significantly smaller and distal sensory latencies were significantly longer in groups with forceful hand exertions ($p<0.05$). Age, height, and finger circumference were included in statistical models.

Temporality, Force and CTS

Temporal issues can usually best be addressed using longitudinal studies. However, study limitations, such as survivor bias, can cloud the findings of even prospective studies. In our re-analysis of Nathan et al.'s [1992a] data, 2 of 3 groups exposed to forceful hand/wrist exertions were more likely to have median nerve slowing when nerve conduction testing was repeated 5 years later. The highest exposure group had the same prevalence of slowing as the lowest exposure group in 1989, whereas there had been a higher prevalence rate in 1984. As discussed above, this apparent decrease in prevalence over 5 years can likely be explained by survivor bias. Our interpretations of the data differ from those of the author. Further study is needed to clarify these issues. To our knowledge, there is no evidence that workers with pre-existing CTS are more likely to seek or to be employed in jobs with high force requirements. We believe that employment practices would, if they had any influence, tend to exclude new hires with CTS from jobs with high force requirements for the hand/wrist.

Case definitions in most of the cross-sectional studies excluded cases that occurred before working on the current job. This limits CTS cases studied to those that occurred following current exposure. Several of the studies reviewed also required a minimum time period of working on the job before counting CTS cases. This increases the likelihood that exposure to forceful hand/wrist exertion occurred for a sufficient length of time to develop CTS.

There is evidence that CTS is also attributable to nonwork causes (hobbies, sports, other medical conditions, and hormonal status in women, etc.). One issue which deals with temporality is whether those with nonwork-related CTS would be more likely to be hired into jobs requiring more forceful hand/wrist exertions than those without CTS. Again, it seems unlikely that those with pre-existing CTS would be preferentially hired into jobs requiring highly forceful hand/wrist exertions.

Consistency of Association for Force and CTS

Most of the statistically significant estimates of RR for CTS among workers with exposure to forceful hand/wrist exertions were positive. No studies found statistically significant negative associations between forceful hand/wrist exertions and CTS. One study reported ORs that were less than one among the groups that were described as exposed to repetitive hand movements; chance and study limitations cannot be ruled out as possible explanations for this finding. The other nonsignificant estimates of RR were, with one exception, greater than one.

Statistical significance can be a function of power (the ability of a study to detect an association when one does exist). In general, larger studies are necessary in order to have sufficient power to detect associations with rare diseases. CTS is a less frequently observed disorder than tendinitis, for example, and so larger studies are required to detect associations with confidence.

Coherence of Evidence, Force and CTS

Please refer to the Repetition and CTS Section.

Exposure-Response Relationship, Force and CTS

None of the studies reviewed demonstrated that increasing levels of force alone resulted in increased risk for CTS. The only evidence for an increasing risk for CTS that can be attributed to increasing levels of force alone is from a comparison across 2 studies that used the same methods. Chiang et al. [1993] and Silverstein et al. [1987] used the same methods to measure hand/wrist force requirements and repetitiveness of jobs. Chiang et al. [1993] used a lower cutoff point (3 kg compared to 4 kg) in Silverstein et al.'s [1987] study for classifying jobs as "high force"; these investigators used identical definitions of repetitiveness. Therefore, a comparison of the RR estimates between the 2 studies provides some information about the level of risk associated with different levels of force. Chiang et al. [1993] reported an OR of 2.6 (95% CI 1.0–7.3) for the high force and repetitive (HF/HR) (>3 kg) group (limited to females to avoid confounding) compared to the low force and repetitive (LF/LR) group; whereas Silverstein et al. [1987] reported an OR of 15.5 (95% CI 1.7–142) for the HF/HR group (in a statistical model that included gender, age, years on the job, plant and exposure level) compared to the LF/LR group. This comparison provides limited evidence of an increased RR for CTS with increasing level of hand/wrist force.

There is more evidence of a dose-response relationship for CTS with increasing levels of force and repetition combined. Chiang et al. [1993] reported a statistically significant trend of increasing prevalence of CTS with increasing exposure level (8.2% [LF/LR], 15.3% [HF or HR], and 28.6% [HF/HR], $p<0.01$). Silverstein et al. [1987] suggested a multiplicative effect when exposure to high force and high repetitiveness were combined (15.5), compared to high force (1.8) or high repetitiveness (2.7) alone.

Of the remaining nine studies, seven are consistent with the combined effect of force and repetition [Stetson et al. 1993; Moore and Garg 1994; Osorio et al. 1994; Armstrong and Chaffin 1979; Nathan et al. 1988; Punnett et al. 1985; Baron et al. 1991], one is not [McCormack et al. 1990]; and one is equivocal [Nathan et al. 1992a].

In conclusion, there is **evidence** that force alone is associated with CTS. There is **strong evidence** that a combination of forceful hand/wrist exertion and repetitiveness are associated with CTS.

POSTURE AND CTS

Definition of Extreme Postures For CTS

We selected those studies which addressed posture of the hand/wrist area including those addressing pinch grip, ulnar deviation, wrist flexion/extension. Posture is a difficult variable to examine in ergonomic epidemiologic studies. It is hypothesized that extreme or awkward postures increase the required force necessary to complete a task. Posture may increase or decrease forceful effort; its impact on MSDs may not be accurately reflected in measurement of posture alone. Reasons that the variable “extreme posture” has not been measured or analyzed in many epidemiologic studies are: 1) because of the extreme variability of postures used in different jobs as well as the extreme variability of postures between workers performing the same job tasks,
2) because several studies have taken into account the effects of posture when determining other measured variables such as force [Silverstein et al. 1987; Moore and Garg 1994]; and 3) stature often has a major impact on postures assumed by individual workers during job activities.

Studies Meeting the Four Evaluation Criteria

Two studies fulfilled the four criteria for posture and CTS: Moore and Garg [1994], Silverstein et al. [1987]. The overall study designs are mentioned above; the following section will cover the posture assessment.

For the exposure assessment of the posture variables in the Silverstein et al. [1987] study, three representative workers from each selected job performing the jobs for at least three cycles were videotaped using two cameras. The authors then extrapolated the posture data to non-observed workers.

Moore and Garg [1994] used a wrist classification system similar to that used by Stetson et al. [1993], classifying the wrist angle estimated from videotape as neutral, non-neutral or extreme if the flexion/extension angle was 0° to 25°, 25° to 45° and greater than 45°, respectively; or if ulnar deviation was less than 10°, 10° to 20°, and greater than 20°, respectively.

Strength of Association: Posture and CTS

Silverstein found no significant association between percentages of cycle time observed in extreme wrist postures or pinch grip and CTS. “CTS jobs” had slightly more ulnar deviation and pinching but these differences were not statistically significant. The authors noted that among all the postural variables recorded, the variability between individuals with similar or identical jobs was probably the greatest for wrist postural variables. This individual variation within jobs was not taken into account in the analysis, creating a potential for misclassification of individuals by using the variable “job category” in the analysis. The effect of exposure misclassification is usually to decrease differences between exposure groups and decrease the magnitude of association.

Moore and Garg's [1994] classification of jobs did not separate the posture variables from other work factors, and used posture along with other variables to classify jobs into "hazardous" and "safe" categories. The RR of CTS occurring in hazardous jobs was 2.8 but not statistically significant (p=0.44).

Studies Not Meeting All Four Evaluation Criteria

deKrom et al. [1990] compared certain exposure factors between 28 CTS cases from a community sample and 128 CTS cases from a hospital (a total of 156 CTS cases) to 473 community "non-cases" (n=473). The authors relied on self-reported information about duration of exposure (hours per week) to CTS risk factors (flexed wrist, extended wrist, extended and flexed wrists combined; pinch grasp and typing), with respondents recalling exposure from the present to 5 years prior from the questionnaire date. Four groups of duration were used in the analyses (0; 1–7; 8–19, 20–40 hours/week). In this study, the selection process of cases was not consistent. Initially, a random population sample was used, then hospital outpatients were used to supplement the number of CTS cases when numbers were found to be insufficient. This may be a problem when estimating the etiologic role of workload, as cases seeking medical care may cause a referral bias. However, the authors stated that they came up with the same relationship between flexed and extended wrist using only CTS cases from the population-based data. The risk of CTS was found to increase with the reported duration of activities with flexed wrist (RRs from 1.5 to 8.7, with increasing hours) or activities with extended wrist (RR from 1.4 to 5.4 with increasing hours) over the past 5 years, but not for working with a flexed or extended wrist in combination, or working with a pinched grasp. Given the period of recall for self-reported exposure (0–5 years), and no independent observation or attributes of exposure, these results must be interpreted with caution (meaning that within the limitations of the data and conclusions, when considered with other studies that have more stringent methods, the RRs seem consistent and supportive and do not offer alternate conclusions).

Armstrong and Chaffin's [1979] pilot study of female sewing machine operators with symptoms and/or signs for CTS compared to controls found that pinch force exertion (exposure measurements estimated from EMG, film analysis) was significantly associated (OR 2.0). Pinch force was a combination of factors—posture and forceful exertion. The authors reported that CTS-diagnosed subjects used deviated wrist postures more frequently than nondiseased, particularly during forceful exertions. What is unable to be answered due to the study design, was whether the deviated postures were necessitated due to symptoms and signs of CTS, or the deviated postures caused or exacerbated the symptoms and signs.

Stetson et al. [1993] found that "gripping greater than 6 pounds" per hand was a significant risk factor for median distal sensory dysfunction (an indicator of CTS) when the study population was divided into exposed and non-exposed groups. "Gripping greater than 6 pounds" is a variable which combines two work-related variables, posture and forceful exertion. As seen with other studies referenced above, the single work-related variable was not found to be associated with median nerve dysfunction, but the combination of variables was significant. Looking specifically at wrist deviation in the Stetson et al. [1993] study, the midpalm to wrist sensory amplitude was smaller in the group not exposed to wrist deviation (*p*=0.04) compared to those exposed to wrist deviation (contrary to what was expected). Also, no significant differences were found in the mean measurements between nonexposed and exposed groups for use of pinch grip.

Tanaka et al. [1995] analysis of the Occupational Health Supplement of the NHIS population survey depended on self-reported CTS, self-reported exposure factors, and occupation of the respondent for analysis. Self-reported bending and twisting of the hand and wrist (OR 5.9) was found to be the strongest variable associated with “medically-called CTS” among recent workers, followed by race, gender, vibration and age (repetition and force were not included in the logistic models). Limitations of self-reported health outcome and exposure do not allow the conclusions of this study to stand alone; however, when examined with the other studies, it suggests a relationship between posture and CTS.

The two other studies which examined posture and its relationship to CTS did not focus on the hand and wrist. English et al. [1995] found a relationship between self-reported rotation of the shoulder and elevated arm and CTS, an OR of 1.8. Liss et al. [1995] found an OR of 3.7 for self-reported CTS comparing risk factors from dental hygienists to dental assistants, with self-reported percent of time the trunk was in a rotated position relative to the lower body as one of the factors.

Given these limitations of categorizing posture, three studies [Stetson et al. 1993; Loslever and Ranaivosoa 1993; Armstrong and Chaffin 1979] using different methods to measure posture and estimate force, found that the combination of significant force and posture was significantly related to CTS. Marras and Shoenmarklin [1993] also found posture to be significantly associated with CTS when comparing jobs where grip strength was three times greater than in the low risk jobs. In those studies which used self-reports for categorizing posture, the associations were also positive.

Temporal Relationship

There were no longitudinal studies which examined the relationship between extreme posture and CTS. Two cross-sectional studies that met the evaluation criteria addressed the association between posture and CTS. Silverstein et al. [1987] did not find a significant relationship between CTS and extreme posture, but exposure assessment was limited to representative workers; inter-individual variability limited the ability to identify actual relationships between postures and CTS. In the Stetson et al. [1993] study, the authors mentioned the limitations of interpretation of their posture results due to misclassification of workers. They extrapolated exposure data to non-observed workers, so individual variability in work methods and differing anthropometry are not accounted for. These limitations all influence outcome, and the conclusions must be interpreted with caution, and considered along with biomechanical and laboratory studies.

Coherence of Evidence

Flexed wrist postures may reduce the area of the carpal tunnel thus potentially increasing the pressure in the tunnel with a concomitant increase in the risk of CTS [Skie et al. 1990; Armstrong et al. 1991]. Marras and Shoenmarklin [1993] found that the variables of wrist flexion, extension, angular velocity, and wrist flexion, extension, angular acceleration discriminated between jobs with a high versus a low risk of having an upper extremity reportable injury (an OSHA recordable disorder due to repetitive trauma). The authors suggested that this result was due to high accelerations requiring high forces in tendons. Szabo and Chidgey [1989] showed that repetitive flexion and extension of the wrist created elevated pressures in the carpal tunnel compared to normal subjects, and that these pressures took longer to dissipate than in normal subjects. Observed repetitive passive flexion and extension appeared to "pump up" the carpal tunnel pressure; active motion of the wrist and fingers also had an effect over and above that of the passive motions tested. Laboratory studies demonstrate that carpal canal pressure is increased from less than 5mmHg to more than 30 mmHg during wrist flexion and extension [Gelberman et al. 1981].

Exposure-Response Relationship, CTS and Posture

Few studies address exposure-response relationship between CTS and extreme posture. deKrom et al. [1990] reported an increased risk of CTS with workers reporting increasing weekly hours of exposure to wrist flexion or extension (but not a combination of flexion/extension). Laboratory studies also support a dose-response relationship of increased carpal tunnel pressure due to increasing wrist deviation from neutral [Weiss et al. 1995] and pinch force [Rempel 1995].

In conclusion, there is **insufficient evidence** in the current epidemiologic literature to demonstrate that awkward postures alone are associated with CTS.

VIBRATION AND CTS

Definition of Vibration for CTS

We selected studies that addressed manual work involving vibrating power tools and CTS specifically.

Studies Meeting the Four Evaluation Criteria

Two studies examining the association between vibration and CTS fulfilled the four criteria [Chatterjee 1992; Silverstein et al. 1987]. Chatterjee et al. [1982] performed independent exposure assessment of the vibrating tools, and found the rock drillers to be exposed to vibration between the frequencies of 31.5 and 62 Hertz.

Silverstein et al. [1987] is discussed above. Silverstein [1987] had no quantitative measures of vibration, but observed exposure from videotapes and found all jobs with vibration exposure to be highly repetitive and mostly forceful jobs.

Studies Not Meeting the Evaluation Criteria

There are seven studies on Table 5a–4 that meet at least one of the four criteria.

In addition, there are 2 clinical case studies of vibration and CTS [Rothfleish and Sherman 1978; Lukas 1970] that were not controlled for confounders and not referenced in Table 5a–4. Rothfleisch and Sherman [1978] found an excess of power hand tool users among CTS patients. Lucas [1970] examined workers using vibrating hand tools including stone cutters, tunnelers, coal miners, forest workers and grinders (all with a mean of 14 years exposure to vibration) and found CTS in 21%. He found that the prevalence of CTS in some groups was as high as 33% (neither study had a referent group.)

Cannon et al. [1981] found that the self-reported use of vibrating tools, in combination with reported forceful and repetitive hand motions, was associated with a greater incidence of CTS than was repetitive motion alone.

Bovenzi's study in 1994 compared stone workers (145 quarry drillers and 425 stone carvers) exposed to hand-transmitted vibration to 258 polishers and machine operators who performed manual activity only not exposed to hand-transmitted vibration. CTS was assessed by a physician, and exposure was assessed through direct observation to vibrating tools and by interview. Vibration was also measured in a sample of tools.

Strength of Association: Vibration and CTS

Chatterjee et al. [1982] found a significant difference between rock drillers with symptoms and signs of CTS and the controls using the following NCS measurements: median motor latency, median sensory latency, median sensory amplitude, and median sensory duration, all at the $p<0.05$ level. Based on nerve conduction measurements, they also found an OR of 10.9 for rock drillers having abnormal NCS amplitudes in the median and ulnar nerves compared to controls. Bovenzi et al. [1991] found an OR of 21.3 for CTS based on symptoms and physical exam comparing vibration-exposed forestry operators using chain-saws to maintenance workers performing manual tasks. Bovenzi's study in 1994 found an OR of 0.43 for CTS defined by signs and symptoms, controlling for several confounders. In the Silverstein et al. [1987] study the crude OR for high force/high repetition jobs with vibration compared to high force/high repetition without vibration was 1.9, but not statistically significant. This suggested that there may have been confounding (the OR was not statistically significant) between high force/high repetition and vibration. Nilsson et al. [1990] found that platers operating tools such as grinders and chipping hammers had a CTS prevalence of 14% compared to 1.7% among office workers. Nathan et al. [1988] found a PR of 2.0 (95% CI 1.3–3.4) for slowing of nerve conduction velocity when grinders were compared to administrative and clerical workers. Cannon et al. [1981] found an OR of 7.0 for CTS with the use of vibrating hand tools, although there was a strong potential for confounding by hand or wrist posture and forceful exertion.

Temporal Relationship

There were no longitudinal studies which examined the relationship between vibration and CTS.

Consistency in Association

All studies on Table 5a–4 examining vibration and CTS found a significantly positive relationship between CTS and vibration exposure. Most studies had ORs greater than 3.0, so that results were less likely to be due to confounding.

Coherence of Evidence and Vibration

The mechanism by which vibration contributes to CTS and tendinitis development is not well understood, probably because vibration exposure is usually accompanied by exposure to forceful and repetitive movements. Muscles exposed to vibration exhibit a tonic vibration reflex that leads to increasing involuntary muscle contraction. Vibration has also been shown to produce short-term tactility impairments which can lead to an increase in the amount of force exerted during manipulative tasks. Vibration can also lead to mechanical abrasion of tendon sheaths. Neurological and circulatory disturbances probably occur independently by unrelated mechanisms. Vibration may directly injure the peripheral nerves, nerve endings, and mechanoreceptors, producing symptoms of numbness, tingling, pain, and loss of sensitivity. It has been found in rats that vibration has caused epineural edema in the sciatic nerve [Lundborg et al. 1987]. Vibration may also have direct effects on the digital arteries. The innermost layer of cells in the blood vessel walls appears especially susceptible to mechanical injury by vibration. If damaged, these vessels may become less sensitive to the actions of certain vasodilators that require an intact endothelium. The NIOSH Criteria Document on exposure to hand-arm vibration NIOSH [1989] quoted Taylor [1982] as follows: " It is not known whether vibration directly injures the peripheral nerves thereby causing numbness and subsequent sensory loss, or whether the para-anaesthesia of the hands is secondary to the vascular constriction of the blood vessels causing ischemia . . . in the nerve organs."

Exposure-Response Relationship, CTS and Vibration

In the studies examined, only dichotomous categorizations were made, so conclusions concerning an exposure-response relationship cannot be drawn. However, we can see significantly contrasting rates of CTS between high and low exposure groups. Wieslander et al. [1989] found that based on exposure information obtained from telephone interviews, CTS surgery was significantly associated with vibration exposure. Exposure for 1–20 years gave an OR of 2.7, more than 20 years gave an OR of 4.8.

Conclusion

In conclusion, there is **evidence** supporting

an association between exposure to vibration and CTS.

CONFOUNDING AND CTS

It is clear that CTS has several non-occupational causes. When examining the relationship of occupational factors to CTS, it is important to take into account the effects of these individual factors; that is, to control for their confounding or modifying effects. Studies that fail to control for the influence of individual factors may either mask or amplify the effects of work-related factors. Most of the epidemiologic studies of CTS that address work factors also take into account potential confounders.

Almost all of the studies reviewed controlled for the effects of age in their analysis [Chiang et al. 1990, 1993; Stetson et al. 1993; Silverstein et al. 1987; Wieslander et al. 1989; Baron et al. 1991; Tanaka et al. 1995, In Press; McCormack et al. 1990]. Likewise, most studies included gender in their analysis, either by stratifying [Schottland et al. 1991; Chiang et al. 1993], by selection of single gender study groups [Morganstern et al. 1991; Punnett et al. 1985] or by including the variable in the logistic regression model [Silverstein et al. 1987; Stetson et al. 1991; Baron et al. 1991]. Through selection of the study population and exclusion of those with metabolic diseases, most studies were able to eliminate the effects from these conditions. Other studies did control for systemic disease [Chiang et al. 1993; Baron et al. 1991]. Anthropometric factors have also been addressed in several studies [Stetson et al. 1993; Nathan et al. 1997; 1992b; Werner et al. 1997]. As more is learned about confounding, more variables tend to be addressed in more recent studies (smoking, caffeine, alcohol, hobbies). In those older studies which may not have controlled for multiple confounders, it is unlikely that they are highly correlated with exposure, especially those with ORs above 3.0. When examining those studies that have good exposure assessment, widely contrasting levels of exposure, and that control for multiple confounders, the evidence supports a positive association between occupational factors and CTS.

CONCLUSIONS

There are over 30 epidemiologic studies which have examined workplace factors and their relationship to CTS. These studies generally compared workers in jobs with higher levels of exposure to workers with lower levels of exposure, following observation or measurement of job characteristics. Using epidemiologic criteria to examine these studies, and taking into account issues of confounding, bias, and strengths and limitations of the studies, we conclude the following:

There is **evidence** for a positive association between highly repetitive work and CTS. Studies that based exposure assessment on quantitative or semiquantitative data tended to show a stronger relationship for CTS and repetition. The higher estimates of RR were found when contrasting highly repetitive jobs to low repetitive jobs, and when repetition is in combination with high levels of forceful exertion. There is **evidence** for a positive association between force and CTS based on currently available epidemiologic data. There is **insufficient evidence** for a positive association between posture and CTS. There is **evidence** for a positive association between jobs with exposure to vibration and CTS. There is **strong evidence** for a relationship between exposure to a combination of risk factors (e.g., force and repetition, force and posture) and CTS. Ten studies allowed a comparison of the effect of individual versus combined work risk factors [Chiang et al. 1990, 1993; Moore and Garg 1994; Nathan et al. 1988, 1992a; Silverstein et al. 1987; Schottland et al. 1991; McCormack et al. 1990; Stetson et al. 1993; Tanaka et al. [In Press]. Nine of these studies demonstrated higher estimates of RR when exposure was to a combination of risk factors, compared to the effect of individual risk factors. Based on the epidemiologic studies reviewed above, especially those with quantitative evaluation of the risk factors, the evidence is clear that exposure to a combination of job factors studied (repetition, force, posture, etc.) increases the risk for CTS. This is consistent with the evidence that is found in the biomechanical, physiologic, and psychosocial literature.

Table 5a-1. Epidemiologic criteria used to examine studies of carpal tunnel syndrome (CTS) associated with repetition

Study (first author and year)	Risk indicator (OR, PRR, IR or *p*-value)[*,†]	Participation rate $70%	Physical examination, and/or nerve conduction studies	Investigator blinded to case and/or exposure status	Basis for assessing hand exposure to repetition
Met all four criteria:					
Chiang 1990	1.87[†]	Yes	Yes	Yes	Observation or measurements
Chiang 1993	1.1	Yes	Yes	Yes	Observation or measurements
Moore 1994	2.8	Yes	Yes	Yes	Observation or measurements
Osorio 1994	6.7	Yes	Yes	Yes	Observation or measurements
Silverstein 1987	5.5[†]	Yes	Yes	Yes	Observation or measurements
Met at least one criterion:					
Barnhart 1991	1.9–4.0[†]	No	Yes	Yes	Observation or measurements
Baron 1991	3.7	No	Yes	Yes	Observation or measurements
Cannon 1981	2.1	NR[‡]	Yes	NR	Job titles or self-reports
English 1995	0.4	Yes	Yes	Yes	Job titles or self-reports
Feldman 1987	2.26[†]	Yes	No	NR	Observation or measurements
McCormack 1990	0.5	Yes	Yes	NR	Job titles or self-reports
Morgenstern 1991	1.88	Yes	No	No	Job titles or self-reports
Nathan 1988	1.0	NR	Yes	NR	Observation or measurements
Nathan 1992a	1.0	No	Yes	NR	Observation or measurements
Punnett 1985	2.7[†]	No	Yes	NR	Job titles or self-reports
Schottland 1991	2.86[†], 1.87	NR	Yes	NR	Job titles or self-reports
Stetson 1993	NR	Yes	Yes	NR	Observation or measurements
Weislander 1989	2.7[†]	Yes	Yes	No	Job titles or self-reports
Met none of the criteria:					
Liss 1995	5.2 3.7[†]	No	No	No	Job titles or self-reports

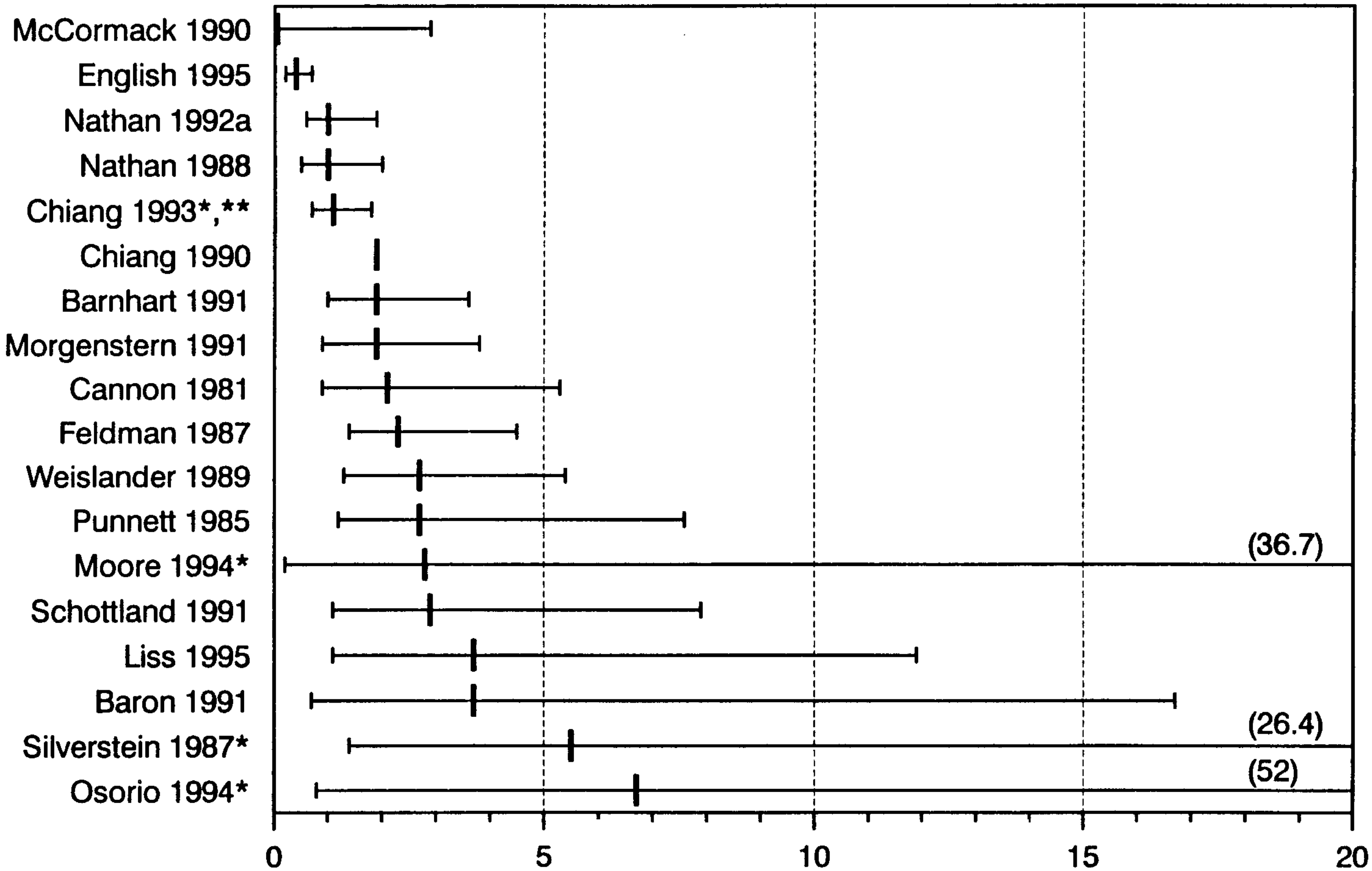
[*]Some risk indicators are based on a combination of risk factors—not on repetition alone (i.e., repetition plus force, posture, or vibration). Odds ratio (OR), prevalence rate ratio (PRR), or incidence ratio (IR).

[†]Indicates statistical significance.

[‡]Not reported.

Figure 5a-1. **Risk Indicator for "Repetition" and Carpal Tunnel Syndrome**

(Odds Ratios and Confidence Intervals)



* Studies which met all four criteria.
**Significant risk indicator reported without confidence limits.
Note: Two studies indicated statistically significant associations without reporting odds ratios. See Table 5a-1.

Table 5a-2. Epidemiologic criteria used to examine studies of carpal tunnel syndrome (CTS) associated with force

Study (first author and year)	Risk indicator (OR, PRR, IR, or *p*-value)*,†	Participation rate $\geq$70%	Physical examination, and/or nerve conduction studies	Investigator blinded to case and/or exposure status	Basis for assessing hand exposure to force
Met all four criteria:					
Chiang 1993	1.8†	Yes	Yes	Yes	Observation or measurements
Moore 1994	2.8	Yes	Yes	Yes	Observation or measurements
Osorio 1994	6.7	Yes	Yes	Yes	Observation or measurements
Silverstein 1987	15.5†	Yes	Yes	Yes	Observation or measurements
Met at least one criterion:					
Armstrong 1979	2.0†	NR‡	No	No	Observation or measurements
Baron 1991	3.7	No	Yes	Yes	Observation or measurements
McCormack 1990	0.4-0.9	Yes	Yes	NR	Job titles or self-reports
Nathan 1988	1.7-2.0†	NR	Yes	NR	Observation or measurements
Nathan 1992a	1.0, 1.4†, 1.6	No	Yes	NR	Observation or measurements
Punnett 1985	2.7†	No	Yes	NR	Job titles or self-reports
Stetson 1993	NR†	Yes	Yes	NR	Observation or measurements

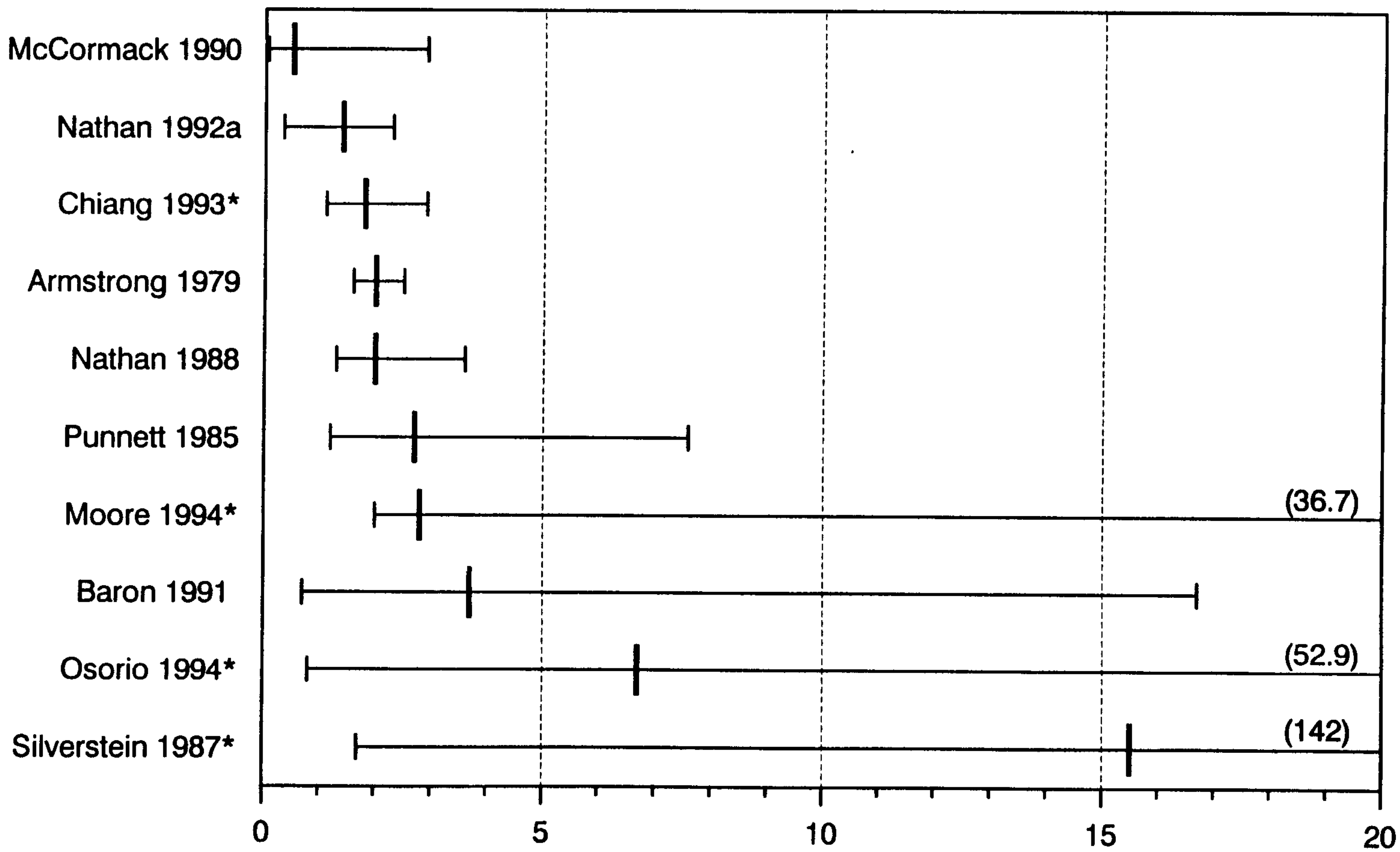
*Some risk indicators are based on a combination of risk factors—not on force alone (i.e., force plus repetition, posture, or vibration). Odds ratio (OR), prevalence rate ratio (PRR), or incidence ratio (IR).

†Indicates statistical significance. If combined with NR, a significant association was reported without a numerical value.

‡Not reported.

Figure 5a-2. **Risk Indicator for "Force" and Carpal Tunnel Syndrome**

(Odds Ratios and Confidence Intervals)



* Studies which met all four criteria.

Note: Some studies indicate statistical significance without a risk indicator or reported a statistically significant association without a risk indicator. See Table 5a-2.

Table 5a-3. Epidemiologic criteria used to examine studies of carpal tunnel syndrome (CTS) associated with posture

Study (first author and year)	Risk indicator (OR, PRR, IR, or *p*-value)*,†	Participaton rate $70%	Physical examination, and/or nerve conduction studies	Investigator blinded to case and/or exposure status	Basis for assessing hand exposure to posture
Met all four criteria:					
Moore 1994	2.8	Yes	Yes	Yes	Observation or measurements
Silverstein 1987	NR‡	Yes	Yes	Yes	Observation or measurements
Met at least one criterion:					
Armstrong 1979	2.0†	NR	No	No	Observation or measurements
deKrom 1990	5.4†	Yes	Yes	NR	Job titles or self-reports
English 1995	1.8†	Yes	Yes	Yes	Job titles or self-reports
Stetson 1993	NR†	Yes	Yes	NR	Observation or measurements
Tanaka 1995	5.9†	Yes	No	No	Job titles or self-reports
Met none of the criteria:					
Liss 1995	3.7†	No	No	No	Job titles or self-reports

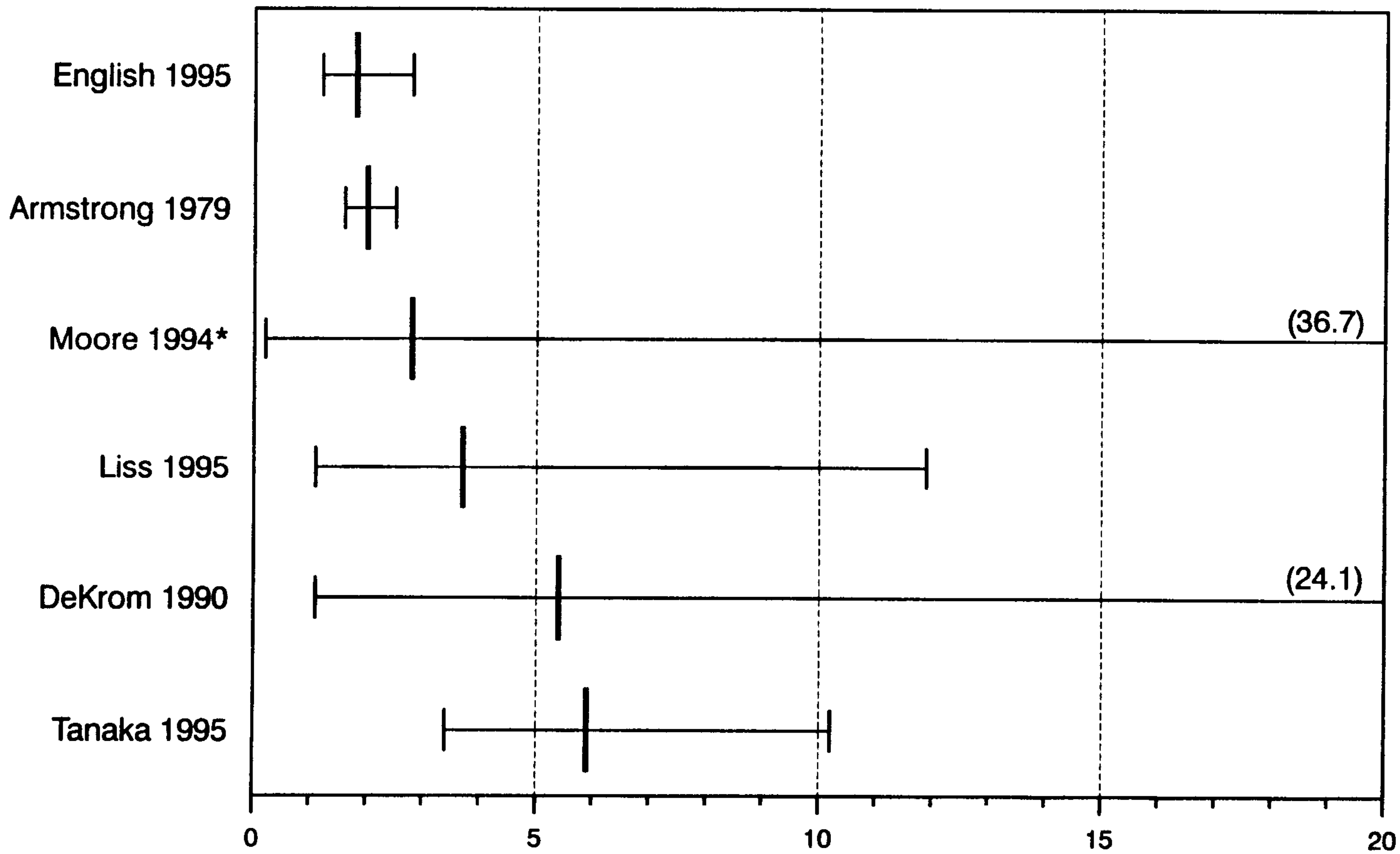
*Some risk indicators are based on a combination of risk factors—not on posture alone (i.e., posture plus repetition, force, or vibration). Odds ratio (OR), prevalence rate ratio (PRR), or incidence ratio (IR).

†Indicates statistical significance. If combined with NR, a significant association was reported without a numerical value.

‡Not reported.

Figure 5a-3. **Risk Indicator for "Posture" and Carpal Tunnel Syndrome**

(Odds Ratios and Confidence Intervals)



* Studies which met all four criteria.

Note: One study indicated statistically significant association without reporting odds ratios. See Table 5a-3.

Table 5a-4. Epidemiologic criteria used to examine studies of carpal tunnel syndrome (CTS) associated with vibration

Study (first author and year)	Risk indicator (OR, PRR, IR, or p-value)[*,†]	Participation rate ≥70%	Physical examination, and/or nerve conduction studies	Investigator blinded to case and/or exposure status	Basis for assessing hand exposure to vibration
Met all four criteria:					
Chatterjee 1992	10.9[†]	Yes	Yes	Yes	Observation or measurements
Silverstein 1987	5.3[†]	Yes	Yes	Yes	Observation or measurements
Met at least one criterion:					
Bovenzi 1991	21.3[†]	NR[‡]	Yes	Yes	Observation or measurements
Bovenzi 1994	3.4[†]	Yes	Yes	No	Observation or measurements
Cannon 1981	7.0[†]	NR	Yes	NR	Job titles or self-reports
Färkkilä 1988	NR[†]	NR	Yes	NR	Job titles or self-reports
Koskimies 1990	NR[†]	NR	Yes	No	Observation or measurements
Tanaka *In Press*	1.8[†]	Yes	No	No	Job titles or self-reports
Weislander 1989	3.3[†]	Yes	Yes	No	Job titles or self-reports

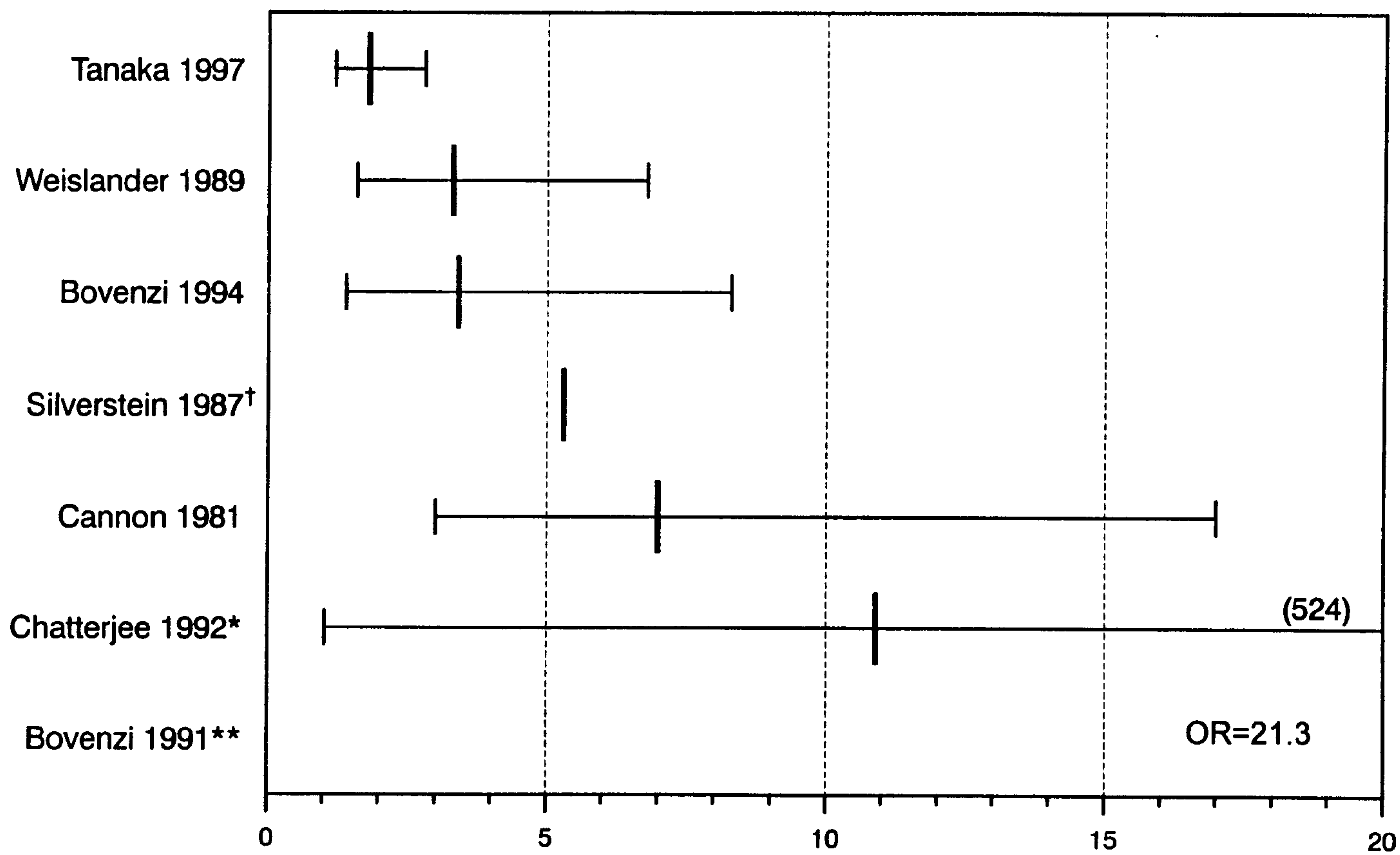
[*]Some risk indicators are based on a combination of risk factors—not on vibration alone (i.e., vibration plus repetition, posture, or force). Odds ratio (OR), prevalence rate ratio (PRR), or incidence ratio (IR).

[†]Indicates statistical significance. If combined with NR, a significant association was reported without a numerical value.

[‡]Not reported.

Figure 5a-4. **Risk Indicator for "Vibration" and Carpal Tunnel Syndrome**

(Odds Ratios and Confidence Intervals)



* Studies which met all four criteria.

**Significant risk indicator reported without confidence limits.

† Studies which met all four criteria and had significant risk indicator reported without confidence limits.

Note: Two studies indicated statistically significant associations without reporting odds ratios. See Table 5a-4.

Table 5a–5. Epidemiologic studies evaluating work-related carpal tunnel syndrome (CTS)

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Armstrong and Chaffin 1979	Case-control	18 female sewing machine operators with CTS histories compared to 18 female sewing machine operators without CTS histories.	Outcome: CTS defined as history of symptoms, surgical decompression of the median nerve, positive Phalen's test, or thenar atrophy. Exposure: Hand/wrist postures and estimation of forearm flexor force in various wrist and hand postures assessed by film analysis and EMG.	õ	õ	For pinch force exertion: 2.0 For hand force: 1.05	1.6-2.5 1.0-1.2	Participation rate: Not reported. All cases of CTS diagnosed prior to study in working sewing machine operators, may cause referral bias in estimating role of workload. Subjects excluded if history of fractures, metabolic or soft tissue disease. No association found between hand size or shape and CTS. CTS diagnosed subjects used deviated wrist more frequently than non-diseased, particularly during forceful exertions.

(Continued)

Table 5a–5 (Continued). Epidemiologic studies evaluating work-related carpal tunnel syndrome (CTS)

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	Referent group	RR, OR, or PRR	95% CI	Comments
Barnhart et al. 1991	Cross-sectional	Ski manufacturing workers: 106 with repetitive jobs compared to 67 with non-repetitive jobs.	Outcome: CTS determined by: (1) Case 1: Electro-diagnosis of median-ulnar difference (latency on response time); (2) Case 2: Either Tinel's or Phalen's test and electro-diagnosis; (3) Case 3: Ever having symptoms of hand pain, tingling, numbness, or nocturnal hand pain and Tinel's or Phalen's test and electro-diagnosis. Exposure: Jobs classified as repetitive and non-repetitive. Repetitive jobs entailed repeated or sustained flexion, extension, or ulnar deviation of the wrist by 45E, radial deviation by 30E, or pinch grip (determined by observation).	Case 1: 34% Case 2: 15.4% Case 3: 32.5%	19% 3.1% 18.2%	1.9 3.95 1.6	1.0-3.6 1.0-15.8 0.8-3.2	Participation rate: 70% (repetitive jobs), 64% (non-repetitive jobs). Examiner blinded to subject's job status but clothing may have biased observations. Controlled for age and gender. Found for both right and left hand of those with repetitive jobs; mean difference between distal sensory latencies of median and ulnar nerves were primarily due to a shorter mean sensory latency of the ulnar nerve. There was no difference in median nerve distal sensory latencies between groups. Hormonal status, systemic disease included in questionnaire. Diabetes significantly more frequent in those with CTS than without (*p*=0.01).

(Continued)

Table 5a–5 (Continued). Epidemiologic studies evaluating work-related carpal tunnel syndrome (CTS)

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	RR, OR, or PRR	95% CI	Comments
Baron et al. 1991	Cross-sectional	119 female grocery checkers vs. 56 other female grocery store employees (comparison group).	Outcome: CTS case defined as having moderate to severe symptoms of pain, stiffness, numbness, tingling. Symptoms begun after employment in the current job; lasted > one week or occurred > once a month during the past year; no history of acute injury to part of body in question and a positive physical exam of either Phalen's or Tinel's test. Exposure: Based on job category, estimates of repetitive, average, and peak forces based on observed and videotaped postures, weight of scanned items, and subjective assessment of exertion. Exposure level in checkers: Average forces: Low Peak force: Medium Repetition: Medium Exposure level in referents: Average force: Medium Peak force: Medium to low Repetition: Medium.	11%	4%	3.7	0.7-16.7	Participation rate: 85% checkers; 55% non-checkers in field study. Following telephone survey 91% checkers and 85% non-checkers. Adjusted for duration of work. Total repetitions/hr ranged from 1,432 to 1,782 for right hand and 882 to 1,260 for left hand. Multiple awkward postures of all upper extremities recorded but not analyzed in models. Examiners blinded to worker's job and health status. Controlled for duration of work, hobbies.

(Continued)

Table 5a–5 (Continued). Epidemiologic studies evaluating work-related carpal tunnel syndrome (CTS)

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Bovenzi et al. 1991	Cross-sectional	65 vibration-exposed forestry operators using chain-saws compared to referents composed of 31 maintenance workers (electricians, mechanics, and painters).	Outcome: CTS cases defined as having symptoms of pain, numbness, or tingling in the median nerve distribution, and physical exam findings of Tinel's or Phalen's test, diminished sensitivity to touch or pain in 3½ fingers on radial side, weakness in pinching or gripping. Exposure: Direct observation of awkward postures, manual forces, and repetitiveness evaluated via checklist. The focus of the study was to compare vibration-exposed workers to controls doing manual work. Vibration measured from two chain-saws. Vibration exposure for each worker assessed in terms of 4-hr energy-equivalent frequency-weighted acceleration according to ISO 5349.	38.4%	3.2%	21.3 (adjusted)	p=0.002	Participation rate: Not reported. Examiners blinded to case status. Controlled for age and ponderal index (height and weight variable). Metabolic disease also considered. Controls also found to have several risk factors for MSDs at work—static arm and hand overload, overhead work, stressful postures, non-vibrating hand-tool use. Controls had a greater proportion of time in work cycles shorter than 30 sec than forestry workers. Chain saw operators worked outdoors and were exposed to lower temperatures than maintenance workers.

(Continued)

Table 5a–5 (Continued). Epidemiologic studies evaluating work-related carpal tunnel syndrome (CTS)

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Bovenzi and the Italian Group 1994	Cross-sectional	Case group: Stone workers employed in 9 districts in Northern and Central Italy; 145 quarry drillers and 425 stone carvers exposed to vibration. Referent group: Polishers and machine operators (n=258) who performed manual activity but were not exposed to hand-transmitted vibration. All stone workers employed in 6 districts participated in the survey (n=578, 69.8%), whereas, in the three other districts they were selected on basis of random sampling of the quarries and mills in the geographic areas (n=250, 30.2%).	Outcome: CTS assessed by physician assessment. CTS defined as symptoms, (1) parathesias, numbness, or pain in median nerve distribution; (2) nocturnal exacerbation of symptoms and positive Tinel's or Phalen's test. Exposure: Direct observation of vibrating tools assessed by interview. Vibration measured in a sample of tools.	8.8%	2.3%	3.4	1.4-8.3	Participation rate: 100%. "All the active stone workers participated in the study, so self-selection was not a source of bias." Physician administered questionnaires containing work history and examinations, so unlikely to be blinded to case status. Adjusted for age, smoking, alcohol consumption, and upper limb injuries. Leisure activities and systemic diseases included in questionnaire. Univariate analysis showed no association between systemic diseases and vibration so were not criteria for exclusion. Dose-response for CTS and lifetime vibration exposure not significant.

(Continued)

Table 5a–5 (Continued). Epidemiologic studies evaluating work-related carpal tunnel syndrome (CTS)

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Cannon et al. 1981	Case-control	Aircraft engine workers at 4 plants: 30 CTS cases identified through worker's compensation claims and medical department records during a 2-year period compared to 90 controls from the same plant, 16 workers receiving compensation benefits for treatment of CTS, and 14 cases who had not received compensation benefits. Three controls randomly chosen from the same plant for each CTS case.	Outcome: CTS cases identified through worker's compensation claims and medical department records during a 2-year period. Exposure: Based on job category, years on the job, identified through record review and interviews. Exposure to vibrating tools, repetitive motion. Buffing, grinding, and hand tools were measured with an accelerometer and found to be in the range of 10 to 60 Hz.	õ	õ	For vibrating hand tool use: 7.0 For repetitive motion tasks: 2.1 History of gynecologic surgery: 3.7 Years on the job: 0.9	3.0-17 0.9-5.3 1.7-8.1 0.8-1.0	Participation rate: Participation rate unable to be calculated from data presented. 30 cases identified through record review of 20,000 workers. Cases and controls on gender. Controlled for gynecologic surgery, race, diabetic history, years on the job, use of low-frequency vibrating tools. Information obtained through self-administered questionnaires and personal interviews on cases and controls on age, sex, race, weight, occupation, years employed, worker compensation status, history of metabolic disease, hormonal status of females, history of gynecologic surgery. Number of years employed significantly different among cases (5.5 years) and controls (11.7 years). Range of years employed among cases included 0.1 year to 28 years.

(Continued)

Table 5a–5 (Continued). Epidemiologic studies evaluating work-related carpal tunnel syndrome (CTS)

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	Referent group	RR, OR, or PRR	95% CI	Comments
Chatterjee et al. 1982	Case-control	16 rock drillers compared with 15 controls.	Outcome: CTS was determined by symptoms from questionnaire and interview by medical investigator, clinical exams carried out blindly, and nerve conduction studies. For Table 5-7, CTS based solely on NCS results; Table 5-9 based on symptoms and NCS. Exposure: To vibration carried out by measurement of vibration spectra of the rock drills and observation of jobs. Exposed group were those miners who regularly used rock-drills in the fluorspar mines or other miners using similar rock-drills. Exposure varied from 18 months to 25 years (mean 10 years). The rock drillers were exposed to vibration level in excess of the damage level criterion between the frequencies of 31.5 and 62 Hz.	44%	7%	Abnormal amplitudes of digital-action potentials from fingers supplied by the median and ulnar nerves; the OR in vibration exposed vs. controls: OR=10.89	1.02-524	Participation rate: 93%. Examiners blinded to case status. Groups standardized for age and gender. Exclusionary criteria: History of constitutional white finger, secondary causes of Raynaud's phenomenon, > one laceration or fracture in the hands or digits, severe or complicated injury involving nerve or blood vessels or significant surgical operation, history of exposure to vibration from tools other than rock drills. Significant differences found between controls and vibration group for symptoms of numbness and tingling: median motor latency; median sensory latency; median sensory amplitude; median sensory duration. All at the $p < 0.05$ level. Skin temperature controlled for in NCVs.

(Continued)

Table 5a–5 (Continued). Epidemiologic studies evaluating work-related carpal tunnel syndrome (CTS)

				MSD prevalence				
Study	**Study design**	**Study population**	**Outcome and exposure**	**Exposed workers**	**Referent group**	**RR, OR, or PRR**	**95% CI**	**Comments**
Chiang et al. 1990	Cross-sectional	207 active workers from 2 frozen food plants divided into 3 groups: (1) low-cold, low-repetition (comparison group, mainly office staff and technicians, n=49), (2) low-cold, high-repetition (non-frozen food packers, n=37), (3) high-cold, high-repetition (frozen food packers, n=121).	Outcome: CTS defined as symptoms of numbness, pain, tingling in the fingers innervated by the median nerve, onset since work in current job, no relationship to systemic disease or injury and physical exam of Tinel's test or Phalen's sign. Nerve conduction testing was performed on motor and sensory nerves of both upper limbs. If subject had abnormal results and symptoms and physical exam findings, was considered CTS. If no symptoms, considered as subclinical CTS. Exposure: Job analyses conducted by industrial hygienist, to cold and repetition assessed by observation. Highly repetitive jobs had cycle times <30 sec. >50% of cycle time cold exposure was defined as whether the job required hands to be locally exposed to cold. The mean skin temperature of their hands was in the range of 26 to 28EC, even with wearing gloves.	Group 2: 40.5% clinical plus 8.1% sub-clinical Group 3: 37.2% clinical plus 22.3% sub-clinical	Group 1: 4% clinical plus 2% sub-clinical	Group 2 vs. Group 1: OR=8.28 Group 3 vs. Group 1: OR=11.66 Logistic Regression Model: Cold: OR=1.85 (*p*<0.22) Repetitiveness: OR=1.87 (*p*<0.018) Cold x Repetitive-ness: OR=1.77 (*p*<0.03)	1.18-58.3 2.92-46.6	Participation rate: Not specifically mentioned, however, paper states that “in order to prevent selective bias, all of the employees in the factories were observed initially.” Examiners blinded to exposure status and medical history. Controlled for age, sex, and length of employment. Interaction terms tested. Excluded subjects with diabetes, thyroid function disorders, history of forearm fracture, unspecified polyneuropathy, rheumatoid arthritis. Workers in cold groups wore gloves and exerted higher forces than workers in non-cold groups. Force was not evaluated in this study. Confounding is possible according to authors. CTS was independent of age and length of employment. Authors considered this to be due to healthy worker effect. OR for group 1 vs. group 2 is 8.3 (1.2-58.3) when adjusted for sex but 2.2 (0.2-21.1) when adjusted for sex, age, and length of employment suggesting survival bias.

(Continued)

Table 5a–5 (Continued). Epidemiologic studies evaluating work-related carpal tunnel syndrome (CTS)

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Chiang et al. 1993	Cross-sectional	207 fish processing workers divided in 3 groups: (1) low-force, low-repetition (comparison group, n=61); (2) high-force or high-repetition (n=118); (3) high-force and high-repetition (n=28).	Outcome: CTS defined as having symptoms of numbness, pain, or tingling in the fingers innervated by the median nerve, onset after job began, and no evidence of systemic disease or injury and physical exam findings of positive Tinel's sign or Phalen's test. Exposure: Assessed by observation and recording of tasks and biomechanical movements of 3 workers, each representing 1 of 3 study groups. Highly repetitive jobs with cycle time <30 sec or >50% of cycle time performing the same fundamental cycles. Hand force from EMG recordings of forearm flexor muscles. Classification of workers into 3 groups according to the ergonomic risks of the shoulders and upper limbs: Group 1: low-repetition and low-force; Group 2: high-repetition and high-force; Group 3: high-repetition or high-force.	Group 2 (Male): 6.9% Group 2 (Female): 18.0% Group 3 (Male): 0.0% Group 3 (Female): 36.4%	Group 1 (Male): 3.1% Group 1 (Female): 13.8%	2 vs. 1 (male): OR= 2.2 2 vs. 1 (female): OR=1.3 3 vs. 1 (male): õ 3 vs. 1 (female): OR=2.6 Repetition: OR=1.1 Force: OR=1.8 Repetition and force: OR=1.1 Male vs. female: OR=2.6	0.2-22.0 0.5-3.5 õ 1.0-7.3 0.7-1.8 1.1-2.9 0.7-1.8 1.3-5.2	Participation rate: Paper stated that all of the workers who entered the fish-processing industry before June 1990 and were employed there full-time were part of the cohort. Workers examined in random sequence to prevent observer bias; examiners blinded to case status. Analysis controlled for age, stratified by gender. Contraceptive use (females): significant (OR=2.0, 95% CI 1.2 to 5.4); tubal ligation not significant. Workers with hypertension, diabetes, history of traumatic injuries to upper limbs, arthritis, collagen diseases excluded from study group. No significant age difference in exposure groups. Physician-observed cases about ½ the prevalence of symptoms of elbow pain (9.8 vs. 18.0; 15.3 vs. 19.5; 35.7 vs. 17.9). Dose-response for symptoms both in the hand and in the wrist ($p<0.03$) and physician-observed CTS ($p<0.015$). Age, gender, repetitiveness, forceful movement of upper limbs and interaction of repetitiveness and forceful movement calculated in logistic regression. Significant trend for duration of employment in <12 months but not 12 to 60 months or >60 months.

(Continued)

Table 5a–5 (Continued). Epidemiologic studies evaluating work-related carpal tunnel syndrome (CTS)

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
deKrom et al. 1990	Nested case control	28 CTS cases from a community sample and 128 CTS cases from a hospital (total n=156) compared to community non-cases (n=473). Participants blinded to aim of study—told it was about "general health."	Outcome: Tingling pain and numbness in median distribution, frequency $2/week, awakened at night and nerve conduction studies. Motor latency < 4.5 months, different median to ulnar DSL < 4.0 months, controlled for temperature. CTS diagnosed by clinical history and neurophysiological tests. Exposure: Awkward hand/finger postures and pinch grasps assessed by questionnaire: Self-reported information about duration of exposure (hr/wk) to flexed wrist, extended wrist, extended and flexed wrist combined, pinched grasp. Typing hr categorized as 0, 1 to 7, 8 to 19, 20 to 40 hr/wk of exposure 0 to 5 years ago, responses truncated at 40 hr/wk.	5.6% prevalence in the general population (28 cases from 501 subject community sample)	Õ	For work: 20 to 40 hr/wk with flexed wrist: OR=8.7 For work: 20 to 40 hr/wk with extended wrist: OR= 5.4	3.124.1 1.127.4	Participation rate: 70% response rate obtained for both hospital and community samples. Controlled for age, weight, slimming courses, gender, and checked for interactions. Cases seeking medical care may cause referral bias in estimating etiologic role of work-load. However, authors came up with same relationship between flexed and extended wrist using only CTS cases from population-based data. The associations from this study are based on very small sample sizes. >64% of cases reported 0 hr/wk to each of the exposures. In random sample, age, and sex stratified, included twice as many females as males. No significant relationship between pinch grasp or typing. Dose-response found for duration of activities with flexed or extended wrist statistically significant; dose-response relationship for both present but not statistically significant. Typing hr not significant but very small numbers (<5 in comparison groups); may have been unable to detect a difference. Females with hysterectomy without oophorectomy significantly increased risk, PRR=2.0 (1 to 3.6), compared to females not operated on; increase may be detection bias. Wrist fractures, thyroid disease, rheumatism, and diabetes not significant for CTS. Varicosis significant risk for males 12.0 (3.6-40.1). Oral contraceptives not significantly associated with CTS.

(Continued)

Table 5a–5 (Continued). Epidemiologic studies evaluating work-related carpal tunnel syndrome (CTS)

				MSD prevalence				
Study	Study design	Study population	Outcome and exposure	Exposed workers	Referent group	RR, OR, or PRR	95% CI	Comments
English et al. 1995	Case-control	Cases: CTS patients (n=171) ages 16 to 65 years from orthopedic clinics. Controls: (n=996) 558 males and 438 females attending the same clinics diagnosed with conditions other than diseases of the upper limb, cervical, or thoracic spine; ages 16 to 65 years.	Outcome: CTS based on agreed criteria diagnosed by orthopedic surgeons using common diagnostic criteria (not specified). Exposure: Based on self-reported risk factors at work: questions addressed: awkward postures, grip types, wrist motions, lifting, shoulder postures, static postures, etc. and job category.	Õ	Õ	Rotating shoulder with elevated arm and CTS: OR=1.8 Repeated finger tapping and CTS: OR=0.4	1.2-2.8 0.2-0.7	Participation rate: 96%. Due to design of study (cases selected by diagnoses), blinding of examiners not an issue. Adjusted for height, weight, and gender. Significant negative association with height and presentation at the clinic as a result of an accident and CTS. A significantly positive association with height. Included “frequency of movements” in regression analysis.

(Continued)

Table 5a–5 (Continued). Epidemiologic studies evaluating work-related carpal tunnel syndrome (CTS)

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Färkkilä et al. 1988	Cross-sectional	79 chain saw users randomly selected from 186 forestry workers with >500 hr of sawing/year.	Outcome: CTS based on nerve conduction studies, motor and sensory conduction velocity, distal and proximal latencies, Tinel's and Phalen's tests and subjective symptoms. Exposure: Chain saw vibration not measured. Duration of chain saw use determined by interview.	26%	Õ	Significant correlation between numbness in the hands (r=0.38, *p*<0.05) and CTS and muscle fatigue (r=0.47, *p*<0.05) and CTS.	Õ	Participation rate: 100% of professional forestry workers. Significant correlation between CTS and HAVs found. Randomly selected from EMG out of 186. Alcohol consumption did not correlate with numbness in the hands or arms (r=0.14, p=NS) or sensory disturbances. Only motor nerve recordings were analyzed for this study.

(Continued)

Table 5a–5 (Continued). Epidemiologic studies evaluating work-related carpal tunnel syndrome (CTS)

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Feldman et al. 1987	Cross-sectional for symptom survey Pro-spective for nerve con-duction studies	586 electronics workers at a manufacturing firm with 700 employees.	Outcome: Based on questionnaire survey and in some an abbreviated neurologic examination that involved tests of hand sensation, finger grip, and strength of thenar muscles. Tinel's and Phalen's done. "Standard nerve conduction" of left and right median nerves. Exposure: Two subjects randomly selected for biomechanical analyses from each of four high-risk areas, determined from questionnaire and walk-through observations of tasks involving repetitive flexion, extension, pinching, and deviated wrist postures. Videotaping and electromyography done. Highly repetitive job task defined as <30 sec cycle or >50% of cycle performing the fundamental cycle. Wrist posture characterized in terms of flexion and extension: >45 flexed, 15 to 45 flexion, neutral, 15 to 45 extension, and >45 extension and deviation. Hand posture characterized by 6 types of grip. No quantitative measures of vibration were obtained.	Wrist tingling and numbness: 18%	Wrist tingling and numbness: 8.7%	Numbness and tingling in fingers: OR=2.26 High-risk vs. low-risk jobs: *p*<0.005	1.4-4.46	Participation rate: 84%. Examiners blinded to case and exposure status: Not stated. Analysis not controlled for confounders. Questionnaire obtained data on past medical history, exposure to neurotoxins, cigarettes, hobbies, and symptoms. For nerve conduction testing, the temperature of limbs was monitored and controlled for. More females were in high-risk areas and jobs than males. There were no workers >60 years old in high-risk group. There were 34 workers >60 years in comparison groups. Rheumatoid arthritis more prominent in low-risk group (8.2%) than high-risk (2.4%) group. Nerve conduction in high-risk workers performed year 1 and year 2. Right sensory amplitude abnormal (<8µV) in 22% of workers at year 1 and 35.5% at year 2. Left sensory amplitude abnormal in 16.7% and 29% at year 2. Most apparent changes (increases) seen in bilateral sensory velocities and motor latencies (abnormal >4.5). Right motor latency abnormal in 8% at year 1 and 11% in year 2. Left motor latency abnormal in 2% in year 1 and 23% at year 2. Authors offered parameters for staging CTS in high-risk subjects (0 to 4 stages).

(Continued)

Table 5a–5 (Continued). Epidemiologic studies evaluating work-related carpal tunnel syndrome (CTS)

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Franklin et al. 1991	Retro-spective cohort: from 1984 to 1988	Workers in Washington State (n=1.3 million full-time workers in 1988). Worker's compensation data for Washington State, using compensable (time loss) and non-compensable claims for January 1984 to December 1988.	Outcome: Assessed using workers' compensation claims for CTS using ICD codes 354.0 and 354.1. Incident claim was the first appearance of a paid bill for claimant with a physician diagnosis. Algorithm was developed to identify unique claimants which removed multiple claims. Exposure: Not measured. Workers in the same industrial classification assumed to share similar workplace exposures.	25.7 claims/ 1,000 FTEs (oyster and crab packers) 23.9 claims/ 1,000 FTEs (meat and poultry workers)	1.74 claims/ 1,000 FTEs (industry wide rate)	14.8 (oyster and crab packers) 13.8 (meat and poultry workers)	11.2- 19.5 11.6- 16.4	Participation rate: This is a records review so it does not apply. Among claimants, the female-to-male ratio was 1.2:1. Mean age of claimants was 37.4. Diagnosis and data entry errors comprised 25% of CTS surgery claims—cases were not coded as CTS. 82% of claims were true cases of CTS.

(Continued)

Table 5a–5 (Continued). Epidemiologic studies evaluating work-related carpal tunnel syndrome (CTS)

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Koskimies et al. 1990	Cross-sectional	217 forestry workers who used chain saw >500 hr during previous 3 years.	Outcome: 125 randomly selected for EMG of sensory and motor nerves both hands. CTS diagnosis based on symptoms, exclusion of other conditions, results of Phalen's and Tinel's test, and findings in sensory and motor nerve EMG. Exposure: Number of years of vibration exposure (only workers who had 500 hr during previous 3 years were included.	Active vibration: 5% white finger CTS: 20%		Alcohol consumption and CTS cases r=0.15 Vibration exposure time and motor NCV in median nerve of right hand: r=-0.27 but not left hand: r=-0.12 Exposure time with both motor NCV in ulnar nerve of right hand r=-0.26 and left hand r=-0.39. Distal latencies in median nerve and exposure in right hand r=0.17; left hand r=0.21. Numbness and sensory NCS of median nerve; right hand r=0.679; left hand r=0.53.	*p*=NS *p*=0.01 *p*=NS *p*=0.05 *p*<0.001 *p*=0.05 *p*=0.05 *p*<0.001 *p*<0.01	Participation rate: Not reported. Examiners may not have been blinded to exposure status because of design of study. No comparison group because study was part of longitudinal study of workers followed since 1972. Most of 25 CTS workers had mild symptoms at work despite severe reduction of sensory NCS of median nerve. Males with primary Raynaud's disease, rheumatoid arthritis, diabetes, or positive urine glucose slide test results excluded from study. 12 (48%) of those with CTS had bilateral diagnosis. The authors stated that the left hand is the dominant working hand in sawing, the right hand acting more to direct the saw during the operation.

(Continued)

Table 5a–5 (Continued). Epidemiologic studies evaluating work-related carpal tunnel syndrome (CTS)

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Liss et al. 1995	Cross-sectional	1,066 of 2,142 dental hygienists from Ontario Canada Dental Hygienists Association compared to referent group, 154 of 305 dental assistants.	Outcome: Mailed survey, 2 CTS case definitions: (1) based on positive response to "told by a physician that you had CTS", (2) if during last 12 months, for >7 days experienced numbness and tingling, pain, or burning in distribution of median nerve, night pain or numbness in hands, and no previous wrist/hand injury. Exposure: Based on mailed survey: Length of practice, days/wk worked, patients/day, patients with heavy calculus, percent of time trunk in rotated position relative to lower body, instruments used, hr of typing/wk, type of practice.	Responder told that they had CTS: 7% Question-naire based CTS: 11%	Responder told that they had CTS: 0.9% Question-naire based CTS: 3.0%	OR=5.2 OR=3.7	0.9-32 1.1-11.9	Participation rate: 50% response rate from both groups. Study population >99% female. OR were age adjusted. Confounders considered included typing, hobbies, and taking estrogens.

(Continued)

Table 5a–5 (Continued). Epidemiologic studies evaluating work-related carpal tunnel syndrome (CTS)

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Loslever and Ranaivosoa 1993	Cross-sectional	17 selected jobs with frequent and repeated absences of workers due to CTS investigated at the request of occupational doctors and managers. Biomechanical data recorded on a number of workers from each job, ranging from 1 to 4 workers. Involving 961 workers.	Outcome: Occupational physician from each factory involved in the study completed questionnaire concerning each job and the number of CTS cases. The prevalence of CTS was then calculated from ratio of CTS cases and total number of employees that worked at that place. Exposure: Videotaping of movements, use of vibrating tools, and two measurement techniques used: (1) Flexion-extension measurements: Subjects recorded at several points during the day for 15 min. An angle meter used to measure flexion-extension angles of the wrist: Rated high flexion, low flexion, low extension, and high extension using fuzzy cutting functions. Each modality characterized by its arithmetic mean and its relative duration. (2) Force: Electromyography used; values under 2 daN considered as low forces. Calculated time spent over 2 daN, maximal force, number of peak exertions, and the arithmetic mean of the n values during a period.	Mean prevalence rate among jobs (jobs chosen at workplaces where CTS had been reported): 35% (range 8 to 66%); prevalence of CTS in both hands: 20%		High force with high flexion and CTS: r=0.62 High force and high extension and CTS: r=0.29		Participation rate: Cases selected. Occupational doctor supplied information on gender, age, years on the job, hand orientation, has or has not contracted CTS. Subjects spent 60 to 80% of their time in extension ranging from 13 to 30E. Vibratory tools more often used in tasks with high prevalence of CTS (27%) than in ones with low prevalence of CTS (13%). 92% of population were female. Non-standard data analysis approaches, no statistical testing. Examiners not blinded. Authors believe higher rate of CTS in both hands (20%) vs. dominant hand (100%) argue for non-occupational factors being more important.

(Continued)

Table 5a–5 (Continued). Epidemiologic studies evaluating work-related carpal tunnel syndrome (CTS)

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Marras and Shoenmarklin 1993	Cross-sectional	40 volunteers at a highly repetitive, hand-intensive industrial jobs in 8 different plants. Half the workers were employed in jobs that had OSHA recordable repetitive trauma incidents, half the workers were in jobs with no history of recordable repetitive trauma incidents. Two subjects from 10 repetitive, hand-intensive jobs were randomly chosen to participate.	Outcome: CTS was determined from evaluation of OSHA illness and injury logs and medical records. The independent variable was exposure to jobs in which CTS had occurred previously. A low-risk job was defined as having a zero incidence rate; a high-risk job was defined as having an incidence rate of eight or more recordable repetitive trauma. Exposure: Included number of wrist motions/8-hr shift, weight of loads, handgrip types and forces, work heights, and motion descriptions. Wrist motion monitors measured in the radial/ulnar, flexion/extension, and pronation/supination planes: wrist angles, angular velocity, angular acceleration.	High-risk job: 8 incidents/ 200,000 hr exposure	Low-risk job: 0 incidents	Model for predicting high vs. low job risk based upon motion component: Position Radial/ulnar ROM: OR=1.52 Flexion/extension ROM: OR=1.3 Pronation/ supination ROM: OR=1.2 Velocity Radialulnar vel: OR= 2.4 Flexion/ extension vel: OR=3.8 Pronation/ supination vel: OR=1.9 Acceleration Radial/ulnar accel: OR=2.7 Flexion/ extension accel: OR=6.1 Pronation/ supination accel: OR=2.96	 1.1-2.1 1.0-1.7 0.9-1.6 1.3-4.3 1.5-9.6 1.2-3.2 1.5-4.9 1.7-22 1.4-6.4	Participation rate: Not reported. Examiners blinded: not stated. Confounders controlled for: Age, gender, handedness, job satisfaction. All the jobs required gloves except two-one "low-risk" and one "high-risk." Significant difference between groups with regards to age, years with the company, and trunk depth. No significant difference in job satisfaction, number of wrist movements, age, weight, stature, hand dimensions. Turnover rate: High-risk jobs: 33%; low-risk jobs: 0.5%. Grip forces were three times as great in the high-risk jobs than in the low-risk jobs. Variance between subjects within jobs accounted for a substantial percentage of total variance in wrist motion.

(Continued)

Table 5a–5 (Continued). Epidemiologic studies evaluating work-related carpal tunnel syndrome (CTS)

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
McCormack et al. 1990	Cross-sectional	Textile workers: 4 broad job categories involving intensive upper extremity use. Workers randomly chosen: Sewing workers (n=562); boarding workers (n=296); packaging workers (n=369); and knitting workers (n=352) compared to other non-office workers (n=468).	Outcome: Assessed by questionnaire and screening physical examination initially by nurse. CTS diagnosed on clinical grounds of symptoms and positive Tinel's sign and Phalen's test. Physician reassessed physical findings by "standardized methods." Exposure: Assessment by observation of jobs. Exposure to repetitive finger, wrist and elbow motions assumed from job title; no objective measurements performed.	Prevalences of CTS Boarding: 0.7% Sewing: 1.2% Packaging: 0.5% Knitting: 0.9%	1.3% (non-office)	Boarding vs. non-office OR=0.5 Sewing vs. non-office OR=0.9 Packaging vs. non-office OR=0.4 Knitting vs. non-office OR=0.6	0.05-2.9 0.3-2.9 0.04-2.4 0.1-3.1	Participation rate: 91%. Physician or nurse examiners not blinded to case or exposure status (personal communication). Prevalence higher in workers with <3 years of employment. Race and age not related to outcome. Females found to have significantly more CTS than males. Job category not found to be significant, however no measurement of force, repetition, posture analysis, etc. Questionnaire asked types of jobs, length of time on job, production rate, nature and type of upper extremity complaint, and general health history. 11 physician examiners; interexaminer reliability potential problem acknowledged.

(Continued)

Table 5a–5 (Continued). Epidemiologic studies evaluating work-related carpal tunnel syndrome (CTS)

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Moore and Garg 1994	Cross-sectional	32 jobs in which 230 workers were employed. This study was more an evaluation of jobs than of individuals.	Outcome: CTS identified from OSHA logs and medical records. A case required electrophysiologic testing, confirmed as abnormal by electromyographer and presence of suggestive symptoms. Exposure: Observation and videotape analysis of jobs. Force, wrist posture, grasp type, high-speed work, localized mechanical stress, vibration, cold, and work time assessed via observation of videotape. Jobs classified as hazardous or safe based on data and judgement.	13.7%	4.9%	2.8	0.2-36.7	Participation rate: Study based on records. Investigators blinded to exposure, case outcome status, and personal identifiers on medical records. Repetitiveness, "type of grasp" were not significant factors between hazardous and safe job categories. No pattern of morbidity according to date of clinic visits. Strength demands significantly increased for hazardous job categories compared to safe job categories. IR based on full-time equivalents and not individual workers, may have influenced overall results. Workers had a maximum of 32-months of exposure at plant–so duration of employment analysis limited. Average maximal strength derived from population-based data stratified for age, gender, and hand dominance. Using estimates of Silverstein's classification, association between forcefulness and overall observed morbidity was statistically significant; repetition was not. No control for confounders. No information on work history, number of unaffected workers, or exposure duration.

(Continued)

Table 5a–5 (Continued). Epidemiologic studies evaluating work-related carpal tunnel syndrome (CTS)

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Morgenstern et al. 1991	Cross-sectional	1,058 female grocery cashiers from a single union. Comparison group was those who reported no symptoms. Cashiers were also compared to results from a general population study from Rochester, Minnesota (Stevens et al. 1988).	Outcome: Defined CTS as self-reported hand/wrist pain, nocturnal pain, tingling in the hands or fingers, and numbness. Exposure: Duration, use of laser scanner determined from survey (no measurements).	12%	5.4%	For a difference of 25 hr/wk: 1.88	0.9-3.8	Participation rate: 82%. Controlled for age. Information collected on age, sex, pregnancy status, work history as a checker, specific job-related tasks, use of selected drugs, history of wrist injury. In logistic regression, "Use of diuretics" significantly associated with CTS, OR=2.66 (1.00-7.04); thought to be related to fluid retention by authors. Laser scanning found not to be significant factor.

(Continued)

Table 5a–5 (Continued). Epidemiologic studies evaluating work-related carpal tunnel syndrome (CTS)

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Nathan et al. 1988	Cross-sectional	471 industrial workers from 27 occupations in 4 industries. Jobs grouped into 5 classes based on resistance and repetition rate.	Outcome: Case defined as NCS-determined impaired sensory conduction (sensory latency). Sensory latencies assessed antidromically for eight consecutive 1-cm segments of the nerve. A maximum latency difference of 0.4 ms or greater used to define impaired sensory conduction. Case definition did not deal with symptoms. Exposure: Jobs grouped into 27 occupations with similarities of characteristics as to type of grip, wrist position, handedness pattern, resistance, frequency, and duration of grasp and presence of vibratory and ballistic components. The 27 occupations then grouped into 5 classes. Resistance (Res.) rated from very light to very heavy; repetition rate rated from low to high. Group I: very light resistance and low repetition Group II: light resistance and very high repetition Group III: moderate resistance and moderately high repetition Group IV: heavy resistance and moderate repetition Group V: very heavy resistance and high repetition.	Prevalence of abnormal nerve conduction sensory latency: Group II: 27% Group III: 47% Group IV: 38% Group V: 61%	Prevalence of abnormal nerve conduction sensory latency: Group I: 28%	Group II vs. I: PR=1.0 Group I vs. III: PR=1.9 Group I vs. IV: PR=1.7 Group I vs. V: PR=2.0	0.5-2.0 1.3-2.7 1.3-2.7 1.1-3.4	Participation rate: Not reported. Analysis controlled for age and gender. No description of symptom status for defining CTS. Method of categorization of jobs and occupations not described. Classification system is based on only repetition and not resistance as listed. Initially excluded cases of CTS in study population, yet was supposedly identifying prevalences of CTS in exposure groups. For nerve conduction analysis, wrongly assumed that each hand's nerve conduction study results in an individual were independent. The 2 hands in a single individual are not independent of each other.

(Continued)

Table 5a–5 (Continued). Epidemiologic studies evaluating work-related carpal tunnel syndrome (CTS)

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Nathan 1992a	Long-itudinal	315 workers using both hands (each hand analyzed separately) from four industries. These represented 67% of original group of workers from 1988 published study randomly selected from four industries (67% of original subjects) Group I: Very light resistance and low repetition Group II: Light resistance and very high repetition Group III: Moderate resistance and moderately high repetition Group IV: Heavy resistance and moderate repetition Group V: Very heavy resistance.	Outcome: Case defined as NCS-determined impaired sensory conduction (sensory latency). Sensory latencies assessed antidromically for eight consecutive 1-cm segments of the nerve. A maximum latency difference of 0.4 ms or greater used to define impaired sensory conduction. Probable CTS: Presence of any two primary symptoms (numbness, tingling, nocturnal awakening) or one primary symptom and 2 secondary symptoms (pain, tightness, clumsiness). Exposure: For this article, previous exposure classification was used from 1988 Nathan article. Jobs had been grouped into 27 occupations with similarities of characteristics as to type of grip, wrist position, handedness pattern, resistance, frequency, and duration of grasp and presence of vibratory and ballistic components. The 27 occupations then grouped into 5 classes. Resistance rated from very light to very heavy; repetition rate rated from low to high.	Group II: 19% Group III: 26% Group IV: 24% Group V: 18%	Group 1: 18%	Groups II vs. Group I: PR=1.1 Group III vs. Group I: PR=1.5 Group IV vs. Group I: PR=1.4 Group V vs Group I: PR=1.0	0.6-1.9 1.0-2.2 0.9-2.1 0.5-2.2	Participation rate: Overall: 67%; Group 3 participation rate was 59%. Examiners blinded: Not reported. Analyzed using gender, hand dominance, occupational hand use, duration of employment, and industry. 76% of participants employed in same occupational hand-use class as in 1988. A lower percentage of novice workers returned (56%) than non-novice workers (69%) for follow-up study. Analysis of "hands" instead of individual would cancel contribution of exposure effect if there was unilateral slowing. Data in table two for 1984 subjects is not the same data as presented in previous article; numbers have shifted to other groups. The significant difference seen between nerve slowing between Class 1 and Class 5 in 1988 paper is no longer significantly different. Authors note that "130 hands experienced a decrease in occupational use." No parameters given for decrease and assumption is made that both hands in an individual had similar decrease in use. With one-third of cohort missing from 1984 study, there is no way to determine if homogeneity in symptoms prevalence in 1984 and 1989 reflects absence of progression or drop-out.

(Continued)

Table 5a–5 (Continued). Epidemiologic studies evaluating work-related carpal tunnel syndrome (CTS)

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Nathan 1994b	Long-itudinal	101 Japanese furniture factory workers. There were 27 managers, 35 clerical workers, 21 assembly-line or food service workers and 18 machine operators. Their NCS results were compared to 315 workers using both hands (each hand analyzed separately) from four industries. (These represented 67% of original group of workers from 1988 published study randomly selected from four industries (67% of original subjects) and are the subject of a separate table entry in this document. Group I: Very light resistance and low repetition. Group II: Light resistance and very high repetition. Group III: Moderate resistance and moderately high repetition. Group IV: Heavy resistance and moderate repetition. Group V: Very heavy resistance.	Outcome: Case defined as NCS-determined impaired sensory conduction (sensory latency). Sensory latencies assessed antidromically for eight consecutive 1 cm. segments of the nerve. A maximum latency difference of 0.4 ms or greater used to define impaired sensory conduction. Probable CTS: Presence of any two primary symptoms (numbness, tingling, nocturnal awakening or one primary symptom and 2 secondary symptoms (pain, tightness, clumsiness). Exposure: Exposure was not addressed except is assumed to be self-reported by questionnaire for the Japanese workers. The jobs were grouped into 5 classes. Resistance rated from very light to very heavy; repetition rate rated from low to high repetition.	8 cm. Sensory latency: 0.30 14 cm. Sensory latency: 0.36 Probable CTS: 2.5% Definite CTS: 2.0	8 cm. Sensory latency: 0.31 14 cm. Sensory latency: 0.45 Probable CTS: 2.0% Definite CTS: 8.3			Participation rate: For Japanese Workers: 100% Americans: Overall: 67%; Group 3 participation rate was 59%. Examiners blinded: Not reported. Analyzed using gender, hand dominance, occupational hand use, duration of employment, and industry. Analysis of "hands" instead of individual would cancel contribution of exposure effect if there was unilateral slowing. Conducted step-wise regression analysis for Probable CTS and reported that repetitions and duration of employment were protective. Cigarettes and Age were also retained in the model.

(Continued)

Table 5a–5 (Continued). Epidemiologic studies evaluating work-related carpal tunnel syndrome (CTS)

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Osorio et al. 1994	Cross-sectional	56 supermarket workers. Comparison was between high and low exposure groups.	Outcome: CTS assessed via medical history, physical exam, median nerve conduction studies, and vibratory thresholds. A. CTS-like syndrome: Probable diagnosis: (1) Pain tingling numbness in median nerve distribution and (2) symptoms last >1 wk or $ 12 times in last year, no acute trauma or systemic disease, onset or exacerbation since working on current job. B. Median neuropathy: Sensory median nerve conduction velocity 44 m/sec or less. Exposure: Observation of jobs by ergonomist and industrial hygienist. Analysis based on categorization by job title after observation. Jobs divided into 3 categories based on the likelihood of exposure to forceful and repetitive wrist motions (low, moderate, high), years worked at this store, total years worked as checker, total years using laser scanners.	Symptoms: 63% in high-exposure; 10% in moderate-exposure group Positive NCS: 33% in high-exposure; 7% in moderate-exposure group	0% for low-exposure group 0% for low-exposure group	8.3 (for CTS-symptoms high vs. low exposure groups) 6.7 (for abnormal NCS, high vs. low exposure groups)	2.6-26.4 0.8-52.9	Participation rate: 81%. Adjusted for age, gender, alcohol consumption, and high-risk medical history. Interview and testing procedures performed by personnel blinded to case status. Skin surface temperature not controlled. Dose response for presumptive (symptoms of) exposure to forceful, repetitive wrist motion: CTS-prevalence 63% high exposure; 10% medium exposure; 0% low exposure. Dose response for prevalence of abnormal median nerve velocity: 33% high; 7% medium; 0% low. Linear regression showed significant relationship between years worked and worsening of nerve conduction (decreased nerve conduction velocity and decreased nerve conduction amplitude) adjusted for confounders (above), however small sample size.

(Continued)

Table 5a–5 (Continued). Epidemiologic studies evaluating work-related carpal tunnel syndrome (CTS)

				MSD prevalence				
Study	Study design	Study population	Outcome and exposure	Exposed workers	Referent group	RR, OR, or PRR	95% CI	Comments
Punnett et al. 1985	Cross-sectional	162 female garment workers; 85% were employed as sewing machine operators who sewed and trimmed by hand. Comparison: 76 of 190 full- or part-time workers on day shift in a hospital who worked as nurses or aids; lab technicians or therapists, or food service workers. Employees typing >4 hr/day excluded from comparison group. 162 female garment workers compared to 73 female hospital workers.	Outcome: CTS assessed by symptom questionnaire and physical exam. Cases defined as the presence of persistent pain (lasted for most days for one month or more within the past year); were not associated with previous injury; and, began after first employment in garment manufacturing or hospital employment. Key questions based on the arthritis supplement questionnaire of the National Health and Nutrition Examination Survey (NHANES). Median nerve symptoms (pain, numbness, or tingling) if present at night or early in the morning or met 2 of 3 criteria: (1) accompanied by weakness in pinching or gripping; (2) alleviated by absence from work for >1 wk; (3) aggravated by housework or other non-occupational tasks. Exposure: Observation of job tasks. Information on work history obtained by questionnaire. Job title used as a proxy for exposure in analyses.	18%	6%	2.7	1.2-7.6	Participation rate: 97% (garment workers), 40% (hospital workers). Controlled for age, hormonal status, and native language. Pain in the wrist and hand significantly correlated (p<0.01; r=0.41). Age distribution not significantly different metabolic disease. Symptoms of CTS showed trend by age (p<0.01). Prevalence of pain not associated with years of employment in garment workers. Length of employment not predictor of risk. Change in hormonal status significantly associated with CTS symptoms but negatively associated with employment in garment shop. Logistic model found garment work and age significant for symptoms of CTS. Neither metabolic disease nor change in hormonal status statistically significant risk.

(Continued)

Table 5a–5 (Continued). Epidemiologic studies evaluating work-related carpal tunnel syndrome (CTS)

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	RR, OR, or PRR	95% CI	Comments
Schottland et al. 1991	Cross-sectional	Poultry workers (27 males, 66 females) compared to job applicants (44 males, 41 females).	Outcome: Defined as prolonged motor or sensory median latencies. No symptoms or physical exam included in case definition. Exposure: Based on current employment status at plant. No measurements made. Repetitive tasks (15 to 50 complex operations/min not rare), requiring firm grip, with wrists in flexion or extension, with internal deviations.	41% exceeding 2.2 ms for sensory latency value of median nerve on NCS (right-hand, females, corrected for age)	20% exceeding 2.2 ms for median sensory latency value (right-hand, females, corrected for age)	2.86	1.1-7.9	Participation rate: Not reported. Not mentioned whether examiners blinded to case status or exposure. Controlled for age and gender. Referents not excluded if prior employment at poultry plant; 15 referents had previous employment in poultry plant; this would result in poor selection of controls, would tend to bias results towards the null.
				24% exceeding 2.2 ms for median nerve sensory latency value on NCS (left-hand, females, corrected for age)	15% exceeding 2.2 ms for median nerve sensory latency value on NCS (left-hand, females, corrected for age)	1.87	0.6-9.8	Right-hand of female applicants who never worked in a poultry plant had significantly longer median palmar latency (MPS) on nerve conduction than referents (*p*<0.04). Symptoms of CTS not inquired. Right hand of male workers had longer MPS on nerve conduction but not significant (*p*<0.07). From Table 5-2 in paper it shows there is inadequate sample size for detecting differences in female's left-hand and male's left- and right-hand MPS. Concluded there is an elevated risk of CTS, roughly equal to risk from aging for the right hands of female workers, less risk for male both hands and female left hands.

(Continued)

Table 5a–5 (Continued). Epidemiologic studies evaluating work-related carpal tunnel syndrome (CTS)

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Silverstein et al. 1987	Cross-sectional	652 industrial workers in 4 groups: (1) low-force, low-repetition (comparison group, n=93 males, 64 females); (2) high-force, low-repetition (n=139 males, 56 females); (3) low-force, high-repetition (n=43 males, 100 females); (4) high-force, high-repetition (n=83 males, 74 females).	Outcome: CTS determined by medical examination and interviews. Symptoms of pain, numbness or tingling in median nerve distribution. Nocturnal exacerbation; symptoms >20 times or >1 wk in previous year; no history of acute trauma; no history of rheumatoid arthritis; onset of symptoms since current job; positive modified Phalen's test (45 to 60 sec) or Tinel's sign; rule out cervical root thoracic outlet, pronator teres syndrome. Exposure: To (1) forceful, (2) repetitive, and (3) awkward hand movements assessed by EMG and video analysis of jobs. Three workers in each selected job videotaped for (at least) 3 cycles. High-force job: A mean adjusted force >6 kg (mean adjusted force = [(variance/mean force)+ mean force]); low-force job: A mean adjusted force <6 kg. High repetition = work cycles <30 sec or work cycles constituting >50% of the work cycle.	1.0 (Group 2) 2.1 (Group 3) 5.6 (Group 4)	0.6	Group 2 vs. Group 1: OR=1.8 Group 3 vs. Group 1: OR=2.7 Group 4 vs. Group 1: OR=15.5 In separate logistic models: (1) Repetitiveness: OR=5.5 (p<0.05) (2) Force: OR=2.9 (non-significant)	0.2-21 0.3-28 1.7-142	Participation rate: 90% response rate obtained. Controlled for age, gender, plant, years on the job. No interactions found. Jobs evaluated by investigators blinded to worker health status. Examiner blinded to medical history and exposure. Random sample of 12 to 20 active workers/job with 1 year's seniority, stratified by age and gender. Interview data included prior health and injuries, chronic diseases, reproductive status of females, recreational activities, prior job activities. No association found with wrist posture, type of grasp, or use of vibrating tool. Positive associated with age but not statistically significance. No differences in health history or recreational activities. No association with gender, or industrial plant. Negatively associated with years on the job but not statistically associated. Repetitiveness found to be stronger risk factor than force. No association with hormonal status.

(Continued)

Table 5a–5 (Continued). Epidemiologic studies evaluating work-related carpal tunnel syndrome (CTS)

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Stetson et al. 1993	Cross-sectional	Comparison of 137 asymptomatic industrial workers, 103 industrial workers with hand/wrist symptoms, and 105 control subjects randomly selected not exposed to highly forceful or repetitive hand exertions.	Outcome: Symptoms consistent with CTS defined as numbness, tingling, or burning localized to median nerve anatomic area, not caused by acute injury, and occurred >20 times in previous year. Nerve conduction studies conducted on the dominant hand; median sensory and motor, ulnar sensory, distal amplitudes and latencies were measured. Temperature monitored. Exposure: Observation and worker interviews using ergonomic checklist. One or more workers on each job were evaluated based on repetitiveness, forcefulness, mechanical stress, pinch grip, and wrist deviation, then data extrapolated to other workers performing jobs. A 3-point ordinal scale used to estimate exposure (none, some, frequent or persistent).			Õ	Õ	Participation rate: 71% seen, 16% refused, others unavailable because of layoffs, transfers, or sick leave. Industrial population randomly selected. Controlled for age, height, skin temperature, and dominant index finger circumference. Comparing the means of the nerve conduction measures, the following were statistically significantly different between: (1) the asymptomatic hand group and the controls: median sensory amplitude and distal latency, and median to ulnar comparison measures; (2) the symptomatic hand group and controls: median sensory distal latency, and median to ulnar comparison measures. Median sensory amplitudes were smaller and distal latencies longer in symptomatic compared to asymptomatic hand group. Forceful hand and upper extremity exertions were significantly different between exposed and non-exposed groups. Repetition not significantly different, but little statistical power to detect difference.

(Continued)

Table 5a–5 (Continued). Epidemiologic studies evaluating work-related carpal tunnel syndrome (CTS)

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	Referent group	RR, OR, or PRR	95% CI	Comments
Tanaka et al. *In Press*	Cross-sectional interview survey	Data from the Occupational Health Supplement of 1988 National Health Interview Survey conducted by the National Center for Health Statistics. Households are selected by multistage probability sampling strategy. One adult, 18 years or older, was randomly selected for interview. 44,233 interviews completed.	Outcome: Outcomes included those "Recent Workers" who worked anytime during the past 12 months (excluding armed forces). Self-reported carpal tunnel syndrome= "yes" to question: During the past 12 months, have you had a condition affecting the wrist and hand called carpal tunnel syndrome? Medically called CTS = a response of "carpal tunnel syndrome" to the question: "What did the medical person call your hand discomfort?" Exposure: By questionnaire: Did the most recent job require you to bend or twist your hands or wrists many times an hr? Did you work with hand-held or hand-operated tools or machinery.	Prevalence of self-reported CTS among recent workers: 1.47% Prevalence of medically called CTS among recent workers: 0.53%		Logistic model for medically called CTS among recent workers Bend/twist: OR=5.9 White race: OR=4.2 Female gender: OR=2.4 Vibration: OR=1.85 BMI $25: OR=2.1 Cigarette use: OR=1.6 Age $40: OR=1.3 Annual income $$20,000: OR=1.5 Education >12: OR=1.2	 3.4-10.2 1.9-15.6 1.6-3.8 1.2-2.8 1.4-3.1 1-2.5 0.2-1.9 1-2.4 0.8-1.8	Participation rate: 91.5%. Multiple logistic regression used to examine age, gender, race, exposure to vibration, and bending/twisting of the hand/wrists to odds of reporting CTS. Interactions were checked for. Self-reported CTS prevalence among recent workers higher in whites compared to non-whites, highest in white females. When vibration was not in the model the bend/twist OR=5.99. When bend/twist is not in the model, vibration OR=3.00. Major limitation is CTS is based on self-reports without medical validation. No temporal relationship could be found between reported CTS and the reported occupation/industry or exposure to bending/twisting of the hand/wrist.

(Continued)

Table 5a–5 (Continued). Epidemiologic studies evaluating work-related carpal tunnel syndrome (CTS)

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	RR, OR, or PRR	95% CI	Comments
Weislander et al. 1989	Case-control	34 male CTS patients, each matched to 2 other hospital referents (drawn from among other surgical cases, one referent had been operated on for gall bladder surgery and the other for varicose veins) and 2 population referents (from a general population register and telephone directory) (total comparison group=143 males).	Outcome: CTS diagnosed clinically by a hand surgeon, confirmed by electro-diagnostic studies. Exposure: To vibrating tools, repetitive wrist movements, and loads on the wrist assessed via telephone interview using a standardized questionnaire. The degree of exposure was evaluated both with regard to the total number of work years and the average number of exposed hr a wk. Repetitive movements classified independently by physician interviewer and occupational hygienist. Exposure to repetitive wrist movements was considered to exist if they agreed.	Õ	Õ	Cases compared to all referents (hospital- and population-based): Vibrating tool use: OR=3.3 Use of hand-held vibrating tools 1-20 years: OR=2.7 Loads on the wrist: OR=1.8 Cases compared to population referents alone: Vibrating tool use: OR=6.1 Repetitive wrist movement for >20 years: OR=4.6 Repetitive wrist movement: OR=2.7 Obesity: OR=3.4	1.6-6.8 1.1-6.7 1.0-3.5 2.4-15 1.8-11.9 1.3-5.4 1.2-9.8	Participation rate: 93%. Referents matched for gender and age (±3 years.), hospital referents for year of operation. Hospital referents and population referents statistically different comparing: use of vibrating tool, repetitive movements of wrist, workload on wrist, obesity. Hospital-based population may not reflect industrial workplace. Interviewers not blinded to case status. Elevated OR for repetitive movements of the wrist only statistically significant for the category '>20 years.' Odds ratios (OR) for any of the three diseases (thyroid disease, diabetes, rheumatoid arthritis) found to be statistically significant among cases with CTS compared to 143 referents; OR=2.8 (1.0-7.6). ORs tended to increase with increasing number of risk factors present. One factor, OR=1.7 (0.6-4.4); two factors, OR=3.3 (1.2-9.1); >two factors, OR=7.1 (2.2-22.7). Obesity is >10% above reference weight.

CHAPTER 5b
Hand/Wrist Tendinitis

SUMMARY
Eight epidemiologic studies have examined physical workplace factors and their relationship to hand/wrist tendinitis. Several studies fulfill the four epidemiologic criteria that were used in this review, and appropriately address important methodologic issues. The studies generally involved populations exposed to a combination of work factors; one study assessed single work factors such as repetitive motions of the hand. We examined each of these studies, whether the findings were positive, negative, or equivocal, to evaluate the strength of work-relatedness, using causal inference.

There is **evidence** of an association between any single factor (repetition, force, and posture) and hand/wrist tendinitis, based on currently available epidemiologic data. There is **strong evidence** that job tasks that require a combination of risk factors (e.g., highly repetitious, forceful hand/wrist exertions) increase risk for hand/wrist tendinitis.

INTRODUCTION

Since the hand/wrist area may be affected by more than one musculoskeletal disorder, only those studies that specifically address hand/wrist tendinitis are considered here. Studies with outcomes described as hand/wrist disorders or symptoms in general, or those in which hand/wrist tendinitis was combined with epicondylitis, e.g., were excluded from this section because it was not possible to evaluate evidence for work-related hand/wrist tendinitis from the data. The seven studies referenced in Table 5b-1 provided data specifically addressing hand/wrist tendinitis. In each of these studies the outcome was determined using physical examination criteria, although the case definitions varied among studies. Prevalence or incidence rates of hand/wrist tendinitis reported in these exposed groups ranged from 4% to 56%, and in unexposed groups from 0% to 14%. Such wide ranges of prevalence rates probably reflect the variability in diagnostic criteria as much as they do the range of workplace exposures in these studies. For example, one study used very strict criteria [Byström et al. 1995]. The case definition required observation of swelling along the tendon at the time of the physical examination. The only cases of tendinitis diagnosed were deQuervain’s disease; no other cases of tenosynovitis or peritendinitis were diagnosed among 199 automobile assembly line workers. In contrast, the studies with the highest prevalence rates either did not clearly state what diagnostic criteria were used to determine the case definition, or the case definition considered recurrences of tendinitis new cases. Whether case definitions were inclusive or exclusive would not affect the relative risk (RR) as long as they were applied non-differentially between groups designated as exposed or unexposed.

Although several studies reported odds ratios, published data were reanalyzed and the results presented here and in
Tables 5b1-3 as prevalence ratios (PRs). This was done because odds ratios may overestimate RR when prevalence rates are

high, and to make estimates of RR comparable across studies. In studies that presented odds ratios in the original articles, the recalculation of data as PRs resulted in lower estimates of the RR. In the one prospective cohort study [Kurppa et al. 1991] incidence rates and risk ratios are presented.

Except for a study reported by Armstrong et al. [1987a], risk estimates were not reported separately for single risk factors. Only the Armstrong et al. study used a formal quantitative exposure assessment as the basis for determining exposure groups. Other studies grouped jobs with similar risk factors together and compared them to jobs without those risk factors. Typically, the selection of jobs for the exposed and unexposed groups was based on general knowledge of the jobs, previously published literature, or questionnaire data. Repetition, force, and extreme postures were considered in combination to determine which workers were exposed or unexposed. Formal exposure assessment (such as videotape analysis for cycle time, repetition, extreme postures, and estimates of force), was usually conducted on a sample of jobs and used as rationale in the grouping of jobs into exposed and unexposed categories, rather than to create quantitative measures of risk factors. In some cases (e.g., Luopajärvi et al. [1979]), investigators noted the difficulty in examining risk factors separately because of job rotation. For the purpose of this review, we have grouped study findings according to the risk factors present in the exposed job categories, based on the information in published articles. In Tables 5b1–3, studies are listed under single risk factors if there was evidence that the exposed and unexposed groups differed in that risk factor, though the risk estimates mostly refer to combined exposures.

REPETITION

Definition of Repetition for Hand/Wrist Tendinitis

Armstrong et al. [1987a] analyzed videotaped job tasks of a sample of workers, then divided job tasks according to level of repetitiveness: high repetition (cycle time <30 sec, or $50% of the cycle spent performing the same fundamental motions) or low repetition. Kuorinka and Koskinen [1979] created a "workload index" based on the number of pieces handled per hour multiplied by the number of hours worked, for a dose-response analysis within the exposed group. Comparison groups in the other studies were job categories; selection of the groups to be compared was based on observations, questionnaire data, or surveillance data.

Studies Reporting on the Association of Repetition and Hand/Wrist Tendinitis

Seven studies addressed repetition: Amano et al. [1988]; Armstrong et al. [1987a]; Byström et al. [1995]; Luopajärvi et al. [1979]; Roto and Kivi [1984]; Kuorinka and Koskinen [1979]; and McCormack et al. [1990].

Studies Meeting the Four Evaluation Criteria

Two of the seven studies that addressed repetition met all four of the evaluation criteria: Armstrong et al. [1987a], and Luopajärvi et al. [1979]. Armstrong et al. studied 652 industrial workers at seven manufacturing plants (electronics, sewing, appliance, bearing fabrication, bearing assembly, and investment casting). Exposure assessment of jobs included videotape analysis and electromyography (EMG) of a sample of workers. Data from this assessment were then used to categorize jobs according to level of repetitiveness and force. Health assessment of workers focused on deQuervain's disease, trigger finger, tendinitis, and tenosynovitis. The hand/wrist tendinitis case definition required abnormal physical examination findings (increased pain with resisted but not passive motion or tendon locking with a palpable nodule, or a positive Finkelstein's test) in addition to meeting symptom criteria on standardized interviews. The PR for the high repetition/low force group (n=143) compared to the low repetition/low force group (n=157) was 5.5 (95% confidence interval [CI] 0.7–46.3). The PR for the high repetition/high force group (n=157) compared to the low repetition/low force group (n=157) was 17.0 (95% CI 2.3–126.2). The effect of age, gender, years on the job, and plant were analyzed. A higher prevalence of tendinitis was noted among women but was not significantly associated with personal factors, whereas significant differences in posture were observed between males and females.

Luopajärvi et al. [1979] compared the prevalence of hand/wrist tendinitis among 152 female assembly line packers in a food production factory to 133 female shop assistants in a department store. Exposure to repetitive work, awkward hand/arm postures, and static work was assessed by observation and videotape analysis of factory workers. No formal exposure assessment was conducted on the department store workers; their job tasks were described as variable. Cashiers were excluded, presumably because their work was repetitive. The health assessment consisted of interviews and physical examinations conducted by a physiotherapist (active and passive motions, grip-strength testing, observation, and palpation). Diagnoses of tenosynovitis and peritendinitis were later determined by medical specialists using these findings and predetermined criteria. The PR for tendinitis among the assembly line packers compared to the shop assistants was 4.13 (95% CI 2.63–6.49). Age, hobbies and housework were addressed and no associations with musculoskeletal disorders were identified.

Studies Meeting at Least One Criteria

Amano et al. [1988] reported the prevalence of cervicobrachial disorders, including tenosynovitis, among 102 assembly line workers in an athletic shoe factory and 102 age- and gender-matched non-assembly line workers (clerks, nurses, telephone operators, cooks, and key punchers). Exposure assessment was based on videotape analysis of the tasks of 29 workers on one assembly line. Assembly line workers produced about 3,400 shoes a day. All but one task had cycle times less than 30 seconds. No formal exposure assessment of the comparison group was reported. Diagnoses were determined by physical examination, including palpation for tenderness. The PRs for tenosynovitis of the right and left index finger flexors among the shoe factory workers were 3.67 (95% CI 1.85–7.27) and 6.17 (95% CI 2.72–13.97) respectively, compared to the non-factory workers. Tenosynovitis of the other digits was not diagnosed in the comparison group. Shoe assembly workers held shoe lasts longer in the left hand and had greater frequency of symptoms in the left hand. Comparison subjects were matched to shoe factory workers on gender and age (within five years).

Byström et al. [1995] studied forearm and hand disorders among 199 automobile assembly line workers and compared them to 186 randomly selected subjects from the general Swedish population. For both groups, exposure was assessed using rating scales on nurse-administered questionnaires that addressed daily duration of hand and finger movements, wrist position, grip, and hand tool use [Fransson-Hall et al. 1995]. Videotape analysis and electromyograms were conducted on a subgroup [Hägg et al. 1996]. A diagnosis of tenosynovitis or peritendinitis required the observation of swelling and pain during active movement on physical examination. A diagnosis of deQuervain's disease required a positive Finkelstein's test. No cases of tenosynovitis or peritendinitis, other than deQuervain's disease, were found in this study, probably because of strict clinical criteria used for the case definition. The PR for deQuervain's disease among the automobile assembly line workers was 2.49 (95% CI 1.00–6.23) compared to the general population group. Psychosocial variables and other potential confounders or effect modifiers were addressed by Fransson-Hall et al. [1995]. A higher prevalence of deQuervain's disease was noted among men than women.

Kuorinka and Koskinen [1979] studied occupational rheumatic diseases and upper limb strain among 93 scissor makers and compared them to the same group of department store assistants (n=143) that Luopajärvi used as a comparison group. Temporary workers and those with recent trauma were excluded from the scissor makers group. Exposure assessment included videotape analysis of scissor maker tasks. The time spent in deviated wrist postures per work cycle was multiplied by the number of pieces handled per hour and the number of hours worked to create a workload index. Cycle times ranged from 2 to 26 seconds; the number of pieces handled per hour ranged from 150 to 605. No formal exposure assessment was conducted on the shop assistants. Health assessment involved interview and physical examination by a physiotherapist following a standard protocol. Diagnoses of tenosynovitis and peritendinitis were later determined from these findings using predetermined criteria (localized tenderness and pain during movement, low-grip force, swelling of wrist tendons [Waris et al. 1979]). In equivocal cases, orthopedic and physiatric teams determined case status. The PR for muscle-tendon syndrome among the scissor makers was 1.38 (95% CI 0.76–2.51) compared to the department store assistants. Whether or not cashiers were excluded from the comparison group in this study, as they were in the Luopajärvi et al. [1979] study is unclear. The study group was 99% female. No relationship was found between age- or body-mass index and muscle-tendon syndrome. The number of symptoms increased with the number of parts handled per year. Analyses of subgroups of scissor makers showed non-significant increased prevalence of muscle-tendon syndrome in short versus long cycle tasks and in manipulation versus inspection tasks. The authors noted a lack of contrast in exposures between the subgroups. A non-significant trend of increasing prevalence of diagnosed muscle-tendon syndrome with increasing number of pieces handled per year was noted in a nested case-control analysis (n=36).

McCormack et al. [1990] studied tendinitis and related disorders of the upper extremity among

1,579 textile production workers compared to 468 non-production textile workers, a reference group that included machine maintenance workers, transportation workers, cleaners, and sweepers. The textile production workers were reported as being exposed to repetitive finger, wrist and elbow motions based on knowledge of jobs; no formal exposure assessment was conducted. Health assessment included a questionnaire and screening physical examination followed by a diagnostic physical examination. The diagnosis of tendinitis required positive physical findings suggestive of inflammation. The textile production workers were divided into four broad job categories: boarding (n=296), which was noted to require forceful work as well as the repetitive hand-intensive work of the other categories; sewing (n=562); packaging (n=369); and knitting (n=352). The PR for tendinitis among all textile production workers was 1.75 (95% CI 0.9–3.39), compared to the reference group non-production textile workers. The PRs and 95% CIs comparing tendinitis among each broad category of textile production workers to the reference group are as follows: boarding—3.0 (1.4, 6.4); sewing—2.1 (1.0, 4.3); packaging—1.5 (0.7, 3.5); and knitting—0.4 (0.1, 1.4). The authors noted that the knitting work was more automated than the other textile production job categories. Race and age were not related to outcome, but the prevalence of tendinitis was higher in workers with less than three years of employment. Female gender was a significant predictor of tendinitis (p=0.01), but job category was a stronger predictor (p=0.001).

Roto and Kivi [1984] studied the prevalence of tenosynovitis among 92 male meatcutters compared to 72 male construction foremen. No formal exposure assessment was conducted. Meatcutters' work entailed repetitive physical exertion of upper extremities and shoulders. Construction foremen's work did not involve repetitive movements of the upper extremities. Health assessment was by questionnaire and physical examination. Tenosynovitis was defined as swelling, local pain, and finger weakness during movement. The prevalence of tenosynovitis among the meatcutters was 4.5%. The PR for tenosynovitis as defined by physical examination could not be calculated because there were no cases among the comparison group. The PR of tendinitis-like symptoms reported on the questionnaire among the meatcutters was 3.09 (1.43, 6.67) compared to the construction foremen. Serologic testing for rheumatoid arthritis was done to control for potential confounding, none was detected. Authors noted that tenosynovitis occurred in younger age groups.

Strength of Association—Repetition and Hand/Wrist Tendinitis

The PRs for repetitive work and hand/wrist tendinitis in the studies reviewed above ranged from 1.4 to 6.2:

Repetition and Hand/Wrist Tendinitis

PR and 95% CI	Authors	Exposed/Unexposed Groups
5.5 (0.7–46.3) 17.0 (2.3–126.2)	Armstrong et al. [1987a]*	HI REP & LO FORCE/LO REP & LO FORCE HI REP & HI FORCE/LO REP & LO FORCE
3.7 (1.9–7.3) to 6.2 (2.7–14.0)	Amano et al. [1988]	Shoe assemblers/clerks, nurses, operators, cooks, keypunchers
2.5 (1.0–6.23)	Byström et al. [1995]	Auto assemblers/general population
1.4 (0.8–2.5)	Kuorinka and Koskinen [1979]	Scissor makers/department store assistants
1.8 (0.9–3.4)	McCormack et al. [1990]	Textile production/ maintenance workers, etc.
3.1 (1.4–6.7)	Roto and Kivi [1984]	Meatcutters/construction foremen
4.1 (2.6–6.5)	Luopajärvi et al. [1979]*	Food packers/department store assistants excluding cashiers

*Study met all four criteria.

In evaluating these RR estimates, study limitations should be considered in addition to statistical significance. Statistical significance addresses the likelihood that the results are not due to chance alone, whereas study limitations can bias the RR estimates in either direction. All of the PRs were greater than one, and four of the seven were statistically significant. The range (1.4–6.2) might reflect the level of contrast in repetitiveness between the exposed and comparison groups. For example, in McCormack et al. [1990], the comparison group consisted of machine maintenance workers, transportation workers, and cleaners and sweepers, whose exposure to repetition was not measured. If there were some exposure to repetitive work in the comparison group, then this would tend to decrease the RR for hand/wrist tendinitis among the textile workers. Another concern with this study is the possibility that the knitting workers may not have been exposed to very repetitive work due to greater automation in the knitting process. The effect of this potential misclassification of exposure would also be to decrease the RR.

Note that Kuorinka and Koskinen and Luopajärvi et al. both used the same comparison group, but the number of subjects in the department store assistant group was 143 for Kuorinka and Koskinen, and 133 for Luopajärvi (who excluded cashiers from the comparison group). If Kuorinka and Koskinen did not exclude cashiers, this might tend to decrease the RR.

The highest RR (6.2) reported for repetitive work was by Amano et al. [1988]. In this study it is unclear whether the examiner was blinded to whether the subjects were shoe assemblers or in the comparison group of non-assembly line workers that included clerks, nurses, telephone operators, cooks, and key punchers. Because the occupational groups were examined on separate dates blinding seems unlikely. The lack of a clear case definition leaves open the possibility of examiner bias, which might lead to an increased RR. Alternatively, if there were a significant number of key punchers in the comparison group, who may have been exposed to repetitive work, that would tend to decrease the contrast in exposure and might lead to a decrease in the RR.

In summary, the potential for underestimation of the RR has been noted in studies where the RR is at the low end of the range, and the potential for overestimation of the RR has been noted at the high end of the range. Considering these concerns and statistical significance, the RR for hand/wrist tendinitis attributable to repetitiveness is probably more likely to be in the middle range of the estimates, based on the studies reviewed. The statistically significant estimates of RR in this middle group range from 2.5 to 4.1.

Temporal Relationship—Repetition and Hand/Wrist Tendinitis

All of the studies reviewed for this section were cross-sectional, so proving that exposure to repetitive work occurred before hand/wrist tendinitis is not possible. However, information in several of the studies suggests the likelihood that exposure to repetitive work occurred before the diagnosis of tendinitis. For example, recently employed workers were excluded by Kuorinka and Koskinen [1979]. In Luopajärvi et al.'s [1979] study group, the minimum length of employment was 3 years. In the McCormack et al. [1990] study, the minimum average length of employment in the job categories was more than 7 years. Byström et al. [1995] noted that subjects were selected for clinical examination 5 months after completion of questionnaires on exposure. Roto and Kivi's [1984] subjects had all worked in the food industry for more than one year. Armstrong and Chaffin [1979] required a minimum length of employment of one year. Case definitions generally required that symptoms began after starting the current job or employment at the plant. This also suggests that exposure occurred before disease.

Consistency in Association for Repetition and Hand/Wrist Tendinitis

All of the studies reviewed showed positive RR estimates for hand/wrist tendinitis among occupational groups exposed to repetitive work, ranging from 1.4 to 6.2. Four of the seven studies resulted in statistically significant PRs. Considering only statistically significant estimates from studies not noted to have serious limitations (which might bias the RR), the range narrows to 2.5–4.1.

Coherence of Evidence for Repetition and Hand/Wrist Tendinitis

DeQuervain's disease and other tenosynovitis of the hand, wrist, and forearm have been associated for decades with repetitive and forceful hand activities as one of the possible causal factors [Amadio 1995]. DeQuervain's disease is the entrapment of the tendons of the extensor pollicis brevis and abductor pollicis longus. Other similar conditions are trigger thumb and triggering of the middle and ring fingers, characterized by pain with motion of the affected tendon. Despite the fact that the tendon and its sheath may be swollen and tender, the histopathology shows peritendinous fibrosis without inflammation, and fibrocartilaginous metaplasia of the tendon sheath tissue. The role of inflammation early in the process is not clear [Hart et al. 1995]. As in carpal tunnel syndrome or epicondylitis, acute classical inflammation does not seem a critical pathophysiological component of the clinical condition, at least once it becomes chronic. Despite the observations that too much forceful and repetitive activity contributes to carpal tunnel syndrome and epicondylitis, the response of the tendons and the muscles to repetitive activity is likely that of a U-shaped curve. Too little and too much activity may be harmful, but intermediate levels of activity are probably beneficial. The studies of tendon and muscle physiology suggest that a certain amount of activity maintains the normal state of these tissues and leads to adaptive changes. These tissues have the ability to repair significant amounts of damage from some overuse; the poorly understood issue is when overuse exceeds the ability of the tissue to repair the damage or triggers a more harmful type of damage [Hart et al. 1995]. Marras and Schoenmarklin [1991] reported that velocity and acceleration significantly predicted upper extremity musculoskeletal disorders (including tendinitis) among industrial workers performing hand-intensive job tasks.

Dose-Response Relationship For Repetition and Hand/Wrist Tendinitis

Kuorinka and Koskinen [1979] reported that within the group of scissor makers, increased prevalence of muscle-tendon syndrome occurred in short versus long cycle tasks and in manipulation versus inspection tasks. These increases were not statistically significant. The authors noted a lack of contrast in exposures between the subgroups. A non-significant trend of increasing prevalence of diagnosed muscle-tendon syndrome with increasing number of pieces handled per year was also noted in a nested case-control analysis (n=36) in the same study.

The Armstrong et al. [1987a] data resulted in a PR of 17.0 (2.3, 126.2) for jobs that were highly repetitious and required highly forceful exertions. This suggests a synergistic effect when both risk factors are present because the estimate is greater than the sum of the RR estimate for force or repetition alone.

Conclusions on Repetition and Hand/Wrist Tendinitis

There is strong evidence for a positive association between highly repetitive work, in combination with other job risk factors, and hand/wrist tendinitis based on currently available epidemiologic data. All seven of the studies reviewed reported positive RR estimates. Four of these estimates were statistically significant. Potential confounders (factors associated with both exposure and outcome that may distort interpretation of findings) considered in the studies of hand/wrist tendinitis included gender, age, other medical conditions, and outside activities. There is no evidence that the associations reported here between repetitive work and hand/wrist tendinitis are distorted by gender, age, or other factors.

FORCE

Definition of Force for Hand/Wrist Tendinitis

Armstrong et al. [1987a] based high and low force categories on electromyographs of forearm flexor muscles of representative workers. Comparison groups in the other studies were job categories; selection of the groups to be compared was based on observations, questionnaire data, or surveillance data.

Studies Reporting on the Association of Force and Hand/Wrist Tendinitis

Five studies addressed force: Armstrong et al. [1987a]; Byström et al. [1995]; Kurppa et al. [1991]; McCormack et al. [1990]; and Roto and Kivi [1984].

Studies Meeting the Four Criteria

One of the studies that addressed force met all four of the evaluation criteria: Armstrong et al. [1987a]. Armstrong et al. studied 652 industrial workers at seven manufacturing plants (electronics, sewing, appliance, bearing fabrication, bearing assembly, and investment molding). Exposure assessment of jobs included videotape analysis and EMG of a sample of workers. Data from this assessment were then used to categorize jobs according to level of repetitiveness and force. Health assessment of workers focused on deQuervain's disease, trigger finger, tendinitis, and tenosynovitis. The hand/wrist tendinitis case definition required abnormal physical examination findings (increased pain with resisted but not passive motion or tendon locking with a palpable nodule, or a positive Finkelstein's test) in addition to meeting symptom criteria on standardized interviews. The PR for the high force/low repetition group (n=195) compared to the low force/low repetition group (n=157) was 4.8 (95% CI 0.6–39.7). The PR for the high repetition/high force group (n=157) compared to the low repetition/low force group (n=157) was 17.0 (95% CI 2.3–126.2). The effect of age, gender, years on the job and plant were analyzed. A higher prevalence of tendinitis was noted among women, but was not significantly associated with personal factors, whereas significant differences in posture were observed between males and females.

Studies Meeting at Least One Criteria

Byström et al. [1995] studied forearm and hand disorders among 199 automobile assembly line workers and compared them to 186 randomly selected subjects from the general Swedish population. For both groups, exposure was assessed using rating scales on nurse-administered questionnaires that addressed daily duration of hand and finger movements, wrist position, grip, and hand-tool use [Fransson-Hall et al. 1995]. Videotape analysis and electromyograms were conducted on a subgroup [Hägg et al. 1996]. A diagnosis of tenosynovitis or peritendinitis required the observation of swelling and pain during active movement on physical examination. A diagnosis of deQuervain's disease required a positive

Finkelstein's test. No cases of tenosynovitis or peritendinitis, other than deQuervain's disease, were found in this study, probably because of strict clinical criteria used for the case definition. The PR for deQuervain's disease among the automobile assembly line workers was 2.49 (95% CI 1.00–6.23) compared to the general population group. Psychosocial variables and other potential confounders or effect modifiers were addressed by Fransson-Hall et al. [1995]. A higher prevalence of deQuervain's disease was noted among men than women.

Kurppa et al. [1991] conducted a prospective cohort study of tenosynovitis or peritendinitis (and epicondylitis) in a meat processing factory in Finland. Three hundred seventy-seven meatcutters, meatpackers, and sausage makers were compared to 338 office workers, maintenance workers, and supervisors. Exposure assessment was based on previously published literature and knowledge of jobs at the plant. Job categories were selected based on whether or not strenuous manual work was required. The cohort was followed for 31 months. Health assessment consisted of physical examinations by plant physicians who were on-site daily, using predetermined criteria for diagnosing tenosynovitis or peritendinitis (swelling or crepitation and tenderness to palpation along the tendon and pain at the tendon sheath, in the peritendinous area, or at the muscle-tendon junction during active movement) and deQuervain's disease (positive Finkelstein's test). Incidence density rates (if a recurrence of tendinitis occurred after 60 days, it was considered a new case) for tendinitis were compared between each of the strenuous job categories and either the male or female comparison group of combined non-strenuous job categories (office workers, maintenance workers and supervisors). The RR for tendinitis among the meatcutters (100% males) compared to the male comparison group was 14.0 (5.7, 34.4); the RR for tendinitis among the meatpackers (79% female) compared to the female comparison group was 38.5 (11.7, 56.1); and the risk ratio for tendinitis among the sausage makers (86% female) was 25.6 (19.2, 77.5). A limitation of the study is the fact that the subjects were not actively evaluated for musculoskeletal disorders. Investigators relied on workers to seek medical care. This could result in a difference in case ascertainment between the exposed and unexposed groups because workers in non-strenuous jobs may not have sought medical care for musculoskeletal disorders since they might still be able to perform their jobs, whereas workers with MSDs in strenuous jobs might not be able to perform their jobs, and would be more likely to seek medical care. If subjects sought medical care, investigators were very likely to capture the information, even if medical care was provided outside the plant, plant nurses received and reimbursed the bills, and recorded the diagnosis and sick leave. However, when diagnoses were made by physicians outside the plant, diagnostic criteria were unknown; this occurred in 25% of the cases. Exposed and comparison groups were similar in age and gender mix, although gender varied with job.

McCormack et al. [1990] studied tendinitis and related disorders of the upper extremity among 1,579 textile production workers compared to 468 referents that included machine maintenance workers, transportation workers, cleaners, and sweepers. The textile production workers

were reported, based on knowledge of the jobs to be exposed to repetitive finger, wrist and elbow motions; no formal exposure assessment was conducted. Health assessment included a questionnaire and screening physical examination followed by a diagnostic physical examination. The diagnosis of tendinitis required positive physical findings suggestive of inflammation. The textile production workers were divided into four broad job categories. Boarding (n=296), was the only category noted to require forceful work. The PR for tendinitis among the boarding workers was 3.0 (95% CI 1.4–6.4), compared to the reference group. Race and age were not related to outcome, but the prevalence of tendinitis was higher in workers with less than three years of employment. Female gender was a significant predictor of tendinitis (p=0.01), but job category was a stronger predictor (p=0.001).

Roto and Kivi [1984] studied the prevalence of tenosynovitis among 92 male meatcutters compared to 72 male construction foremen. No formal exposure assessment was conducted. Meatcutters' work entailed repetitive physical exertion of upper extremities and shoulders. Construction foremen's work did not involve repetitive movements of the upper extremities. Health assessment was by questionnaire and physical examination. Tenosynovitis was defined as swelling, local pain, and finger weakness during movement. The prevalence of tenosynovitis among the meatcutters was 4.5%. The PR for tenosynovitis as defined by physical examination could not be calculated because there were no cases among the comparison group. The PR of tendinitis-like symptoms reported on the questionnaire among the meatcutters was 3.09 (1.43, 6.67) compared to the construction foremen. Serologic testing for rheumatoid arthritis was done to control for potential confounding, none was detected. Authors noted that tenosynovitis occurred in younger age groups.

Strength of Association—Force and Hand/Wrist Tendinitis

Estimates of RR for hand/wrist tendinitis among those in jobs requiring forceful exertion range from 2.5 to 38.5:

The very large risk ratios reported by Kurppa et al. [1991] could be biased upward because of the difference in case ascertainment between the exposed and unexposed groups. Investigators did not actively evaluate subjects for MSDs, but relied on workers to seek medical care. As the authors noted, workers in non-strenuous jobs may not have sought medical care for MSDs since they might still be able to perform their jobs, while workers in strenuous jobs may not have been able to perform their jobs and would be more likely to seek medical care. This potential for differential case ascertainment between the exposed and unexposed groups undermines the credibility of the magnitude of the risk estimate.

Statistically significant estimates of RR for hand/wrist tendinitis among workers who perform strenuous tasks from the remaining studies range from 2.5 to 3.1.

Force and Hand/Wrist Tendinitis

PR and 95% CI	Authors	Exposed/Unexposed Groups
4.8 (0.6–39.7) 17.0 (2.1–26.2)	Armstrong et al. [1987a]	HI FORCE & LO REP/LO FORCE & LO REP HI FORCE & HI REP/ LO FORCE & LO REP
2.5 (1.0–6.23)	Byström et al. [1995]	Auto assemblers/general population
14.0 (5.7–34.4) to 38.5 (11.7–56.1)	Kurppa et al. [1991]	Meat processors/office workers, maintenance workers, supervisors
3.0 (1.4–6.4)	McCormack et al. [1990]	Textile boarding workers/ maintenance workers, etc.
3.1 (1.4–6.7)	Roto and Kivi [1984]	Meatcutters/construction foremen

* Study met all four criteria.

Temporal Relationship—Force and Hand/Wrist Tendinitis

The Kurppa et al. [1991] study determined exposure status of 83% of the cohort on October 2, 1982, and followed their health status until April 30, 1985. The remaining subjects entered the study when they became permanent employees, and were also followed until April 30, 1985.

Although the remaining studies that addressed force were cross-sectional, the following information increases the likelihood that exposure to forceful work occurred before the occurrence of tendinitis; Byström et al. [1995] noted that subjects were selected for clinical examination
5 months after completion of questionnaires on exposure. McCormack et al. [1990] reported that the minimum average length of employment in the job categories studied was more than 7 years. Roto and Kivi's

[1984] subjects had all worked in the food industry for more than one year. Armstrong et al. [1987a] required a minimum of 1 year of employment to be included in the study.

Consistency of Association—Force and Hand/Wrist Tendinitis

All of the studies reviewed reported positive RR estimates for hand/wrist tendinitis among occupational groups exposed to forceful exertions, ranging from 1.8 to 38.5. Four of the five studies reported statistically significant findings. If only statistically significant estimates from studies in which limitations were not noted are considered, RR estimates for force and hand/wrist tendinitis range from 2.5 to 3.1.

Coherence of Evidence—Force and Hand/Wrist Tendinitis

See Repetition Section.

Evidence of a Dose-Response Relationship—Force and Hand/Wrist Tendinitis

Armstrong et al. [1987a] demonstrated a dose-response relationship between jobs requiring forceful exertions and hand/wrist tendinitis. The estimate of RR for hand/wrist tendinitis among workers with jobs that were classified as HIGH FORCE & LOW REPETITION was 4.8 (0.6, 39.7), while the estimate for HIGH FORCE & HIGH REPETITION jobs was 17.0 (2.3, 126.2), compared to the comparison group of LOW FORCE & LOW REPETITION jobs.

Conclusions on Force and Hand/Wrist Tendinitis

There is **strong evidence** for an association between work that requires forceful exertions, in combination with other job risk factors, and hand/wrist tendinitis based on currently available epidemiologic data. All five of the studies reviewed reported data that resulted in positive RR estimates. Four of the five estimates were statistically significant. Eliminating one estimate of RR from a study with noted limitations that might bias the estimate upward does not change this conclusion. Potential confounders such as age and gender were examined in these studies (see discussion of potential confounders on page 5b-16) and there was no evidence that reported associations were distorted by confounders.

POSTURE

Definition of Posture for Hand/Wrist Tendinitis

Kuorinka and Koskinen [1979] determined the time spent in deviated wrist postures per work cycle as part of their “workload index” that was used in a dose-response analysis

within the exposed group. Comparison groups in the other studies were job categories; selection of the groups to be compared was based on observations, questionnaire data, or surveillance data.

Studies Reporting on the Association of Posture and Hand/Wrist Tendinitis

Four studies addressed posture: Amano et al. [1988]; Byström et al. [1995]; Luopajärvi et al. [1979]; and Kuorinka and Koskinen [1979].

Studies Meeting the Four Criteria

Luopajärvi et al. [1979] met all four evaluation criteria. Luopajärvi et al. [1979] compared the prevalence of hand/wrist tendinitis among 152 female assembly line packers in a food production factory to 133 female shop assistants in a department store. Exposure to repetitive work, awkward hand/arm postures, and static work was assessed by observation and videotape analysis of factory workers. No formal exposure assessment was conducted on the department store workers; their job tasks were described as variable. Cashiers were excluded, presumably because their work was repetitive. The health assessment consisted of interviews and physical examinations conducted by a physiotherapist (active and passive motions, grip-strength testing, observation, and palpation); and diagnoses of tenosynovitis and peritendinitis were later determined by medical specialists using these findings and predetermined criteria. The PR for tendinitis among the assembly line packers compared to the shop assistants was 4.13 (95% CI

2.63–6.49). Age, hobbies, and housework were addressed, and no associations with musculoskeletal disorders were identified.

Studies Meeting at Least One Criteria

Amano et al. [1988] reported the prevalence of cervicobrachial disorders, including tenosynovitis, among 102 assembly line workers in an athletic shoe factory and 102 age- and gender-matched non-assembly line workers (clerks, nurses, telephone operators, cooks, and key punchers). Exposure assessment was based on videotape analysis of the tasks of 29 workers on one assembly line. Characteristic basic postures were summarized by the investigators as: holding a shoe or a tool, extending or bending the arms, and keeping the arms in a certain position. Assembly line workers produced about 3,400 shoes a day. All but one task had cycle times less than 30 seconds. No formal exposure assessment of the comparison group was reported. Diagnoses were determined by physical examination, including palpation for tenderness. The PRs for tenosynovitis of the right and left index finger flexors among the shoe factory workers were 3.67 (95% CI 1.85–7.27) and 6.17 (95% CI 2.72–13.97) respectively, compared to the non-factory workers. Tenosynovitis of the other digits was not diagnosed in the comparison group. Shoe assembly workers held shoe lasts longer in the left hand and had greater frequency of symptoms in the left hand. Comparison subjects were matched to shoe factory workers on gender and age (within five years).

Byström et al. [1995] studied forearm and hand disorders among 199 automobile assembly line workers and compared them to 186 randomly selected subjects from the general Swedish population. For both groups, exposure was assessed using rating scales on nurse-administered questionnaires that addressed daily duration of hand and finger movements, wrist position, grip, and hand-tool use [Fransson-Hall et al. 1995]. Videotape analysis and electromyograms were conducted on a subgroup [Hägg et al. 1996]. A diagnosis of tenosynovitis or peritendinitis required the observation of swelling and pain during active movement on physical examination. A diagnosis of deQuervain's disease required a positive Finkelstein's test. No cases of tenosynovitis or peritendinitis, other than deQuervain's disease, were found in this study, probably because of strict clinical criteria used for the case definition. The PR for deQuervain's disease among the automobile assembly line workers was 2.49 (95% CI 1.00–6.23) compared to the general population group. Psychosocial variables and other potential confounders or effect modifiers were addressed by Fransson-Hall et al. [1995]. A higher prevalence of deQuervain's disease was noted among men than women.

Kuorinka and Koskinen [1979] studied occupational rheumatic diseases and upper limb strain among 93 scissor makers and compared them to the same group of department store assistants (n=143) that Luopajärvi used as a comparison group. Temporary workers and those with recent trauma were excluded from the scissor makers group. Exposure assessment included videotape analysis of scissor maker tasks. The time spent in deviated wrist postures per work cycle was multiplied by the number of pieces handled per hour and the number of hours worked to create a workload index. Cycle times ranged from 2 to 26 seconds; the number of pieces handled per hour ranged from 150 to 605. No formal exposure assessment was conducted on the shop assistants. Health assessment involved interview and physical examination by a

physiotherapist following a standard protocol. Diagnoses of tenosynovitis and peritendinitis were later determined from these findings using predetermined criteria (localized tenderness and pain during movement, low-grip force, swelling of wrist tendons [Waris et al. 1979]). In equivocal cases, orthopedic and physiatric teams determined case status. The PR for muscle-tendon syndrome among the scissor makers as 1.38 (95% CI 0.76–2.51) compared to the department store assistants. Whether or not cashiers were excluded from the comparison group in this study, as they were in the Luopajärvi et al. [1979] study is unclear. The study group was 99% female. No relationship was found between age or body mass index and muscle-tendon syndrome. The number of symptoms increased with the number of parts handled per year. Analyses of subgroups of scissor makers showed non-significant increased prevalence of muscle-tendon syndrome in short versus long cycle tasks and in manipulation versus inspection tasks. The authors noted a lack of contrast in exposures between the subgroups. A non-significant trend of increasing prevalence of diagnosed muscle-tendon syndrome with increasing number of pieces handled per year was noted in a nested case-control analysis (n=36).

Strength of Association—Extreme Posture and Hand/Wrist Tendinitis

The PRs for extreme postures and hand/wrist tendinitis ranged from 1.4 to 6.2. All of the PRs were greater than one and three of the four studies reported statistically significant estimates. As noted in the Repetition Section, the possibility of examiner bias might exist in the study reported by Amano et al. [1988], potentially biasing the RR estimate upward. The middle of the range of statistically significant estimates for RR for hand/wrist tendinitis is 2.5 to 4.1.

Temporal Relationship

Although all of the studies reviewed in this section were cross-sectional, at least two of the studies addressed temporality by reporting a minimum length of employment (Luopajärvi et al. [1979]—5 years) or by evaluating exposure before health outcomes [Byström et al. 1995], as discussed in the previous sections on Repetition and Force.

Consistency

All of the studies reviewed showed positive RR estimates for hand/wrist tendinitis among occupational groups exposed to extreme postures, ranging from 1.4 to 6.2. Three of the four studies reviewed resulted in statistically significant PRs. Considering only statistically significant estimates from studies not noted to have design limitations that might bias the RR, narrows the range to 2.5 to 4.1.

Coherence of Evidence

See Repetition Section.

Dose-Response

See Repetition Section.

Posture and Hand/Wrist Tendinitis

PR and 95% CI	Authors	Exposed/Unexposed Groups
4.1 (2.6–6.5)	Luopajärvi et al. [1979]	Food packers/department store assistants
3.7 (1.9–7.3) to 6.2 (2.7–14.0)	Amano et al. [1988]	Shoe assemblers/clerks, nurses, operators, cooks, keypunchers
2.5 (1.0–6.23)	Byström et al. [1995]	Auto assemblers/general population
1.4 (0.8–2.5)	Kuorinka and Koskinen [1979]	Scissor makers/department. store assistants

There is **strong evidence** for a positive association between work that requires extreme postures, in combination with other job risk factors, and hand/wrist tendinitis, based on currently available epidemiologic data. All of the studies reviewed reported data that resulted in positive RR estimates. Three of the four estimates from these studies were statistically significant. Taking into account the effect of potential confounders (See Repetition Section) such as gender, age, and study limitations does not alter this conclusion.

Potential Confounders

Gender

The association between gender and tendinitis is not uniform. Byström et al. [1995] reported a higher prevalence of deQuervain's tendinitis in men than in women, and proposed the explanation that men in their study group used hand tools more often than women. Ulnar deviation and static muscle loading were likewise more often reported among men. Armstrong et al. [1987a] reported a higher prevalence of tendinitis among women but found no significant associations with other medical factors or activities outside of work. However, significant differences in posture were observed between males and females. Differences in postures may be due to differences in height between men and women whose workstations have uniform dimensions. In McCormack et al.'s [1990] study of textile workers, three of the four exposed groups were largely female (89%–95%), limiting the ability to separate the effect of gender from job effect. However, in an analysis that included gender and job as risk factors, they reported that gender was a significant predictor of tendinitis (p=0.01), but not as significant a predictor as job category (p=0.001). The other studies reviewed did not have both male and female subjects.

Age

Several investigators noted that tendinitis appears to be more prevalent in younger age groups. Byström et al. [1995] reported that most of the cases of deQuervain's tendinitis occurred in the <40-yr age group.

McCormack et al. [1990] reported that age was not a significant predictor of tendinitis, but years on the job was inversely associated—prevalence was higher if less than 3 years on the job. Armstrong et al. [1987] noted that "a significant interaction between sex, age, and years on the job suggested that the risk of hand/wrist tendinitis might actually decrease with an increased number of years on the job, but the effect was too small to merit further discussion." Roto and Kivi [1984] noted that "The few cases of tenosynovitis occurred in younger workers." Kuorinka and Koskinen [1979] and Luopajärvi et al. [1979] found no significant association between age and tendinitis.

Other Potential Confounders

McCormack et al. [1990] reported that race was not associated with tendinitis. Armstrong et al. [1987a] found no significant associations with personal factors—birth control pills, hysterectomy, oophorectomy, recreational activities. No subjects with seropositive rheumatic diseases were included in the Kuorinka and Koskinen [1979] study. They reported that their earlier unpublished questionnaire found no correlations between illness and extra work, work outside the factory, work at home, or hobbies. Luopajärvi et al. [1979] excluded subjects with previous trauma, arthritis, and other pathologies.

There is no evidence in the studies reviewed here that the associations reported between work factors and hand/wrist tendinitis are explained by gender, age, or other factors.

CONCLUSIONS

Eight epidemiologic studies have examined physical workplace factors and their relationship to hand/wrist tendinitis. Several studies fulfill the four epidemiologic criteria that were used in this review, and appropriately address important methodologic issues. The studies generally involved populations exposed to a combination of work factors; one study assessed single work factors such as repetitive motions of the hand. We examined each of these studies, whether the findings were positive, negative, or equivocal, to evaluate the strength of work-relatedness, using causal inference.

There is **evidence** of an association between any single factor (repetition, force, and posture) and hand/wrist tendinitis, based on currently available epidemiologic data. There is **strong evidence** that job tasks that require a combination of risk factors (e.g., highly repetitious, forceful hand/wrist exertions) increase risk for hand/wrist tendinitis.

Table 5b-1. Epidemiologic criteria used to examine studies of hand/wrist tendinitis associated with repetition

Study (first author and year)	Risk indicators (OR, PRR, IR or *p*-value)[*,†]	Participation rate ≥70%	Physical examination	Investigator blinded to case and/or exposure status	Basis for assessing hand/wrist exposure to repetition
Met all four criteria:					
Armstrong 1987a	5.5, 17.0[†]	Yes	Yes	Yes	Observation or measurements
Luopajärvi 1979	4.1[†]	Yes	Yes	Yes	Observation or measurements
Met at least one criterion:					
Amano 1988	3.7–6.2[†]	NR[‡]	Yes	NR	Job titles or self-reports
Byström 1995	2.5[†]	Yes	Yes	No	Job titles or self-reports[§]
Kuorinka 1979	1.4	Yes	Yes	NR	Observation or measurements
McCormack 1990	1.8	Yes	Yes	NR	Job titles or self-reports
Roto 1984	3.1[†]	Yes	Yes	Yes	Job titles or self-reports

[*]Some risk indicators are based on a combination of risk factors—not on repetition alone (i.e., repetition plus force, posture, or vibration). Odds ratio (OR), prevalence rate ratio (PRR), or incidence ratio (IR).

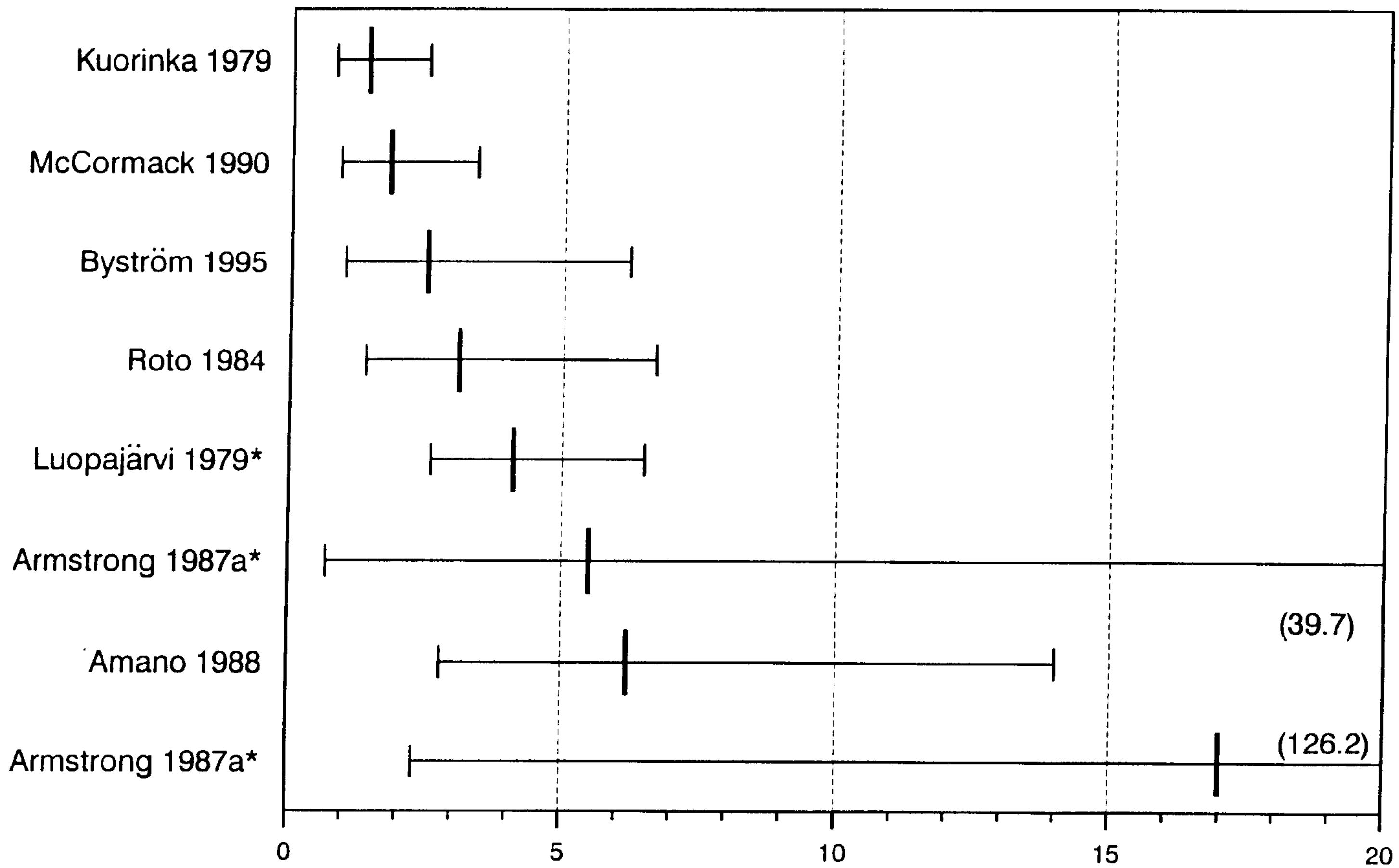
[†]Indicates statistical significance.

[‡]Not reported.

[§]EMG and video analysis of subgroup reported in Hägg et al. [1996].

Figure 5b-1. **Risk Indicator for "Repetition" and Hand/Wrist Tendinitis**

(Odds Ratios and Confidence Intervals)



* Studies which met all four criteria.

Table 5b-2. Epidemiologic criteria used to examine studies of hand/wrist tendinitis MSDs associated with force

Study (first author and year)	Risk indicator (OR, PRR, IR or *p*-value)*,†	Participation rate ≥70%	Physical examination	Investigator blinded to case and/or exposure status	Basis for assessing hand/wrist exposure to force
Met all four criteria:					
Armstrong 1987a	17.0†, 4.8	Yes	Yes	Yes	Observation or measurements
Met at least one criterion:					
Byström 1995	2.5†	Yes	Yes	No	Job titles or self-reports§
Kurppa 1991	14.0–38.5†	Yes	Yes	NR‡	Observation or measurements
McCormack 1990	3.0†	Yes	Yes	NR	Job titles or self-reports
Roto 1984	3.1†	Yes	Yes	Yes	Job titles or self-reports

*Some risk indicators are based on a combination of risk factors—not on force alone (i.e., force plus repetition, posture, or vibration). Odds ratio (OR), prevalence rate ratio (PRR), or incidence ratio (IR).

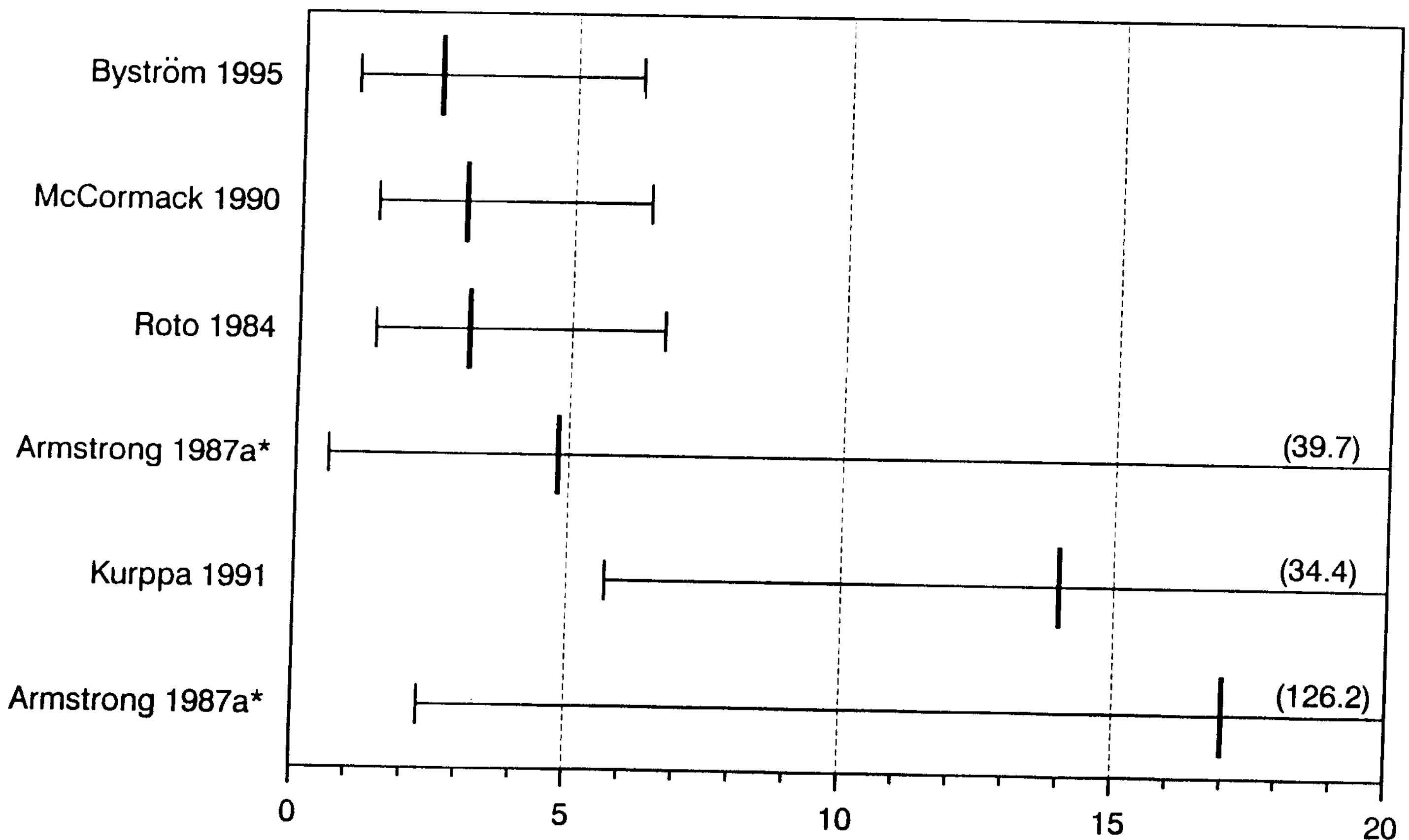
†Indicates statistical significance.

‡Not reported.

§EMG and video analysis of subgroup reported in Hägg et al. [1996].

Figure 5b-2. **Risk Indicator for "Force" and Hand/Wrist Tendinitis**

(Odds Ratios and Confidence Intervals)



* Studies which met all four criteria.

Table 5b-3. Epidemiologic criteria used to examine studies of hand/wrist tendinitis MSDs associated with posture

Study (first author and year)	Risk indicator (OR, PRR, IR or *p*-value)[*,†]	Participation rate ≥70%	Physical examination	Investigator blinded to case and/or exposure status	Basis for assessing hand/wrist exposure to posture
Met all four criteria:					
Luopajärvi 1979	4.1[†]	Yes	Yes	Yes	Observation or measurements
Met at least one criterion:					
Amano 1988	3.7–6.2[†]	NR[‡]	Yes	NR	Job titles or self-reports
Byström 1995	2.5[†]	Yes	Yes	No	Job titles or self-reports[§]
Kuorinka 1979	1.4	Yes	Yes	NR	Observation or measurements

[*]Some risk indicators are based on a combination of risk factors—not on posture alone (i.e., posture plus force, repetition, or vibration). Odds ratio (OR), prevalence rate ratio (PRR), or incidence ratio (IR).

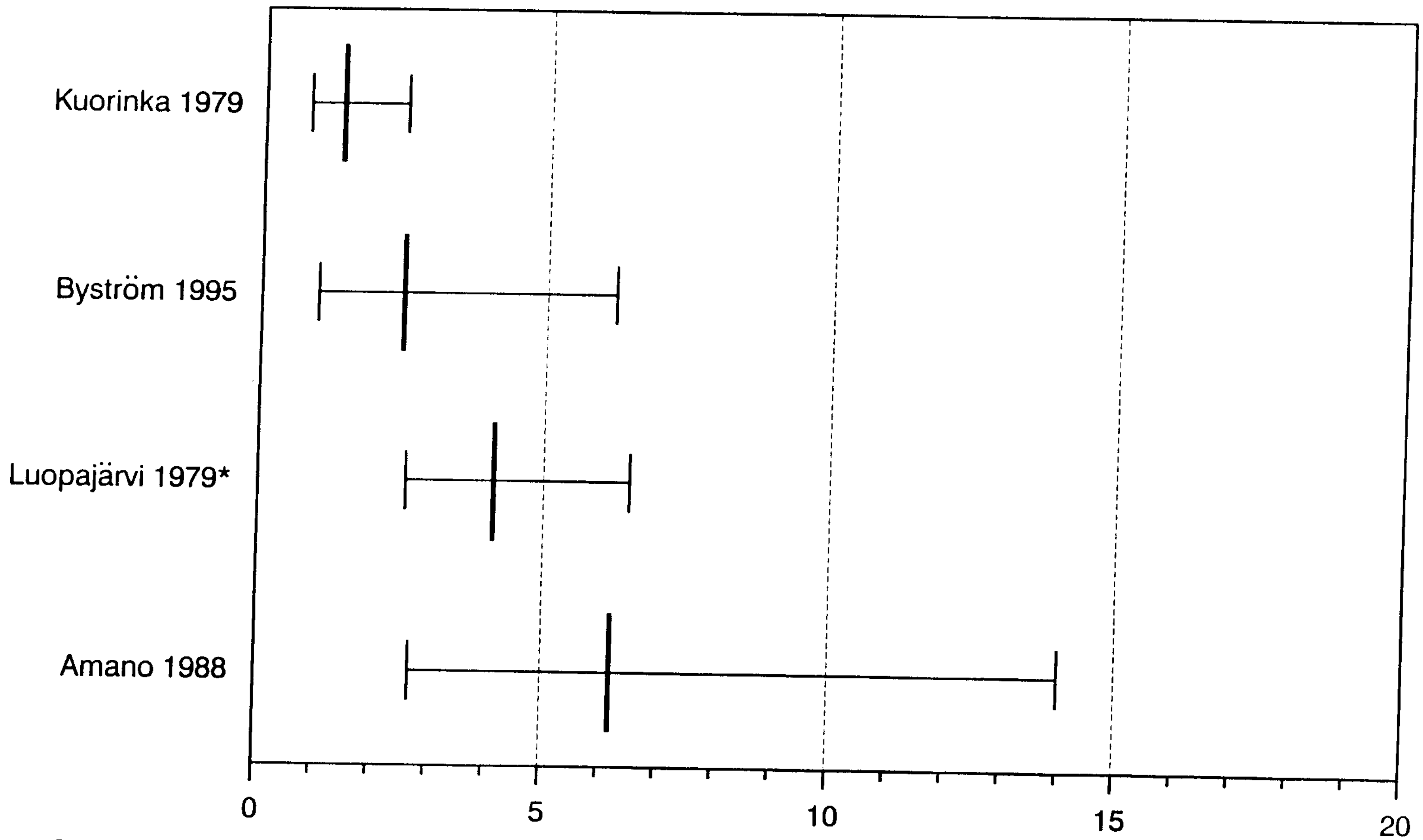
[†]Indicates statistical significance.

[‡]Not reported.

[§]EMG and video analysis of subgroup reported in Hägg et al. [1996].

Figure 5b-3. **Risk Indicator for "Posture" and Hand/Wrist Tendinitis**

(Odds Ratios and Confidence Intervals)



* Studies which met all four criteria.

Table 5b–4. Epidemiologic studies evaluating work-related hand/wrist tendinitis

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Amano et al. 1988	Cross-sectional	102 assembly line workers in an athletic shoe factory compared to 102 age and gender matched non-assembly line workers (clerks, nurses, telephone operators, cooks, and key punchers).	Outcome: Examination by a physician: palpation for tenosynovitis and tenderness. Exposure: One line of 29 shoe assembly workers was selected for job analysis. Videotapes were evaluated for movements of the upper extremities and shoulders and cycle and holding times. No formal exposure assessment of comparison group.	Tenosynovitis, right index finger flexors: 32.35% Tenosynovitis, left index finger flexors: 36.27%	Tenosynovitis right index finger flexors: 8.82% Tenosynovitis left index finger flexors: 5.88%	PRR=3.67 PRR=6.17	1.85-7.27 2.72-13.97	Participation rate: Not reported. Unclear whether examiner was blinded to job category (occupational groups examined on separate dates). No clear case definition provided. Potential for examiner bias exists. Comparison group was matched in gender and age (within 5 years). Tenosynovitis of other digits was not diagnosed in the comparison group. Neurological exam and clinical tests of pinch strength, tapping, pressure, and vibration sensibility were also done. No significant differences between groups in finger-pinch strength. Shoe workers failed the tapping test more often, had lower pressure-sensibility in 1 of 10 fingers tested, and had lower vibration-sensibility in 2 of 10 fingers. One of 3 neurological maneuvers (Morley's test) was more often positive in shoe workers. Exposure to toluene is noted and is a potential confounder for neurological findings. Assembly line workers produced about 3,400 shoes a day. All but one task had cycle times <30 sec. Assembly workers held shoe lasts longer in the left hand and had greater frequency of symptoms in left hand vs. non-assembly workers, who were assumed to use right hand (dominant hand) more frequently.

(Continued)

Table 5b–4 (Continued). Epidemiologic studies evaluating work-related hand/wrist tendinitis

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Armstrong 1987a	Cross-sectional	652 industrial workers divided into 4 groups: (1) low force, low repetition (comparison group, n=157), (2) high force, low repetition (n=195), (3) low force and high repetition (n=143), and (4) high force and high repetition (n=157).	Outcome: Positive findings on interview and physical exam were required for case definition. Tendinitis/teno-synovitis: localized pain or swelling lasting > a week, and increased pain with resisted but not passive motion. Trigger finger: locking in extension or flexion and a palpable nodule at base of finger. DeQuervain's: positive Finkelstein test with localized pain score of >=4 (range 1 to 8). Exposure: To force and repetition assessed by EMG and video analysis of jobs performed by a sample of workers.	3.1% (Group 2) 3.5% (Group 3) 10.8% (Group 4)	0.6%	PRR=4.8 PRR=5.5 PRR=17.0	0.6-39.7 0.7-46.3 2.3-126.2	Participation rate: 90% of workers originally selected for inclusion actually participated. The effect of age, gender, years on the job, and plant were analyzed. Higher prevalence of tendinitis among women, but not significantly associated with personal factors. Significant differences in posture were observed between males and females. Examiners were blinded to exposure status of study participants.

(Continued)

Table 5b–4 (Continued). Epidemiologic studies evaluating work-related hand/wrist tendinitis

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Byström et al. 1995	Cross-sectional	199 automobile assembly line workers, compared to 186 general population.	Outcome: Tenosynovitis or peri-tendinitis were diagnosed based on physical examination observations: swelling and pain at the tendon sheath, peritendinous area or muscle-tendon junction during active movement of the tendon. deQuervain's tendinitis: Positive Finkelstein's test. Exposure: Daily duration of hand and finger movements, manual handling, wrist position, grip type, and hand-tool use were rated by workers on 6-point scales in questionnaires [Fransson-Hall et al. 1995]. Forearm muscular-load and wrist angle were evaluated by EMG and videotape analysis for a subgroup [Hägg et al. 1996].	8.04% (deQuervain's tendinitis)	3.23%	PRR=2.49	1.00-6.23	Participation rate: 96%. Study group randomly selected from assembly division of a plant. Comparison group is from the MUSIC study [Hagberg and Hogstedt 1991]. Examiners blinded to exposure status: no, everyone examined by the authors was in the exposed group. Results are reported separately for males and females, and for age <40 years. Psychosocial variables and other potential confounders or effect modifiers were addressed by Fransson-Hall et al. [1995]. Higher prevalence of deQuervain's tendinitis in males than in females—possibly related to greater use of hand tools, ulnar deviation, and/or static muscle loading. No cases of tenosynovitis or peritendinitis were found in this study, probably because of strict clinical criteria (required observation of swelling).

(Continued)

Table 5b–4 (Continued). Epidemiologic studies evaluating work-related hand/wrist tendinitis

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Kuorinka and Koskinen 1979	Cross-sectional	93 scissor makers compared to 143 shop assistants. Phase One: physical examination and interview. Phase Two: work analysis. 10-month interval between phases. Comparison group was from another study that used the same method [Luopajärvi et al. 1979].	Outcome: Tenosynovitis and peritendinitis diagnosed by interview and physical exam. Physiotherapist examined workers, diagnoses were from predetermined criteria [Waris 1979] (localized tenderness and pain during movement and low grip-force and swelling of wrist tendons). In problem cases orthopedic and physiatric teams determined case status. Exposure: Work history, hr, and production rates for the previous year were taken from company records. A workload index was based on videotape analysis of scissor maker workstations: time spent in deviated wrist-posture (>20E)/work cycle; multiplied by number pieces handled multiplied by hr worked. No exposure assessment of shop assistants.	18.3%	13.5%	PRR=1.38	0.76-2.51	Participation rate: 81%. Examiner was not blinded to case status, but diagnosis was made separately, using predetermined criteria [Waris et al. 1979]. Study group was 99% female. No relationship found between age or body mass index and "muscle-tendon syndrome." The number of symptoms increased with the number of parts handled/year. Workers were paid by piece rate. Within the group of scissor makers, non-significant increased prevalences of muscle-tendon syndrome in short vs. long cycle tasks and in manipulation vs. inspection tasks was reported. The authors noted a lack of contrast in exposures between the subgroups. A non-significant trend of increasing prevalence of diagnosed muscle-tendon syndrome with increasing number of pieces handled/year was noted in a nested case-control analysis (n=36).

(Continued)

Table 5b–4 (Continued). Epidemiologic studies evaluating work-related hand/wrist tendinitis

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Kurppa et al. 1991	Cohort: 31-month follow-up	377 meatcutters, meatpackers and sausage makers compared to 388 office workers, maintenance workers, and supervisors.	Outcome: Defined as physician-diagnosed tenosynovitis or peritendinitis of the hand or forearm. Criteria were swelling or crepitation and tenderness to palpation along the tendon and pain at the tendon sheath, in the peritendinous area, or at the muscle-tendon junction during active movement of the tendon. deQuervain's tendinitis: positive Finkelstein's test (if not positive, included in tendinitis group). 25% of diagnoses made by physicians outside plant, criteria unknown. Exposure: Job categories selected based on whether or not strenuous manual work was required. Exposure data obtained from previous published literature and plant walk-throughs.	12.5/100 person years (meatcutters) 25.3/100 person years (meat-packers) 16.8/100 person years (sausage makers)	0.9/100 person years (males) 0.7/100 person years (females)	14 (meat-cutters) 38.5 (meat-packers) 25.6 (sausage makers)	5.7-34.4 11.7-56.1 19.2-77.5	Participation rate: >70%. Job transfers and employee termination followed up with questionnaire. Questionnaire response rate over 70%. Exposed and comparison groups were similar in age and gender mix, although gender varied with job. If same diagnosis occurred at same site in worker after 60 days, it was considered new episode. Therefore, separate episodes may be recurrences, and thus influence results. Median interval of 233 days between episodes. Packers worked in temperatures 8E to 10EC; sausage makers worked in temperatures 8E to 20EC. Examiners were not blinded to occupation of subjects. Plant selected because of high number of reports of musculoskeletal disorders. All permanent workers in meat cutting, sausage making and packing departments were included, after 3 months of work. Case ascertainment: Workers in non-strenuous jobs may not have sought medical care for MSDs since they might still be able to perform their jobs.

(Continued)

Table 5b–4 (Continued). Epidemiologic studies evaluating work-related hand/wrist tendinitis

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Luopajärvi et al. 1979	Cross-sectional	152 female assembly line packers in a food production factory were compared to 133 female shop assistants in a department store. Cashiers were excluded from comparison group.	Outcome: Tenosynovitis and peritendinitis diagnosed by interview and physical exam. Physiotherapist performed active and passive motions, grip strength tests, observation and palpation. Medical specialists used these findings later to diagnose disorders using predetermined criteria [Waris 1979]. Exposure: Exposure to repetitive work, awkward hand/arm postures, and static work assessed by observation and video analysis of factory workers. No formal exposure assessment of shop assistants.	55.9%	13.5%	PRR= 4.13	2.63-6.49	Participation rate: 84%. Workers excluded from participation for previous trauma, arthritis and other pathologies. Examiner blinded to case status: Not stated in article. No association between age and MSDs or length of employment and MSDs. Factory opened only short time. Hobbies and housework were not significantly associated with outcome. Unable to examine effect of job-specific risk factors because of job rotation.

(Continued)

Table 5b–4 (Continued). Epidemiologic studies evaluating work-related hand/wrist tendinitis

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
McCormack et al. 1990	Cross-sectional	Textile workers: 4 broad job categories involving intensive upper extremity use—sewing (n=562), boarding (n=296), packaging (n=369), and knitting (n=352); compared to other non-office workers (n=468), including machine maintenance workers, transportation workers, and cleaners and sweepers.	Outcome: Assessed by questionnaire and screening physical exam, followed by diagnostic physical examination. Tendinitis: Positive physical findings suggestive of inflammation. Severity reported as mild, moderate or severe. Exposure: To repetitive finger, wrist and elbow motions based on knowledge of jobs; no formal exposure assessment performed.	Boarding: 6.4% Sewing: 4.4% Packaging: 3.3% Knitting: 0.9% Overall exposed group: 3.75%	Other non-office: 2.1%	PRR=3.0 PRR=2.1 PRR=1.5 PRR=0.4 PRR=1.75	1.4-6.4 1.0-4.3 0.7-3.5 0.1-1.4 0.9-3.39	Participation rate: 90.5% for screening; 93.6% of those screened went on to complete physical examination. Stratified random sampling within occupational groups. Not mentioned whether examiners blinded to exposure status (job category). Prevalence higher in workers with <3 years of employment. Race and age not related to outcome. Female gender was a significant predictor of tendinitis (*p*=0.01), but job category was a stronger predictor (*p*=0.001). 10/12 physician examiners recorded diagnoses within 12% of the mean for the group. 47.9% of workers who had either positive screening physical exams or reported symptoms on questionnaire were diagnosed with tendinitis or tendinitis-related syndromes.

(Continued)

Table 5b–4 (Continued). Epidemiologic studies evaluating work-related hand/wrist tendinitis

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Roto and Kivi 1984	Cross-sectional	90 meatcutters compared to reference group of 72 construction foremen who had not been exposed to repetitive movements of the upper extremities in their work. All participants were male.	Outcome: Tenosynovitis defined as swelling, local pain and finger weakness during movement (determined by questionnaire and physical exam). Exposure: Based on job title. Study groups were selected based on general knowledge of job tasks: meatcutters' work entailed physical exertion of upper extremities and shoulders. Construction foremen's work did not involve repetitive movements of the upper extremities. No formal exposure assessment.	4.5% Symptom prevalence rate: 30.0%	0.0% Symptom prevalence rate: 10.0%	Indetermin-ate PRR=3.09	õ 1.43-6.67	Participation rate: 100% for meatcutters, 94% for comparison group. Authors state that examiners were blinded to occupation of subjects because part of larger group of meat processing workers examined, but it is unclear whether construction foremen (referents) were examined separately. Serologic testing for rheumatoid arthritis was done to control for potential confounding (none detected). Relatively strict diagnostic criteria used to avoid false positive cases. Authors note that tenosynovitis occurred in younger age groups. Although the only diagnosed cases of tenosynovitis occurred in the meatcutters (none in the referents), the authors were reluctant to infer association with meatcutting because of the relatively low prevalence rate (4.5%).

CHAPTER 5c
Hand-Arm Vibration Syndrome

SUMMARY

In general, the studies listed in Table 5c–1 show **strong evidence** of a positive association between high level exposure to hand-arm vibration (HAV) and vascular symptoms of hand-arm vibration syndrome (HAVS). These studies are of workers with high levels of exposures such as forestry workers, stone drillers, stone cutters or carvers, shipyard workers, or platers. These workers were typically exposed to HAV acceleration levels of 5 to 36 m/s^2. These studies typically were cross sectional studies which examined the relationship between workers with high levels of exposures to HAV with a non-exposed control group. There is substantial evidence that as intensity and duration of exposure to vibrating tools increase, the risk of developing HAVS increases. There also is evidence that an increase in symptom severity is associated with increased exposure. As intensity and duration of exposure are increased, the time from exposure onset and beginning of symptoms is shortened.

As described above, the relationship between vibration exposure and HAVS was evaluated favorably with regard to other epidemiological causality criteria, including consistency and coherency of available information and evidence describing the temporal sequence of exposure and outcome.

INTRODUCTION

The 20 epidemiologic studies discussed in this review were selected according to criteria that appear in the introduction of this document. In our review, we evaluated the studies according to criteria that enabled us to assess the research. These criteria, including adequate participation rate, definition of health outcome by both symptoms and medical exam criteria, blinding of investigators to exposure/outcome status, and independent/objective measure of exposure, also are described in detail in the Introduction.

In reviewing the studies, we gave greatest qualitative weight to those which fulfilled all four of the above criteria. Table 5c-1 (all tables are presented at the end of the chapter) characterizes the 20 reviewed Hand-Arm Vibration studies according to the four evaluation criteria. Full summary descriptions of all the studies appear at the end of the chapter.

In addition to the four criteria we used to evaluate the studies, we determined whether studies demonstrated statistically significant associations between exposure attributes and health outcomes. We also examined whether the observed associations were likely to be caused or substantially influenced by major study flaws, including confounding and selection bias. Some of these limitations are shown in the descriptions of individual studies (Table 5c–2).

We then reviewed and summarized the studies with regard to standard criteria used by epidemiologists to evaluate the causal relationship between a health outcome and an exposure of interest. These criteria included strength of association, temporal relationship, consistency of association, coherence of association, and exposure-response relationships.

In this review, results of each of the studies examined, whether negative, positive, or equivocal, contributed to the pool of data used to make our decision regarding the strength of the causal relationship between HAVS and workplace risk factors. Greater or lesser confidence in the findings reflected the evaluation criteria described above.

Definition of HAV for HAVS

Hand-Arm Vibration is defined as the transfer of vibration from a tool to a worker's hand and arm. The amount of HAV is characterized by the acceleration level of the tool when grasped by the worker and in use. The vibration is typically measured on the handle of tool while in use to determine the acceleration levels transferred to the worker.

EVIDENCE FOR THE WORK-RELATEDNESS OF HAVS

The hazardous effects of occupational exposure to HAV have been discussed in hundreds of studies dating to the work of Loriga in 1911. The composite of vibration-induced signs and symptoms referred to as hand-arm vibration syndrome includes episodic numbness; tingling and blanching of the fingers, with pain in response to cold exposure; and reduction in grip strength and finger dexterity. These signs and symptoms are known to increase in severity as exposure to vibration increases in intensity and duration.

A review of pertinent epidemiologic studies of HAVS has been previously presented [NIOSH 1989]; therefore, Table 5c–2 includes only those studies completed after 1989. Except for a few longitudinal studies of chain sawyers in the United Kingdom, Finland, and Japan, the literature comprises largely cross-sectional studies carried out within an industry. Cross-sectional studies are limited in their ability to ascertain temporal relationships between exposure and outcome. Because results are obtained at only one point in time, the cross-sectional study design also is subject to underassessment of the health outcome (particularly in groups with longer durations of employment and higher participant attrition).

The studies included in this review varied in design and quality of information. Sixteen were cross-sectional in design, and three were prospective cohort in design. One study was both cross-sectional and prospective, including 10 cross-sectional follow-ups over time and a cohort group [Koskimies et al. 1992]. Thirteen of the 20 studies reported assessing case status using physical exams, while other studies used only a questionnaire to determine outcomes. Of the studies in which the subjects underwent a physical exam, five performed a cold provocation test [Bovenzi et al. 1988; Bovenzi et al. 1995; Brubaker et al. 1983; Brubaker et al. 1987; McKenna et al. 1993], three performed a nail compression test [Mirbod et al. 1992b; Nagata et al. 1993; Saito 1987], one performed a nerve conduction test [Virokannas 1995], one performed sensorineural physician testing [Bovenzi and Betta 1994], one performed a neurological exam [Shinev et al. 1992], one performed an Allan test [Nilsson et al. 1989] and one used physician judgement based on workers' complaints and history [Koskimies et al. 1992].

Twelve of the 20 studies conducted an exposure assessment of the tools subjects were using; an additional study used exposure assessment information the authors had collected in a previous investigation. The remaining studies estimated exposures by self-report or job title.

The one study that met all four criteria and the four studies which met the three criteria are discussed in the following section. Detailed descriptions for all 20 investigations can be found at the end of the chapter.

Comments Related to Specific Studies of HAVS

The Bovenzi et al. [1995] cross-sectional investigation of forestry workers compared vibration white finger (VWF) in this group with shipyard worker referents. VWF was diagnosed by symptom report and cold provocation test; vibration exposures were estimated by questionnaire report on frequency of chain saw work and types of saws used, along with direct measurement of vibration produced by 27 antivibration and 3 non-antivibration saws. Daily exposure to saw vibration was estimated by linking the two assessments. The prevalence rates for VWF were 23.4% in forestry workers and 2.6% in shipyard referents [Odds ratio (OR) 11.8, 95% Confidence Interval (CI) 4.5–31.1]. For workers using only antivibration saws, the OR was 6.2 (95% CI 2.3–17.1); for those using non-antivibration saws, the OR was 32.3 (95% CI 11.2–93). A dose-response was observed for VWF and lifetime vibration dose (OR 34.3, 95% CI 11.9–99, for the highest category). Although participation rates were not stated for referents, the participation appeared to be 100% for forestry workers. Authors included 10 retired workers to lessen the problems with selection out of the workforce. Results demonstrated that antivibration saw use was associated with a lower prevalence of VWF.

Koskimies et al. [1992] examined vibration syndrome in a group of forestry workers employed by the National Board of Forestry in Finland. All those employed in one parish participated in a series of 10 cross-sectional studies from 1972 to 1990. Results also were reported for a cohort of 57 individuals who remained in the study from 1972 to 1986. HAVS symptoms were assessed by questionnaire and physical exam criteria. Exposure to chain saw vibration was determined by measurement of front handle acceleration. Cross-sectional analysis results showed a monotonic decrease in prevalence of VWF from 40% in 1972 to 5% in 1990. In the cohort of 57, VWF increased from 30% in 1972 to 35% in 1975. VWF decreased monotonically to approximately 6% in 1986. Over the same time period, modifications of chain saws used by the workers resulted in a decrease in saw vibration acceleration from 14 m/s^2 to 2 m/s^2. The authors attributed the reduction in VWF to saw changes, although exposures and outcomes were never linked for individual workers. Strengths of the study included observation of similar results from the series of cross-sectional analyses and full participation on the part of the 57 subjects. Limitations included failure to assess chain saw exposure measures at the individual level. The study demonstrated the potential for symptom improvement after exposure reduction.

In the Nilsson et al. [1989] cross-sectional study of male pulp mill machine manufacturing employees, VWF was examined in a group of 89 platers and 61 office workers. VWF was ascertained by physical exam and interview. For platers, vibration exposure was assessed by measuring acceleration intensity on a sample of tools and linking results to subjective ratings of exposure time. Current and past exposures were estimated for both platers and office workers (some office workers had experienced exposures in the past). Prevalence for platers with current exposure was 42%, in comparison to 2.3% for office workers with no exposures (OR 85, 95% CI 15–486). When those exposed to vibration (platers plus office workers with previous vibration exposure) were compared to unexposed office workers, prevalences were 40.0% and 2.3% respectively (OR 56, 95% CI 12–269). A dose-response was observed for VWF and years of exposure. The relationships between outcome and exposure, after adjustment for age, were strong. Representativeness of the referent group of office workers could not be determined.

Bovenzi [1994] examined HAVS cross-sectionally in 570 quarry drillers and stone carvers, along with a referent group of polishers and machine operators who were not exposed to hand-transmitted vibration. HAVS was assessed by physician interview, and sensorineural symptoms were staged and graded. Exposure to vibrating tools was assessed by interview and linked to vibration measurements obtained from assessment of a sample of tools. Prevalences of HAVS were 30.2% in the exposed and 4.3% in the unexposed groups (OR 9.33, 95% CI 4.9–17.8). Symptoms of VWF increased with lifetime vibration dose (OR 10.2, 95% CI 4.8–21.6, for the highest category). Study strengths included detailed exposure assessment and modeling of relationships, 100% participation, and a very stable work population. Because of the work population stability, results were unlikely to be influenced by participant attrition.

The Bovenzi et al. [1988] cross-sectional investigation examined VWF in vibration-exposed stone drillers and stone cutters/chippers and a reference group of quarry and mill workers. VWF was assessed by questionnaire and physical exam. Exposure was assessed by measuring acceleration intensity on a sample of tools and linking it with self-reported exposure time. VWF prevalence rates were 35.5% in exposed and 8.3% in unexposed groups (OR 6.06, 95% CI 2.0–19.6; OR 4.26, 95% CI 1.8–10.4). A significant association was observed between vibration acceleration level and severity of VWF symptoms (0% and 18.4% in the lowest and highest categories, respectively).

Strength of Association

One of the studies examined met all four of the evaluation criteria [Bovenzi et al. 1995]. Five investigations met three of the criteria [Bovenzi et al. 1988, 1994; Kivekäs et al. 1994; Koskimies et al. 1992; and Nilsson et al. 1989]. The criterion that was not met (or not reported) by four of the studies was blinding of the physician with regard to worker job status. However, most studies used objective measures for determining case status: cold provocation [Bovenzi et al. 1988, 1995], sensorineural physician grading [Bovenzi and the Italian Study Group 1994], and the Allan test [Nilsson et al. 1989]. Use of objective measures lessens the likelihood that case status was influenced by knowledge of participants' exposures.

In the Bovenzi et al. [1988] cross-sectional investigation, vibration-exposed stone drillers and stone cutters/chippers showed a 6.06-fold (95% CI 2.0–19.6) increase in risk of VWF in comparison to unexposed quarry and mill workers. Similar results were observed in another study of stone workers conducted by Bovenzi in 1994. Quarry drillers and stone carvers exposed to vibration showed an OR for VWF of 9.33 (95% CI 4.9–17.8) when compared to a reference group of polishers and machine operators. A dose-response relationship was observed for VWF and lifetime vibration dose, with an OR of 10.2 (95% CI 4.8–21.6) for the highest exposure category. A study of forestry workers [Bovenzi et al. 1995] demonstrated an OR of 11.8 (95% CI 4.5–31.1) for VWF when comparing forestry workers with exposure to chain saw vibration to an unexposed group of shipyard workers. A lower risk of VWF (OR 6.2, 95% CI 2.3–17.1) was observed for those using only antivibration saws. A dose-response between VWF and vibration exposure also was observed in this investigation, with an OR of 34.3 (95% CI 11.9–99) for the highest exposure category. Nilsson et al. [1989] observed very strong relationships between VWF and exposure to vibration in machine manufacturing platers. In comparison to office workers with no exposure, platers had an OR of 85 (95% CI 15–486). Kivekäs et al. [1994] found a significantly increased OR in the cumulative incidence of HAVs in a 7-year cohort study (OR 6.5, 95% CI 2.4–17.5). Koskimies et al. [1992] examined a dynamic cohort of forestry workers at 10 intervals from 1972 to 1990 during which time saws were being modified in weight, vibration frequency, and vibration acceleration. Over the 18-year period, a monotonic decrease in VWF was observed in the 10 cross-sectional examinations, with an overall eight-fold reduction in prevalence. A subset of workers followed from 1972 to 1986 showed a decrease in VWF from 30% to 6%. The reductions were attributed to modifications in chain saws during the same time period.

The remaining, less rigorous, studies showed varying relationships between HAVS and exposure. The majority of the studies demonstrated moderate to strong positive associations. Most compared exposed to unexposed groups with little or no detailed analysis by exposure level. Two investigations examined HAVS in exposed groups and found an increase in risk by years of employment, with ORs of 8.4 and 8.9 (95% CI 2.9–28.9) when comparing the highest and lowest categories [Mirbod et al. 1992b; Kivekäs et al. 1994]. Another study that examined HAVS prevalence in power tool users found no association with duration of employment (with a participation rate of only 38%) [Musson et al. 1989]. For other investigations, exposed and unexposed groups were defined by job titles. ORs for these studies ranged from 3.2 to 40.6 (relative risk [RRs] from 3.2 to 16) [Brubaker et al. 1983; Dimberg and Oden 1991; Letz et al. 1992; McKenna et al. 1993; Mirbod et al. 1992a; Mirbod et al. 1994; Nagata et al. 1993]. Three studies demonstrated varying HAVS rates for exposed groups, but included no referents [Shinev et al. 1992; Starck et al. 1990; Virokannas and Tolonen 1995].

Two investigations produced conflicting evidence related to the effects of chain saw modifications on HAVS in forestry workers. The Brubaker et al. [1987] study, observed a 28% increase in prevalence of VWF in a cohort of tree fellers over a 5-year period and claimed that saw modifications were ineffective. Saito [1987] found no new HAVS symptom development over 6 years in a cohort of chain sawyers in reducing symptoms.

Comparing construction workers to office workers, one study demonstrated an OR of 0.5 (95% CI 0.1–11.8) for HAVS. This study met none of our four criteria [Miyashita et al. 1992].

In general, the studies in Table 5c-1 show strong evidence of a positive association between exposure to HAV and vascular symptoms of HAVS.

Temporality

The temporal relationship between HAV exposure and symptoms of HAVS is well established by studies which have determined the latency between exposure and symptom onset. Of 52 studies reviewed by NIOSH in 1989, 44 included some information about the latency period for the development of vascular HAVS symptoms following initial exposure. Latency ranged from 0.7 to 17 years, with a mean of 6.3 years. Unfortunately, because most of these studies were cross-sectional (i.e., latency was determined retrospectively) and because HAVS develop slowly, the possibility of recall bias is strong [Gemne et al. 1993]. However, longitudinal studies provide support for the temporal nature of the association. Kivekäs et al. [1994], in a 7-year follow-up of Finnish lumberjacks, found a cumulative incidence rate (IR) of 14.7%, compared to a cumulative IR of only 2.3% among referents. The cumulative IR of lumberjacks who had more than 25 years of exposure at the end of the follow-up period was 30.6%. Other studies of Finnish forestry workers also showed a marked decrease in HAVS prevalence following the introduction of improved chain saws [Pyykkö and Starak 1986; Koskimies et al. 1992].

Consistency

The literature consistently shows that workers exposed to HAV develop HAVS at a substantially higher rate than workers not exposed to vibration. Although there is considerable variation in the occurrence of HAVS among different groups using similar types of vibrating tools, the lack of consistency probably is explained by methodological differences between studies (i.e., some researchers did not account for exposure variation over time in the summary estimate of exposure) or by differences in work methods, work processes, and work organization [Gemne et al. 1993]. Important also is the difference in the intensity and duration of exposure.

Coherence of Evidence

The mechanisms by which HAV produces neurological, vascular, and musculoskeletal damage are supported by some experimental evidence [Armstrong et al. 1987b; Lundborg et al. 1990; Necking et al. 1992]. Neurological and circulatory disturbances probably occur independently and by unrelated mechanisms. Vibration may directly injure the peripheral nerves, nerve endings, and mechanoreceptors, producing symptoms of numbness, tingling, pain, and loss of sensitivity. Vibration also may have direct effects on the digital arteries. The innermost layer of cells in the blood vessel walls appears especially susceptible to mechanical injury by vibration. If these vessels are damaged, they may become less sensitive to the actions of certain vasodilators that require an intact endothelium. Experiments involving lumberjacks exposed to chain saw vibration support this hypothesis [Gemne et al. 1993]. There also is evidence that the walls of the digital blood vessels are thickened in persons with HAVS [Takeuchi et al. 1986]. During cold exposure, vessels with these changes will become abnormally narrow and may close entirely [Gemne 1982]. Symptoms of numbness and tingling which characterize HAVS may be secondary to vascular constriction of the blood vessels, resulting in ischemia in the nerve-end organs.

Other evidence concerning the coherence of information regarding the association between vibration exposure and HAVS relates to background prevalence of similar disorders in the general population. One estimate placed the prevalence of Raynaud's phenomenon at 4.6% for females and 2.5% for males in the general population [Iwata and Makimo 1987]. Only 7 of the studies examined in this review found prevalence rates less than 20% among workers exposed to HAV. In the 1989 NIOSH review, only 9 of 52 cross-sectional studies reported a prevalence rate of less than 20% among workers exposed to HAV. This provides strong evidence that individuals working in vibration-exposed occupations are at much higher risk of these disorders than those in the general population.

Exposure-Response Relationship

Exposure-response relationships involving HAV have been postulated, including: (1) a relationship between the prevalence of HAVS and vibration acceleration (and cumulative exposure time), (2) a relationship between the dose and symptom severity, and/or (3) a relationship between the dose and the latency of symptom onset.

Support for the first relationship is provided by a few longitudinal studies of workers exposed to HAV. In general, all show strong evidence that decreasing the acceleration level of a hand-held vibrating tool has a positive relationship with prevalence of HAVS. In a study of Finnish forestry workers using chain saws, Koskimies et al. [1992] found that the prevalence of HAVS symptoms declined from a peak of 40% to 5% after the introduction of light-weight, low-vibration chain saws with reduced acceleration from 14 to 2 m/s^2. Likewise, a study of similar workers in Japan found that the prevalence of vascular symptoms among chain saw operators who began their jobs before the introduction of various engineering and administrative controls peaked at 63%. (Vibration acceleration levels for chain saws used during this period ranged from 111 to 304 m/s^2.) In contrast, the peak prevalence for chain saw operators who began working after the introduction of antivibration chain saws (acceleration level: 10-33 m/s^2) and exposure duration limits (2 hrs/day) was only 2% [Futatsuka and Uneno 1985, 1986].

NIOSH authors ranked 23 cross-sectional studies that measured HAV acceleration levels and estimated a prevalence rate for vascular symptoms [NIOSH 1989]. To test whether a linear relationship existed between the HAV level and the prevalence of vascular symptoms, a correlation coefficient was calculated. The correlation analysis found a statistically significant linear relationship between HAV acceleration level and prevalence of vascular symptoms (R 0.67, $p<0.01$), indicating that prevalence of vascular symptoms tends to increase as the HAV acceleration level increases. However, the absorption of vibration energy by the hand is influenced by the vibration intensity, as well as by frequency, transmission direction, grip and feed forces, hand-arm postures, and anthropometric factors [Gemne et al. 1993].

Several studies reviewed for the current document found relationships between prevalence of HAVS and duration of vibration-exposed work [Bovenzi 1994; Bovenzi et al. 1995; Letz et al. 1992; Nilsson et al. 1989]. One cross-sectional study with a very poor response rate found no association with duration of exposure [Musson et al. 1989].

Justification for a relationship between dose and HAVS prevalence and symptom severity is provided by Bovenzi et al. [1988] and Mirbod et al. [1992b]. In a study of stone-cutters using rock drills and chisel hammers, Bovenzi found that HAVS prevalence increased linearly with the total number of working hours, from about 18% for persons with 6,000 hrs of exposure, to more than 50% among persons with more than 26,000 hrs of exposure. Likewise, in a study of 447 workers using chain saws, Mirbod et al. [1992b] found that the prevalence of HAVS increased from 2.5% among workers with less than 14 years of exposure to 11.7% among workers with 20–24 years exposure, to 20.9% among workers exposed 30 years or more. Both studies found a statistically significant correlation between the severity of symptoms (graded according to the Taylor-Pelmear scale) and a dose measure based on total exposure time.

Support for a relationship between dose and latency of symptom onset is provided by British studies conducted in the 1970s among various occupational groups, including chain sawyers, grinders, chiselers and swagers [Gemne et al. 1993]. Exposure to 10-25 m/s^2 chainsaw vibration correlated with a latency of about 3 years. Pedestal grinders using machines with zirconium wheels were exposed to vibration levels of 50 m/s^2 and demonstrated a mean latency of 1.8 years, whereas grinders who used softer wheels with accelerations of 10-20 m/s^2 had a mean latency of 14 years. Exposure to 70 m/s^2 vibration during swaging correlated with a mean latency of about 7 months, although some swagers developed symptoms in as few as 6 weeks.

Confounding and HAVS

Age and metabolic disease are the primary potential confounders for HAVS.

It is important that epidemiologic studies examine non-occupational factors, and control for them. Most of the studies were able to address “age” by stratification in their analyses, or through use of multiple logistic regression. [Bovenzi and Betta 1994; Bovenzi et al. 1995; Brubaker et al. 1983, 1987; Kivekäs et al. 1994; Letz et al. 1992; McKenna et al. 1993; Mirbod et al. [1994]. Several authors controlled for metabolic disease [Bovenzi and Betta 1994; Bovenzi et al. 1995; Letz et al. 1992; McKenna et al. 1993]. This is important because of the effects that some disorders have on peripheral circulation which may have symptoms similar to HAVS.

Nonoccupational Raynaud’s phenomena - a

rare disorder which mimics HAVS has been known to occur in individuals with metabolic disorders, peripheral neuropathy, alcohol-related illness, as well as other conditions.

In reviewing the methods and results of these studies, taking into account substantially elevated ORs and evidence of dose-response relationships, it appears that potential confounders do not account for the consistent relationships seen.

Review of the 20 studies, leads us to the conclusion that there is substantial evidence that as intensity and duration of exposure to vibrating tools increase, the risk of developing HAVS increases. Most of the studies showed a positive association between high level exposure to HAV and vascular symptoms of HAVS. For many of the studies there is a strong association between HAVS and exposure to vibrating tools in the workplace. The temporal relationships and consistency between exposure and symptoms of HAVS are well established in these studies. The mechanisms by which HAV produces neurological, vascular, and musculoskeletal damage are supported by some experimental evidence. Many of the studies showed an exposure-response relationship between dose of HAV and the HAVS prevalence and symptom severity.

Table 5c-1. Epidemiologic criteria used to examine studies of hand/wrist and hand/arm MSDs associated with vibration

Study (first author and year)	Risk indicator (OR, PRR, IR or *p*-value)*,†	Participation rate $70%	Physical examination or cold provocation	Investigator blinded to case and/or exposure status	Basis for assessing hand/wrist or hand/arm exposure to vibration
Met all four criteria:					
Bovenzi 1995	6.2–32.3†	Yes	Yes	Yes	Observation or measurements
Met at least one criterion:					
Bovenzi 1988	6.06†	NR‡	Yes	NR	Observation or measurements
Bovenzi 1994	9.33†	Yes	Yes	No	Observation or measurements
Brubaker 1983	NR	Yes	Yes	NR	Job titles or self-reports
Brubaker 1987	NR	No	Yes	NR	Observation or measurements
Dimberg 1991	NR†	Yes	No	NR	Job titles or self-reports
Kivekäs 1994	3.4–6.5†	Yes	Yes	Yes	Job titles or self-reports
Koskimies 1992	NR	Yes	Yes	NR	Observation or measurements
Letz 1992	5.0–40.6†	Yes	No	No	Job titles or self-reports—previous study results used
McKenna 1993	24.0†	NR	Yes	No	Job titles or self-reports
Mirbod 1992a, 1994	3.77†	NR	No	NR	Observation or measurements
Mirbod 1992b	NR	NR	Yes	No	Observation or measurements
Musson 1989	NR	No	No	NR	Observation or measurements
Nagata 1993	7.1†	NR	Yes	No	Job titles or self-reports
Nilsson 1989	14–85†	Yes	Yes	NR	Observation or measurements
Saito 1987	NR	No	Yes	NR	Job titles or self-reports
Shinev 1992	NR	NR	Yes	NR	Observation or measurements
Starck 1990	NR	NR	No	No	Observation or measurements
Virokannas 1995	NR†	NR	Yes	NR	Observation or measurements
Met none of the criteria:					
Miyashita 1992	0.5	NR	No	No	Job titles or self-reports

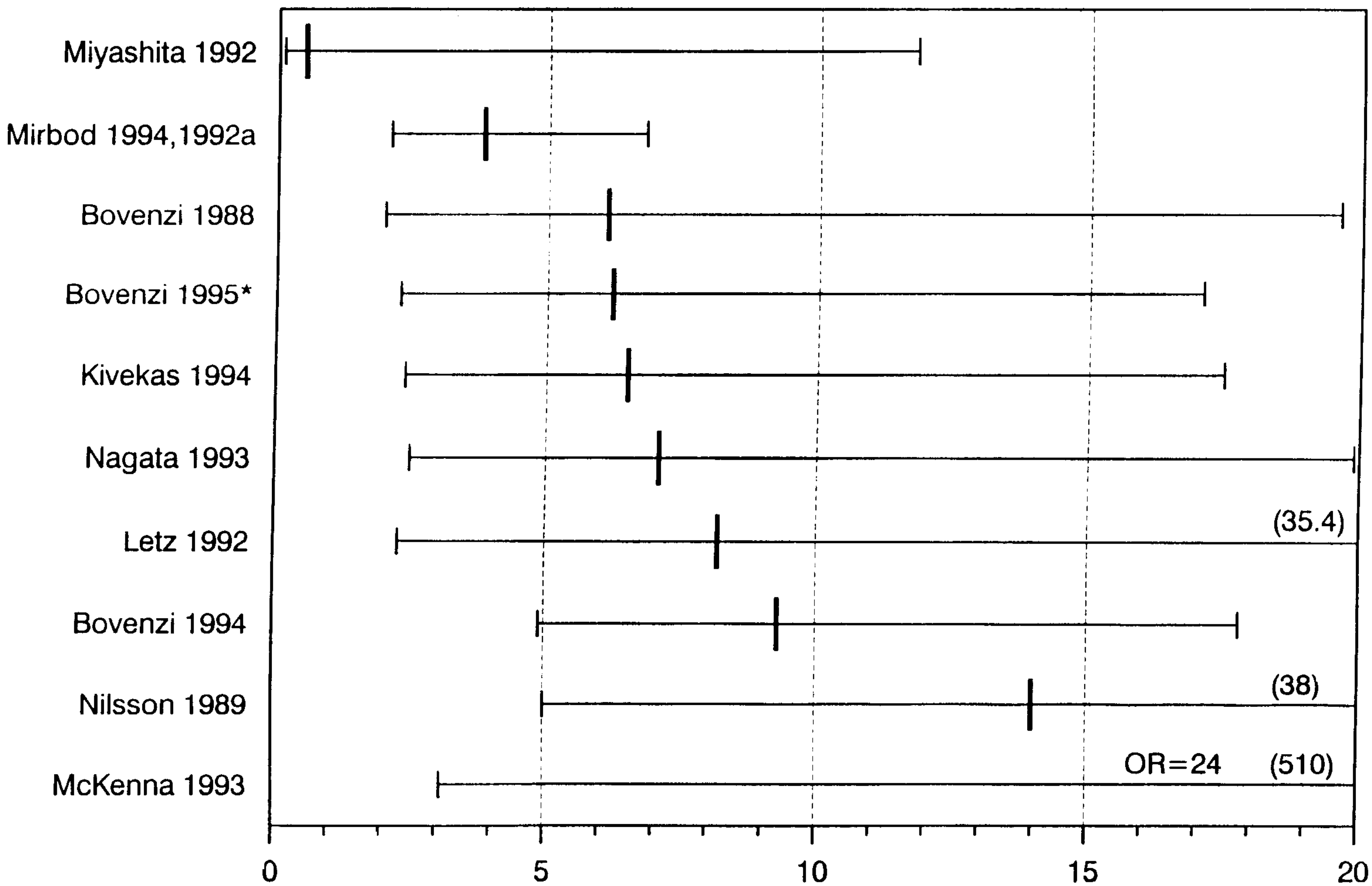
*Some risk indicators are based on a combination of risk factors–not on vibration alone (i.e., vibration plus force, posture, or repetition). Odds ratio (OR), prevalence rate ratio (PRR), or incidence ratio (IR).

†Indicates statistical significance. If combined with NR, a significant association was reported without a numerical value.

‡Not reported.

Figure 5c-1. **Risk Indicator for Hand/Arm Vibration Syndrome**

(Odds Ratios and Confidence Intervals)



* Studies which met all four criteria.

Note: Eleven studies indicated statistically significant associations without reporting odds ratios. See Table 5c-1.

Table 5c–2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Bovenzi et al. 1988	Cross-sectional	Vibration-exposed stone drillers (n=32) and stone cutters/chippers (n=44); quarry and mill workers not exposed to vibration (control group, n=60).	Outcome: Assessed by physical examination and questionnaire. VWF symptoms staged using the Taylor-Pelmear scale. Exposure: Vibration exposure assessed by measuring the acceleration intensity on a sample of tools, together with subjective ratings of exposure time.	35.5%	8.3%	6.06	2.01-19.6	Participation rate: Participation rate cannot be determined from data in the study. Significant association between vibration acceleration level and severity of VWF symptoms. Mean latency period to symptom onset =12.3 yr. Frequency-weighted acceleration levels ranged from 19.7 to 36.4 m/s^2 (rock drills and chipping hammers) and from 2.4 to 4.1 m/s^2 (grinders and hand cutters).

(Continued)

Table 5c–2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Bovenzi and the Italian Group 1994	Cross-sectional	Case group: Stone workers employed in nine districts in Northern and Central Italy: 145 quarry drillers and 425 stone carvers exposed to vibration. Referent group: polishers and machine operators (n=258) who performed manual activity only not exposed to hand-transmitted vibration.	Outcome: HAVs assessed by physician-administered interview; sensineural symptoms staged according to Brammer [1992]. Graded according to the Stockholm scale [Gemne 1987]. Exposure: To vibrating tools assessed by interview. Vibration measured in a sample of tools used.	30.2%	4.3%	9.33	4.9-17.8	Participation rate: 100% "All the active stone workers participated in the study, so self-selection was not a source of bias." Physician administered the questionnaires containing work history and examinations, so unlikely to be blinded to case status. Adjusted for age, smoking, alcohol consumption, and upper limb injuries. Leisure activities, systemic diseases included in questionnaire. Univariate analysis showed no association between systemic diseases and vibration so was not criteria for exclusion. Univariate analysis showed no association between systemic diseases and vibration so was not criteria for exclusion. Dose–response for CTS and lifetime vibration exposure not significant. Frequency-weighted acceleration levels = 15 m/s^2 (stone drills), 21.8 m/s^2 (stone hammers), 2.84 m/s^2 (rotary grinding tools). Percent of workers affected with HAVs increased in proportion to the square root of the exposure duration.

(Continued)

Table 5c–2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Bovenzi et al. 1995	Cross-sectional	222 active forestry workers and 10 retired forestry workers with >400 hr of sawing compared with 195 randomly chosen shipyard workers never exposed to hand vibration. Controls excluded for cardiovascular and metabolic disease.	Outcome: (1) History of episodes of cold provoked well–demarcated blanching in one or more fingers and (2) occurrence after employment and exposure to hand vibration and vibration white finger (VWF) attacks in last 2 years and (3) abnormal digital arterial response to cold provocation. Clinically, VWF graded using Stockholm scale. Exposure: Vibration measured on front and rear of 27 antivibration (AV) chain saws used in the forest; for previous exposure assessment, 3 non-AV chain saws were measured. Vibration measurements were made in the field during cross-cutting operations by skilled workers according to ISO 7505. Forestry workers gave detailed list of chain saws used. Workplace questionnaires validated by direct interviews with employers and employees, employment records, and amount of fuel used by chain saws Daily exposure to saw vibration assessed in terms of 8-hr energy–equivalent frequency–weighted acceleration.	All Forestry workers: 23.4%	Shipyard workers: 2.6%	(adjusted OR's) 11.8	4.5-31.1	Participation rate: 95% vibrating tool users, not reported for control. Analysis controlled for age, smoking, drinking habits. Physicians blinded to case status–since cold provocation test was used, it was not an issue. Smoking, alcohol, metabolic, cardiovascular, neurologic, previous musculoskeletal injuries, use of medicines included in questionnaire and accounted for in logistic regression model. Cold provocation testing performed on both forestry workers and controls. Exposure–response relationship found between VWF and vibration exposure: the expected prevalence of VWF increased almost linearly to either the 8-hr energy–equivalent frequency–weighted acceleration or the number of years of exposure (with equivalent acceleration unchanged).
				Workers using only AV chain saws: 13.4%		6.2	2.3-17.1	
				Workers using chain saws without vibration isolation systems: 51.7%		32.3	11.2-93	
						VWF operators of non-AV and AV saws vs. Operators of antivibration saws only: OR=4.0		
						Lifetime vibration dose in 9m (m^{2}S^{-4} hd) <19: OR=4.1	1.1-16.4	
						19-20: OR=4.7	1.3-16.1	
						20-21: OR=9.4	3.1-28.4	
						>21: OR=34.3	11.9-99	

(Continued)

Table 5c–2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Brubaker et al. 1983	Cross-sectional	146 tree fellers in 7 camps employed for $1 year compared to 142 workers not exposed to vibration matched for location.	Outcome: VWF symptoms staged using Taylor-Pelmear scale. Ischemic water bath testing for VWF completed on all subjects. Exposure was based on questionnaire data.	With symptoms: 51% Stage 3: 22% Excluding other vibration exposure and medical history: 54% Stage 3: 25%	With symptoms: 5% Stage 3: 2% 2% Stage 3: 1%	õ	õ	Participation rate: 100%. Smoking, no significant differences. Age was significantly different between cases and controls. Height and weight not significantly different. Mean latency period between work and symptoms 8.6 years. Records of duration of exposure.

(Continued)

Table 5c–2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Brubaker et al. 1987	Cohort: 5-year follow-up of exposed group.	Fellers at Canadian lumber camps (n=71) who had been interviewed and tested in 1979 to 1980 then again in 1984 to 1985.	Outcome: Defined as HAVs symptoms, assessed by questionnaire and digit systolic blood pressure. VWF symptoms staged using Taylor-Pelmear scale. Ischemic water bath testing for VWF completed on all subjects. Exposure: Vibration measurements recorded from a representative sample of chain saws used in the logging camp.	Raynaud's symptoms: 53% (1984 to 1985) Tingling, numbness: 56% (1984 to 1985)	Raynaud's symptoms: 51% (1979 to 1980) Tingling numbness: 65% (1979 to 1980)	õ	õ	Participation rate: 53%. Original group (1979 to 1980) included 146 fellers. 16 fellers excluded because of potential confounders. Author concluded antivibration saws not effective at preventing HAVs. 15% of fellers reported new symptoms of VWF over 5-year period. 28% increase in prevalence of VWF in workers using antivibration chain-saws. Correlation between objective test and symptoms poor: 54% reporting symptoms with positive findings on objective tests.

(Continued)

Table 5c–2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

				MSD prevalence				
Study	**Study design**	**Study population**	**Outcome and exposure**	**Exposed workers**	**Referent group**	**RR, OR, or PRR**	**95% CI**	**Comments**
Dimberg and Oden 1991	Cross-sectional	2,814 Aircraft engine workers. 68 Sheet metal workers. 26 Polishers/grinders. 20 Cleaners. 40 Forklift-truck drivers. 46 Engine testers. 146 Fitters. 49 Storemen 38 Electric welders. No control group used.	Outcome: Exposure to vibrating hand-tools assessed by questionnaire. White fingers as a spasm in blood vessels occurring in one or more fingers in connection with cooling leading to reversible pallor followed by redness. Exposure: Vibration assessed by questionnaire: working with vibrating tools, time in present job, leisure activities.	23% (polishers/ grinders) 19% (sheet metal workers) 15% (cleaners)	ð	Multivariate analysis showed increased symptoms with increasing age, work with vibrating hand tools and weight loss	ð	Participation rate: 96% questionnaire. Vibrating tool use significantly correlated with HAVs symptom prevalence. Analysis was stratified by gender, age, and employment category.

(Continued)

Table 5c–2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Kivekäs et al. 1994	Cohort with 7-year follow-up (1978 to 1985)	213 lumberjacks and 140 referents.	Outcome: HAVs assessed by questionnaire, clinical examination, and radiographs. Exposure: Not measured. Exposure history determined via questionnaire.	Prevalence (HAVs) 1978: 16.9% 1985: 24.9% Cumulative incidence, HAVs (7 years): 14.7%	Prevalence (HAVs): 1978: 5.0% 1985: 5.7% Cumulative incidence HAVs (7 years): 2.3%	For 1978: OR= 3.4 For 1985: OR= 4.4 OR=6.5	1.7-6.9 2.3-8.1 2.4-17.5	Participation rate: 76% among exposed workers, 78% among control. Follow-up group included 76% of lumberjacks and 78% of referents from original group. Adjusted for age. X-ray films read by radiologists blinded to case status After adjusting for age, no difference in lumberjacks with <15-years exposure and referents, but risk increased with increasing duration of exposure. For those exposed RR=8.9 (2.9-28.9). No X-ray differences in prevalence of detectable translucencies or osteoarthritic changes in wrists or hands.

(Continued)

Table 5c–2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Koskimies et al. 1992	Cohort (18-year follow-up)	Finnish forest workers (n=118-124).	Outcome: HAVs assessed by questionnaire and physical examination. Exposure: Vibration acceleration of the front handle of chain saws analyzed.	Prevalence of HAVs among forestry workers in 1990: 5%	Prevalence of HAVs among forestry workers in 1972: 40%	õ	õ	Participation rate: 100% of those who had a yearly physical exam. Decrease in prevalence attributed to reduction in weight of saws, increase in vibration frequency, and reduction in vibration acceleration (from 14 to 2 m/s^2).

(Continued)

Table 5c–2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Letz et al. 1992	Cross-sectional	Shipyard workers with full-time vibration exposure (n=103); part-time vibration exposure (n=115), and no vibration exposure (n=53, comparison group).	Outcome: HAVs assessed by self-administered questionnaire; graded according to the Stockholm scale. Vibration measurements from 51 pneumatic tools made in 3 studies. Extreme variability precluded direct comparison of tools. Number of hours per week and years using tools asked.	Vascular symptoms among part-time vibration-exposed workers: 33%	Vascular symptoms: 5.7%	Part-time vibration-exposed workers vs. controls: OR=8.23	2.3-35.4	Participation rate: 79%. Participants randomly selected within departments. Significant exposure–response relationship found after adjustment for smoking, not age or race. Average latency to symptom onset <5 years. Alcohol consumption, past medical conditions considered in analysis. Exposure–response relationship found regarding self-reported cumulative exposure to vibratory tools, sensorineural stages, and corresponding vascular classifications but no further increases in workers with > 17,000 hr of exposure. Median latency for appearance of symptoms of white finger was 8,400 hr of vibratory tool/use and 8,200 hr for numbness. Participants not blinded to purpose of questionnaire may have been over-reporting.
				Vascular symptoms among full-time vibration-exposed workers: 70.9%;		Full-time vibration-exposed workers vs. controls: OR=40.6	11-177	
				Sensorineural symptoms among part-time vibration-exposed workers: 50.4%	Sensori-neural symptoms: 17%	Part-time vibration-exposed workers vs. controls: OR= 5.0	2.1-12.1	
				Sensorineural symptoms among full-time vibration-exposed workers: 83.5%		Full-time vibration-exposed workers vs. controls: OR=24.7	9.5-67	

(Continued)

Table 5c–2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
McKenna et al. 1993	Cross-sectional	46 pairs of riveters and matched control subjects (machine operators who had never used vibrating tools).	Outcome: Defined as cold-induced digital vasospasm. Exposure: To specific tools assessed via questionnaire.	35%	2%	24	3.1-510	Participation rate: Not reported. Matched on age and smoking habits. Only males studied. Excluded those with injury to neck, trunk, upper limbs. 44% of riveters had <2.5 years of vibration exposure. Did not of blind examiners because they tested the most symptomatic finger. No differences in resting finger systolic pressure, vibration perception, or finger temperature between cases and controls. 17% of riveters reported symptoms of VWF.

(Continued)

Table 5c–2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Mirbod et al. 1992b	Cross-sectional	Forestry workers (n=447) No control group used.	Outcome: HAVs assessed by interview and physical examination. Symptoms graded using the Stockholm scale. Frequency-weighted vibration-acceleration measurements made on the hands of chain saw operators during different job processes.	9.6% overall 20.9% among workers with 30 or more years experience 2.5% among workers <14 years 11.7% 20 to 24 years	ð	ð	ð	Participation rate: Not reported. HAVs symptom severity positively correlated with exposure duration. Chain saw vibration levels ranged from 2.7 to 5.1 m/s^2. Low prevalence attributed to recent improvements in working conditions.

(Continued)

Table 5c–2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Mirbod et al. 1994; Mirbod et al. 1992a	Cross-sectional	(A) 164 male dental technicians, (B) 54 male orthopedists, (C) 256 male aircraft technicians, (D) 79 male laborers, (E) 27 male grinders, (F) 46 female sewing-machine operators, (G) 23 male tea-harvesting-machine operators, (H) 272 male chain-saw operators; compared with 1,027 males and 1,301 females not exposed to vibration.	Outcome: HAVs assessed by questionnaire, interviews, field visits, or annual health examinations. Exposure: To vibrating tools assessed by questionnaire and interviews. Hand-transmitted vibration measured among a sample of workers using representative tools in actual work activities.	(See first column for job categories) A: 4.8% B: 3.7% C: 2.3% D: 2.5% E: 3.7% F: 4.3% G: 0.0% H: 9.6%	Males: 2.7% Females: 3.4%	H vs. unexposed Males: 3.77	2.1-6.8	Participation restricted to workers age 30 to 59 years. Subjects stratified by age in analysis. Hand-transmitted vibration levels in groups A to G ranged from 1.1 to 2.5 m/s^2. Hand-transmitted vibration levels in group H ranged from 2.7 to 5.1 m/s^2.

(Continued)

Table 5c–2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Miyashita et al. 1992	Cross-sectional	355 Male construction workers (machine operators) compared with 44 male office workers. (A) 184 power shovel operators. (B) 127 bulldozer operators. (C) 44 forklift operators.	Outcome: HAVs assessed by self-administered questionnaire. Exposure: Status assumed from job title (no objective measurements performed).	1.1%	2.3%	0.5	0.1-11.8	Participation rate: Not reported. Participation restricted to male workers age 30 to 49. Vibration due to construction-machinery operation.

(Continued)

Table 5c–2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Musson et al. 1989	Cross-sectional	Impact power-tool users in The Netherlands (n=169). No control group used.	Outcome: HAVs based on symptoms, assessed via postal questionnaire. Exposure: Vibration intensity measured using five representative tools. Duration of vibration exposure assessed via questionnaire.	17%	ô	ô	ô	Participation rate: 38% questionnaire. Adjusted for age. Exposure duration not related to HAV symptoms.

(Continued)

Table 5c–2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Nagata et al. 1993	Cross-sectional	179 chain-saw workers and 205 local inhabitants who had never used vibrating tools (control group).	Outcome: HAVs assessed by dermatological tests and physical examination. Exposure: Vibration not measured directly; exposure duration expressed as years since commencement of occupation.	>20-years exposure: 16% < 20-years exposure: 2.4%	2.9%	7.1 for >20-years vibration exposure	2.5-19.9	Participation rate: Not reported. Adjusted for age. Examiners not blinded to exposure status.

(Continued)

Table 5c–2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Nilsson et al.1989	Cross-sectional	Platers (n=89) and office workers (n=61) divided into 4 groups according to current and past vibration exposure.	Outcome: Assessed by physical examination and interview. VWF symptoms staged using the Taylor-Pelmear scale.	Platers with current exposure: 42%	Office workers with no exposure: 2%	85	15- 486	Participation rate: 79% among platers, not reported among control. Controlled for age.
			Exposure: Vibration exposure assessed by measuring the acceleration intensity on a sample of tools, subjective ratings, and objective measures of exposure time.	Platers with current and former exposure.	Office workers with no vibration exposure and former exposure.	14	5-38	Vibration acceleration levels =5.5 m/s^2 (grinders), 10.3 m/s^2 (hammers), 1.5 m/s^2 (die grinders). Mean latency to symptom onset = 9.8 years.
				Platers and office workers with current or former exposure.	Office workers with no vibration experience.	56	12-269	Odds ratio increased by 11% for each year of exposure. No correlation between the Taylor-Pelmear stage and years of exposure.

(Continued)

Table 5c–2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Saito 1987	Cohort: 6-year follow-up prospect-ive	Chain sawers without HAV symptoms in 1978 (n=155) followed up in 1983.	Outcome: Assessed by symptoms, skin temperature, vibration threshold, nail compression, pain sense, and cold provocation. Exposure: Chain saw operating time determined by questionnaire.	0% in 1983	0% in 1978	õ	õ	Participation: Follow-up of cohort. Improvements in chain saw design, age restrictions, and a decrease in weekly operating time credited for preventing HAV. Recovery rates of skin temperature after 10-min provocation test significantly better in 1982 and 1983 compared to 1978. Vibratory sense thresholds at 5th minute after cold provocation significantly better in 1980, 1982, and 1983 compared with 1978. Age significance correlated to recovery rates from 1978 to 1983.

(Continued)

Table 5c–2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Shinev et al. 1992	Cross-sectional	77 male fettlers; 59 male molders; 85 male polishers. No control group used.	Outcome: HAV assessed by neurological examination. Exposure: Vibration characteristics of chipping and caulking hammers, air tampers, and polishing machines measured.	22.1% (fettlers) 6.8% (molders) 25% (polishers)	ò	ò	ò	Participation rate: Not reported. Percussive vibration had greater effect on muscle and bone pathology than constant high-frequency vibration.

(Continued)

Table 5c–2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Starck et al. 1990	Cross-sectional	Forest workers (n=200), pedestal grinders (n=12), shipyard workers (n=171), stone workers (n=16), and platers (n=5). No control group used.	Outcome: HAV based on symptoms, assessed via questionnaire. Exposure: Vibration measurements taken on a sample of tools during normal operation at the workplace.	40% (forest workers using 1st generation chain saw) 16% (forest workers using 2nd generation chain saw) <7% (forest workers using 3rd generation chain saw) 100% (for pedestal grinders with zirconium wheels) 5% (shipyard workers) 75% (stone workers using pneumatic hammers) 50% (stone workers using chisel heads) 40% (platers)	õ	õ	õ	Participation rate: Not reported. No demographic data about study participants provided. Poor correlation between vibration exposure and HAV when tools were highly impulsive.

(Continued)

Table 5c–2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Virokannas and Tolonen 1995	Cross-sectional	Railway workers (n=31) and lumberjacks (n=32) exposed to HAV. No controls used. Article evaluates the vibration perception threshold (VPT) among exposed workers and tries to determine a dose-response relationship between exposure to HAV and the VPTs.	Outcome: "History of attack" of white finger reported by subjects. VPT and electroneuro-myography used as indicators of sensory nerve damage (outcome measure). Exposure: To vibrating tools assessed by interview. (No measurements performed). Groups asked about exposure time with self-estimated annual use of vibrating tools and vehicles (hr) and number of years of exposure to vibration. Mean (SD) duration of exposure to vibration was 8,050 (3,500) among railway workers and 21,250 (10, 950) hrs among lumberjacks.	Railway workers: 45% VWF Lumberjacks: 38% VWF	õ	õ	õ	Participation rate: Not reported. Total exposure to HAV had significant correlation with VPT in railway workers (r=0.55-0.47; *p*=0.017) and lumberjacks (r=0.77-0.59; *p*=0.003). Increase in VPT approximately 2 times greater in railway workers. 7 workers excluded—2 railway workers with polyneuropathy; 4 railway workers with CTS; 1 lumberjack with CTS. These may have been related to vibration exposure. Lumberjacks used chain saws daily >1,000 hr per year. Railway workers used hand-held tamping machines -500 hrs per year. Found peak value differences for hand-held tamping machines (40 to 60 Hz) and chain saws (120 to 150 Hz). Nerve-conduction measurements adjusted for skin temperature.

CHAPTER 6

Low-Back Musculoskeletal Disorders: Evidence for Work-Relatedness

SUMMARY

Over 40 recent articles provided evidence regarding the relationship between low-back disorder and the five physical workplace factors that were considered in this review. These included (1) heavy physical work, (2) lifting and forceful movements, (3) bending and twisting (awkward postures), (4) whole-body vibration (WBV), and (5) static work postures. Many of the studies addressed multiple work-related factors. All articles that addressed a particular workplace factor contributed to the information used to draw conclusions about that risk factor, regardless of whether results were positive or negative.

The review provided **evidence** for a positive relationship between back disorder and heavy physical work, although risk estimates were more moderate than for lifting/forceful movements, awkward postures, and WBV. This was perhaps due to subjective and imprecise characterization of exposures. Evidence for dose-response was equivocal for this risk factor.

There is **strong evidence** that low-back disorders are associated with work-related lifting and forceful movements. Of 18 epidemiologic studies that were reviewed, 13 were consistent in demonstrating positive relationships. Those using subjective measures of exposure showed a range of risk estimates from 1.2 to 5.2, and those using more objective assessments had odds ratios (ORs) ranging from 2.2 to 11. Studies using objective measures to examine specific lifting activities generally demonstrated risk estimates above three and found dose-response relationships between exposures and outcomes. For the most part, higher ORs were observed in high-exposure populations (e.g., one high-risk group averaged 226 lifts per hour with a mean load weight of 88 newtons [N]) . Most of the investigations reviewed for this document adjusted for potential covariates in analyses; nevertheless, some of the relatively high ORs that were observed were unlikely to be caused by confounding or other effects of lifestyle covariates. Several studies suggested that both lifting and awkward postures were important contributors to the risk of low-back disorder. The observed relationships are consistent with biomechanical and other laboratory evidence regarding the effects of lifting and dynamic motion on back tissues.

The review provided **evidence** that work-related awkward postures are associated with low-back disorders. Results were consistent in showing positive associations, with several risk estimates above three. Exposure-response relationships were demonstrated. Many of the studies adjusted for potential covariates and a few examined the simultaneous effects of other work-related physical factors. Again, it appeared that lifting and awkward postures both contribute to risk of low-back disorder.

There is **strong evidence** of an association between exposure to WBV and low-back disorder. Of 19 studies reviewed for this document, 15 studies were consistent in demonstrating positive associations, with risk estimates ranging from 1.2 to 5.7 for those using subjective exposure measures, and from 1.4 to 39.5 for those using objective assessment methods. Most of the studies that examined relationships in high-exposure groups using detailed quantitative exposure measures found strong positive associations and exposure-response relationships between WBV and low back disorders. These relationships were observed after adjusting for covariates.

Both experimental and epidemiologic evidence suggest that WBV may act in combination with other work-related factors, such as prolonged sitting, lifting, and awkward postures, to cause

increased risk of back disorder. It is possible that effects of WBV may depend on the source of exposure (type of vehicle).

With regard to static work postures and low-back disorder, results from the studies that were reviewed provided **insufficient evidence** that a relationship exists. Few investigations examined effects of static work postures, and exposure characterizations were limited.

INTRODUCTION

Low-back pain (LBP) is common in the general population: lifetime prevalence has been estimated at nearly 70% for industrialized countries; sciatic conditions may occur in one quarter of those experiencing back problems [Andersson 1981]. Studies of workers' compensation data have suggested that LBP represents a significant portion of morbidity in working populations: data from a national insurer indicate that back claims account for 16% of all workers' compensation claims and 33% of total claims costs [Snook 1982; Webster and Snook 1994b]. Studies have demonstrated that back disorder rates vary substantially by industry, occupation, and by job within given industries or facilities [see Bigos et al. 1986a; Riihimäki et al. 1989a; Schibye et al. 1995; Skovron et al. 1994].

Back disorder is multifactorial in origin and may be associated with both occupational and nonwork-related factors and characteristics. The latter may include age, gender, cigarette smoking status, physical fitness level, anthropometric measures, lumbar mobility, strength, medical history, and structural abnormalities [Garg and Moore 1992]. Psychosocial factors, both work- and nonwork-related, have been associated with back disorders. These relationships are discussed at length in Chapter 7 and Appendix B.

The relationship of the disorder with employment can be complex: individuals may experience impairment or disability at work because of back disorders whether the latter was directly caused by job-related factors or not. The degree to which ability to work is impaired is often dependent on the physical demands of the job. Furthermore, when an individual experiences a back disorder at work, it may be a new occurrence or an exacerbation of an existing condition. Again, originally it may have been directly caused by work or by nonwork-related factors. Those suffering back pain may modify their work activities in an effort to prevent or lessen pain. Thus, the relationship between work exposure and disorder may be direct in some cases, but not in others.

When discussing causal factors for low-back disorders, it is important to distinguish among the various outcome measures, such as LBP, impairment, and disability. LBP can be defined as chronic or acute pain of the lumbosacral, buttock, or upper leg region. Sciatic pain refers to pain symptoms that radiate from the back region down one or both legs; lumbago refers to an acute episode of LBP. In many cases of LBP, specific clinical signs are absent. Low-back impairment is generally regarded as a loss of ability to perform physical activities. Low-back disability is defined as necessitating restricted duty or time away from the job. Although it is not clear which outcome measure is best suited for determining the causal relationship between low-back disorder and work-related risk factors, it is important to consider severity when evaluating the literature.

In addition to level of severity, outcomes may be defined in a number of other ways, ranging from subjective to objective. Information on symptoms can be collected by interview or questionnaire self-report. Back "incidents" or "reports" include conditions reported to medical authorities or on injury/illness logs; these may be symptoms or signs that an individual has determined need for medical or other attention. They may be due to acute symptoms, chronic pain, or injury related to a particular incident, and may be subjectively or objectively determined. Whether an incident is reported depends on the individual's situation and inclinations. Other back disorders can be diagnosed using objective criteria—for example, various types of lumbar disc pathology.

There are many conditions in the low back which may cause back pain, including muscular or ligamentous strain, facet joint arthritis, or disc pressure on the annulus fibrosis, vertebral end-plate, or nerve roots. In most patients, the anatomical cause of LBP, regardless of its relationship to work exposures, cannot be determined with any degree of clinical certainty. Muscle strain is probably the most common type of work or nonwork back pain. While there is sometimes a relationship between pain and findings on magnetic resonance imaging (MRI) of disc abnormalities (such as a herniated disc and clinical findings of nerve compression), unfortunately, the most common form of back disorder is "non-specific symptoms," which often cannot be diagnosed.

It is important to include subjectively defined health outcomes in any consideration of work-related back disorders because they comprise such a large subset of the total. It may be too restrictive to define cases of back disorder using "objective" medical criteria. Therefore, in contrast to chapters for musculoskeletal disorders or other anatomic regions, this review of literature on the back used slightly different evaluation criteria. For consideration of back disorders, use of a subjective health outcome was not necessarily considered a study limitation. Furthermore, because back disorders were rarely defined by medical examination criteria, the evaluation criterion related to blinding of assessors (to health or exposure status) was also less relevant to a discussion of this literature.

In this review, epidemiologic studies of all forms of back disorder were included. The term "back disorder" is used to encompass all health outcomes related to the back. It should be pointed out that, in some studies, disorders of the low back were not distinguished from total back disorders. We assumed that a significant portion of these related to the low back, and articles using such a definition were included in our review.

The 42 epidemiologic studies discussed below were selected according to criteria that appear in the introduction of this document. Most (30) used a cross-sectional design, followed by prospective cohort (5), case-control (4), and retrospective cohort (2) designs. One study combined both cross-sectional and cohort analyses. Full descriptions of the studies appear in Table 6-6. Twenty-four investigations defined the health outcome only by report of symptoms on questionnaires or in interviews (for example, total back pain, LBP, and sciatica); used symptoms plus medical examination (back pain, low-back syndrome, sciatica, back insufficiency, lumbago, herniated lumbar disc, and lumbar disc pathology), 2 used sick leaves and medical disability retirements, and 6 used injury/illness reports. The last category included outcomes defined as "low-back complaints, injuries caused specifically by lifting or mechanical energy," and "acute industrial back injury." Clearly, the 42 studies used outcome definitions that correspond to several regions of the back and include disorders that may have been acute or chronic and subjectively or objectively determined.

In the studies included in this review, exposures were assessed primarily by questionnaire or interview (n=17), followed by observation or direct measurement (n=15) and by job title only (n=10). Study groups included general populations (Swedish, Dutch, U.S., Finnish, and English) and occupational groups (nurses, clerical employees, school lunch preparers, baggage handlers, and individuals working in construction, agriculture, maritime, petroleum, paper products, transportation, automobile, aircraft, steel, and machine manufacturing industries).

This review of epidemiologic studies of low-back disorder examined the following potential risk factors related to physical aspects of the workplace: (1) heavy physical work, (2) lifting and forceful movements, (3) bending and twisting (awkward postures), (4) WBV, and (5) static work postures. Psychosocial workplace factors were also included in a number of studies; these relationships are discussed separately in Chapter 7. Following are discussions of the evidence for each work-related physical risk factor.

HEAVY PHYSICAL WORK

Definition

Heavy physical work has been defined as work that has high energy demands or requires some measure of physical strength. Some biomechanical studies interpret heavy work as jobs that impose large compressive forces on the spine [Marras et al. 1995]. In this review, the definition for heavy physical work includes these concepts, along with investigators' perceptions of heavy physical workload, which range from heavy tiring tasks, manual materials handling tasks, and heavy, dynamic, or intense work. In several studies, evaluation of this risk factor was subjective on the part of participant or investigator, and in many cases, "heavy physical work" appeared to include other potential risk factors for back disorder, particularly lifting and awkward postures.

Studies Reporting on the Association Between LBP and Heavy Physical Work

Eighteen studies appeared to address the risk factor related to heavy physical work, although none of them fulfilled all four evaluation criteria (Table 6-1, Figure 6-1). In fact, most (78%) had acceptable participation rates, but only three defined health outcomes using both symptoms and medical exam criteria, and only two assessed exposure independent of self-report.

In nearly all of these studies, covariates were addressed in at least minimal fashion, such as restricting the study population as to gender and conducting age-stratified or adjusted analyses; in many, multivariate analyses were carried out. With regard to health outcome, while only three used medical exams, in addition to symptoms or injury reports, to arrive at case definitions, in many instances standard questionnaire instruments were used. The major study limitations, overall, were related to relatively poor ascertainment of exposure status.

Following are descriptions of seven studies that were most informative. Detailed descriptions for all 18 investigations can be found in Table 6-6.

Bergenudd and Nilsson [1988] followed a Swedish population-based cohort established in 1938. Back pain (total) presence and severity were self-assessed by questionnaire, as of 1983; exposures (light, moderate, or heavy physical work) were assessed based on questionnaires completed by the cohort from 1942 onward. Univariate results demonstrated that those with moderate or heavy physical demands in their jobs had more back pain than those with light physical demands (OR 1.83, 95% Confidence Interval [CI] 1.2-2.7). When stratified by gender, the relationship was slightly stronger for females (OR 2.03, 95% CI 1.1–3.7) than for males (OR 1.76, 95% CI 1.01–3.1). When prevalence was examined by exposure category, rates were 21.4%, 32.8%, and 31.3% for males (no trend was available for females, as none worked in the highest exposure category). Analyses were stratified by gender but did not account for other potential covariates. The longitudinal design ensured that exposures preceded health outcomes. Shortcomings included a relatively low response rate (67%), minimal exposure assessment, limited adjustment for covariates in analyses, and self-reporting of health symptoms.

Burdorf and Zondervan [1990] carried out a cross-sectional study comparing 33 male workers who operated cranes with age-matched workers from the same Dutch steel plant who did not operate cranes. Symptoms of LBP and sciatica were assessed by questionnaire. Exposure was assessed by job title (crane operators were noted to experience frequent twisting, bending, stooping, static sedentary postures, and WBV) and by questionnaire (exposures to sedentary postures, WBV, heavy physical work, and frequent lifting were assessed for both current and past jobs). Crane operators were significantly more likely to experience LBP (OR 3.6, 95% CI 1.2–10.6). Among crane operators alone, the OR for heavy work was 4.0 (95% CI 0.76–21.2) after controlling for age, height, and weight. It was determined that this heavy work occurred in past and not in current jobs. Among crane operators alone, the OR for frequent lifting was 5.2 (95% CI 1.1–25.5). The frequent lifting in crane operators was also determined to be from jobs held in the past. Among workers who were not crane operators, history of frequent lifting was not associated with LBP (OR 0.70, 95% CI 0.14–3.5). Among crane operators, univariate ORs for WBV and prolonged sedentary postures were 0.66 (95% CI 0.14–3.1) and 0.49 (95% CI 0.11–2.2), respectively. In multivariate analyses controlled for age, height, weight, and current crane work, most of the associations with specific work-related factors were substantially reduced. The high prevalence of LBP in crane operators was explained only by current crane work. No measures of dose-response were examined.

Limitations included a relatively low response rate for crane operators (67%)—with some suggestion that those with illness may have been under-represented (perhaps underestimating the OR)—and self-reporting of health outcomes and exposures. The investigators attempted to clarify the temporal relation between exposure and outcome by excluding cases of back pain with onset before the present job.

As part of a Finnish population-based health survey, Heliövaara et al. [1991] conducted a cross-sectional analysis of chronic low-back syndrome, sciatica, and LBP. Health outcomes were determined by interview and examination; work-related exposure information was obtained by a self-administered questionnaire, which included items related to lifting, carrying heavy objects, awkward postures, WBV, repeated movements, and paced work. The total number of factors was designated the "sum index of occupational physical stress." Mental work stress measures were also included. A dose-response was observed for sciatica and the physical stress score (with an OR of 1.9, 95% CI 0.8–4.8 for the highest score) and for low-back syndrome and physical stress (OR 2.5, 95% CI 1.4–4.7), after adjusting for a number of covariates. The study did not address temporal relationships, and exposure information was derived from self-reports. Strengths included a high response rate, objective measure of health outcomes, and multivariate adjustment for covariates.

Johansson and Rubenowitz [1994] examined low-back symptoms cross sectionally in 450 blue- and white-collar workers employed in eight Swedish metal companies. The exposed group included assemblers, truck drivers, welders, smiths, and operators of several types of machines (lathes, punch presses, and milling). Outcome information was obtained by questionnaire. Exposure data were also obtained by questionnaire and included information on occupational, psychosocial, and physical workloads, including sitting, carrying, pushing, pulling, lifting, work postures, and repetitive movements. Questionnaire items related to carrying, pushing, pulling, and lifting were combined to produce an index of manual materials handling. The prevalence of work-related LBP was significantly higher in blue-collar employees than in white-collar workers (RR 1.8, $p<0.05$). In both white and blue-collar workers, work-related LBP was not significantly associated with either heavy or light materials handling, or bent or twisted work postures, after adjustment for age and gender. LBP was significantly associated with extreme work postures (blue-collar workers only) and monotonous working movements (white-collar workers only). In these analyses, relationships were presented as partial correlations; thus, a comparison of risk estimates was not possible. Limitations of the study included the cross-sectional design, collection of outcome and exposure data by self-report, and potential problems with multiple comparisons, as many independent variables were examined in analyses. Many of the exposed group (blue-collar workers) were engaged in machine operation tasks with perhaps limited opportunity for exposure to work with heavy physical demands. Also, heavy physical work and lifting were combined into a single index. Strengths included consideration of age and gender as covariates and inclusion of both physical and psychosocial workplace measures.

Svensson and Andersson [1989] examined LBP in a population-based cross-sectional study of employed Swedish women. Information on LBP and sciatica was obtained by questionnaire, as were exposure-related items. Physical exposures included lifting, bending, twisting, other work postures, sitting, standing, monotony, and physical activity at work. Lifetime incidence rates (IRs) varied by occupation, with ranges from 61%–83% in younger age groups and 53%–75% in older groups. *A posteriori*, the authors noted that, for these women, the highest lifetime incidence of LBP was not found in the jobs with the highest physical demands. The measure for "physical activity at work" was also not significantly associated with LBP in univariate analyses. Bending forward (RR 1.3), lifting (RR 1.2), and standing (RR 1.3) were associated with lifetime incidence of LBP in univariate analyses (p<0.05). None of the measures of physical workplace factors were associated with lifetime incidence of LBP in multivariate analyses.

A cross-sectional study of LBP in Finnish nurses was conducted [Videman et al. 1984]. LBP and sciatica were ascertained by questionnaire; exposure information was also self-reported and included items related to both physical loading factors at work and to work history. Exposures were reclassified as "heavy," "intermediate," and "light," based on questionnaire responses. The derivation of this classification was not clear, but it may have been a combination of responses to questions on lifting, bending, rotation, standing, walking, and sitting. A dose-response was observed between prevalence of previous LBP and workload category in younger women (77%, 79%, and 83% for light, intermediate, and heavy categories). The trend was not observed in older age groups, nor for sciatica in any age group. LBP and sciatica rates were slightly higher for nurse aides than for qualified nurses, although the differences were not statistically significant. The authors suggested that aides had higher rates of back pain because of heavier workload, including patient handling and lifting. Lack of consistency of LBP OR across exposure and age groups suggested that a healthy worker effect was operating and that injured workers might be leaving the field, a phenomenon that the cross-sectional study design could not address.

Videman et al. [1990] carried out a cross-sectional study of 86 males who died in a Helsinki hospital to determine degree of lumbar spinal pathology. Disc degeneration and other pathologies were assessed in the cadaver specimens by discography and radiography. Subjects' symptoms and work exposures—heavy physical work, sedentary work, driving, and mixed—were determined by interview of family members. In comparison to those with mixed work exposures, those with sedentary and heavy work had increased risk of symmetric disc degeneration with ORs of 24.6 (95% CI 1.5–409) and 2.8 (95% CI 0.3–23.7), respectively). Similar relationships were seen for vertebral end-plate defects and facet joint osteoarthrosis. Risk of vertebral osteophytosis was highest for those in the heavy work category (OR 12.1, 95% CI 1.4–107). For most pathologic changes, sedentary work appeared to have a stronger relationship than heavy work. Back pain symptoms were consistently higher in those with any form of spinal pathology, although the difference was significant only for anular ruptures. Results of this study were notable in that anular rupture, a classic pathologic condition of the disc, was not associated with exposure. This study was unusual in design in that it examined a combination of spinal pathological outcomes, symptoms, and workplace factors. However, participation in the study was dependent on obtaining information from family members; participation rates were not stated. While recall bias is often a problem in studies of the deceased, in this case, it should have been nondifferential, if present.

Strength of Association

The most informative studies were generally those that carried out exposure assessments which ranked physical workload based on questionnaire report. In a prospective study of back injury reports, Bigos et al. [1991b] found no associations with physical job characteristics (although the authors stated that the study population had low overall exposures). This study described the biomechanical methods that were used to directly assess spinal loads associated with jobs, but no results related to these measures were presented. Svensson and Andersson [1989] appear to have examined a measure for physical activity at work and its relationship to LBP in Swedish women. No associations were observed. In a population-based study, Bergenudd and Nilsson [1988] observed significantly more back pain in those with heavier physical work (OR 1.8 for moderate/heavy versus light work, $p<0.01$). ORs were slightly higher for females (OR 2.0) than for males (OR 1.8). Leigh and Sheetz [1989] found that back symptoms were associated with self-reporting that “job requires a lot of physical effort” (OR 1.5, 95% CI 1.0–2.2). Masset and Malchaire [1994] observed that LBP was not associated with overall physical workload in a group of Belgian steelworkers, although LBP was related to heavy shoulder efforts. In a study of blue-and white-collar workers, Johansson and Rubenowitz [1994] found higher LBP rates in blue-collar workers (RR 1.8, $p<0.05$). However, in more detailed analyses of exposure, back pain was not associated with indices for heavy or light materials handling after adjustment for age and gender (with partial correlation coefficients of less than 0.10). Burdorf and Zondervan’s 1990 study of crane operators demonstrated increased risk of LBP with exposure to heavy work (OR 4.0, 95% CI 0.8–21.2) after controlling for age, height, and weight. Two studies used indices of physical stress to create questionnaire responses related to lifting, carrying heavy objects, awkward postures, repeated movements, and others. Heliövaara et al. [1991] found that both low-back syndrome and sciatica were associated with physical stress scores, with ORs of 2.5 ($p<0.05$) and 1.9 (not significant) for the highest scores, respectively. A study of Finnish nurses classified exposures as “heavy,” “intermediate,” and “light” based on questionnaire response scores [Videman et al. 1984]; prevalence of LBP was slightly higher in the heavy category than in the light (RR 1.1, not significant) for younger women only. Sciatica was also examined, and no relationships were found.

The other studies that examined heavy physical work as a risk factor for back disorder classified exposure in a simpler manner, either by job title alone or by grouping jobs based on prior knowledge of the work or questionnaire responses. Burdorf et al. [1991] found that heavy physical work was associated with back pain in concrete workers in univariate, but not multivariate models (no risk estimate was reported). Hildebrandt [1995] found that individuals in jobs described as "heavy non-sedentary" were more likely to experience back pain than those in sedentary jobs (OR 1.2, $p<0.05$). In a cadaver study of lumbar disc pathology, Videman et al. [1990] found that those with jobs involving heavy physical work had increased risk of disc pathology in comparison to those with mixed work exposures (e.g., an OR of 2.8, 95% CI 0.3–23.7, for symmetric disc degeneration and an OR of 12.1, 95% CI 1.4–107, for vertebral osteophytosis). For most pathologic changes, sedentary work had a stronger relationship than heavy work.

Finally, several studies examined back disorder rates by job title or occupation alone. Hildebrandt et al. [1996] observed differences in back symptom rates by unit and task group in "nonsedentary" steel workers. The reference group also had high symptom rates; comparisons between the two groups did not yield significant differences. In multivariate analyses, Riihimäki et al. [1989b] found no significant difference in sciatic pain for carpenters and office workers (OR 1.0, 95% CI 0.8–1.3). Partridge and Duthie [1968] found that dock workers had slightly higher LBP rates than civil servants (RR 1.2, not significant). In a similar study, Åstrand [1987] classified pulp mill jobs as heavy and the referent group of clerical jobs as light; mill workers were 2.3 times more likely to experience back pain than clerical staff ($p=0.002$). Clemmer et al. [1991] found that floor hands, roustabouts, and derrickhands had the highest rates for low-back strains and impact injuries, with RRs of 2.2 and 4.3 (no significance testing was done) in comparison to control room operators and maintenance professionals, those with the lowest rates. A study of hospital employees that matched cases with controls by department found that those on the day shift had an OR of 2.2 ($p<0.005$) in comparison to those working other shifts [Ryden et al. 1989]. In the last two studies, the authors determined *a posteriori* that job titles (or shifts) that were observed to have high back disorder rates were those requiring the heaviest physical effort.

Although in all 18 of these studies the authors stated that "heavy physical effort or work" was at least one of the risk factors of interest, the actual estimates of these exposures varied from assumptions based on job title to self-reported scores based on self-reported work activities. In no case were measured physical loads used as independent variables. Study populations included individuals working in health care, office work, manufacturing, construction, and general populations, all with varying degrees of physical work requirements. Some studies created physical "stress" indices that included more than one risk factor. Since most estimates of physical load were subjective, they tended to reflect the relative requirements of the jobs and individuals included in each study. Health outcomes also varied.

In summary, the strength of the relationship between back disorder and heavy physical work in some of the studies with more quantitatively defined exposures ranged from none [Bigos et al. 1991b; Johannsson and Rubenowitz, 1994; Masset and Malchaire 1994; Svensson and Andersson 1989; Videman et al. 1984] to ORs of 1.9 (not significant) for sciatica and 2.5 ($p<0.05$) for low-back syndrome [Heliövaara et al. 1991], 1.5 (95% CI 1.0–2.2) [Leigh and Sheetz 1989], 1.8 (95% CI 1.2–2.7) [Bergenudd and Nilsson 1988], and 4.0 ($p<0.05$) for LBP [Burdorf and Zondervan 1990]. In another study, which used a scoring system and focused on a subject group of nurses, the RR was 1.1 (not significant) for the high-exposure category [Videman et al. 1984].

Dichotomous estimates of physical workload yielded ORs of 1.2 [Hildebrandt 1995], 2.8-12.1 [Videman et al. 1990], and no association (results were observed in univariate but not multivarate analyses, with no risk estimates reported) [Burdorf et al. 1991]. Exposures based on job title alone yielded estimates from none [Hildebrandt et al. 1996], nonsignificant ORs of 1.0 and 1.2 [Partridge and Duthie 1968; Riihimäki et al. 1989b], to significant ORs of 2.2–4.3 [Åstrand 1987; Clemmer et al. 1991; Ryden et al. 1989]. Half of the studies had positive point estimates for this risk factor but were low to moderate in magnitude. In five studies that found no association between back disorder and heavy physical work, no details were given. Two of the highest significant ORs were based on exposed groups in the oil and steel industries [Burdorf and Zondervan 1990; Clemmer et al. 1991]. For these, true exposure to heavy physical work was probably more likely than for some of the other study populations. For many of the investigations, exposure estimates were subjectively assessed. In many cases, study groups had potentially low exposures or exposure to heavy physical work in combination with other risk factors.

Temporal Relationship

Fourteen of the 18 reviewed studies had a cross-sectional design that could not directly address this issue. Three mentioned potential problems related to this study design. Åstrand [1987] suggested that exposure misclassification occurred in her study of paper mill workers (some individuals were transferred to clerical jobs—the unexposed group—after experiencing a back injury in the mill). In the Videman et al. 1984 study of nurses, lack of consistency of LBP OR by age and exposure group suggested that injured workers were leaving the field. A study of cadavers carried out by Videman et al. [1990] seemed to have potential for problems with temporal relationships, as exposure information for past periods depended on recall of study participants' activities by family members.

Two cross-sectional studies attempted to clarify temporal relationships by excluding from analysis the cases with disorder onset prior to current job [Burdorf et al. 1991; Burdorf and Zondervan 1990]. Both showed results suggesting a positive relationship between exposure and back disorders. Three studies had cohort designs in which temporal relationships between outcome and exposure could be determined [Bergenudd and Nilsson 1988; Bigos et al. 1991b; Clemmer et al. 1991]: in one, no association was observed, in another, a modest increase in risk was seen. In the third, exposure (assessed *a posteriori* by job title) was significantly associated with back injuries. A case-control study conducted using hospital personnel records appeared free from recall bias and showed a significant association between low-back injury and working the day shift (assessed *a posteriori* as having the heaviest workload) [Ryden et al. 1989].

Although the majority of studies were limited by their cross-sectional designs, results were similar for these and other studies with designs that could assess temporal relationships.

For most studies, the data are compatible with a temporal relationship in which exposure preceded disorder.

Consistency in Association

Half of the 18 studies examined demonstrated no significant association between exposure and outcome. All of those which showed significant associations (n=9) were positive in direction, (one OR of 1.2, two ORs between 1.5 and 2, and six ORs between 2.2 and 12.1).

Study groups included males working in industrial environments, office workers, health care employees—female, for the most part—and population-based groups that included both genders and many occupations. That some consistency in results was noted among these diverse groups, particularly after adjustment for covariates, suggests that the observed associations have validity and can be generalized across working populations.

Coherence of Evidence

Information derived from a large number of laboratory and field studies using a wide variety of approaches provides a plausible explanation for associations between LBP and physically demanding jobs [Waters et al. 1993]. Research conducted in the 1950s demonstrated that disc degeneration occurs earlier in life among workers who perform heavy physical work than among those who perform lighter work. Similar findings are reported in more recent investigations [Videman et al. 1990]. The stresses induced at the low back during manual materials handling are due to a combination of the weight lifted, and the person's method of handling the load. The internal reaction forces needed to equilibrate the body segment weights and external forces such as weight of the load being lifted are supplied by muscle contraction, ligaments, and body joints. Injury to the supporting tissues can occur when the forces from the load, body position, and movements of the trunk create compressive, shear, or rotational forces that exceed the capacities of the discs and supporting tissues needed to counteract the load moments. Rowe [1985] hypothesized that disc and facet degeneration and ligament strain are responsible for the potentially high rates of LBP disability in those whose jobs demand heavy physical activity.

The Videman et al. [1990] cross-sectional study of cadavers addressed two aspects of the causal chain linking exposure to heavy physical work and back disorder. First, the study demonstrated an association between subjective health outcome measures and more objective measures: back pain symptoms (assessed from family members) were consistently higher in those with signs of spinal pathology. Second, the study demonstrated an association between objective measures of disorder and heavy work exposures: individuals whose jobs included heavy work exposures showed increased risk of symmetric disc degeneration, vertebral osteophytosis, and facet joint osteoarthrosis. Significant relationships were also found for back pain and disability. We agree with the conclusion of Videman et al. [1990] that states that "back injury and sedentary or heavy (but not mixed) work contributed to the development of pathologic findings in the spine. The severity of back pain was related to the heaviness of work. Work-related factors may be responsible for the development of pathologic changes and for increased episodes of LBP and disability."

Another important contribution to the coherence of evidence is that the Bureau of Labor Statistics Annual Survey of Injuries and Illnesses has demonstrated significant elevations in overexertion injuries and disorders in industries which are associated with heavy work, such as nursing and personal care and air transportation. Some broad population surveys such as the National Health Interview Survey (NHIS) from 1988 and the 1990 Ontario Health Survey (OHS) found increased back pain or long-term back problems with exposure to factors such as lifting, pulling, and physical pushing [Guo et al. 1995; Liira et al. 1996]. In the NHIS, the two occupations with the highest significant rates of work-related LBP were male construction laborers (with a prevalence ratio [PR] of 2.1) and female nursing aides, orderlies, and attendants (PR 2.8) [Guo et al. 1995]. In the OHS, the number of simultaneous physical exposures was directly related to risk increase after adjustment for covariates. For the highest exposure index level, the adjusted OR was 3.18 (95% CI 1.72–5.8), which occurred in 3% of the population [Liira et al. 1996]. It is important to point out that truly heavy work probably occurs in only a tiny proportion of all jobs in most industries and in only a minority of many high-risk industries, which is why misclassification of exposures is likely in population-based studies.

Exposure-Response Relationships

Only a few studies examined exposure in sufficient detail to assess exposure-response relationships with low-back disorders. Results were mixed. Heliövaara et al. [1991] observed an exposure-response between sciatica and physical stress score; the Videman et al. [1984] results demonstrated a dose-response between LBP prevalence and workload categories in younger nurses, but not in older groups, or for sciatica in any age group. In Åstrand's 1987 "high exposure group" (pulp mill workers), duration of employment was associated with back pain. Bergenudd and Nilsson [1988] and Johansson and Rubenowitz [1994] observed no exposure-response relationships between back disorders and their exposure measures. On the whole, evidence of exposure-response is equivocal, based on the paucity of information available.

Conclusions: Heavy Physical Work

The reviewed epidemiologic investigations provided evidence that low-back disorders are associated with heavy physical work. Despite the fact that studies defined disorders and assessed exposures in many ways, all studies which demonstrated significant associations between exposure and outcome were positive in direction and showed low to moderate increased risk. Exposures were assessed subjectively, for the most part; and in some cases, classification schemes were crude. This study limitation may have led to misclassification of exposure status to the extent that it caused a dampening effect on risk estimates, where nondifferential misclassification caused bias toward a null value for the measure of association. This may account for the moderate ORs that were observed. A few studies were able to examine dose-response relationships between outcomes and exposure; these results were equivocal. Most studies utilized cross-sectional study designs; however, five of six studies which used specific methodologies to address temporality showed positive associations between exposure and outcome. Many studies addressed potential effects of covariates by restriction in selection of study participants, stratification, or multivariate adjustment in statistical analyses.

In many studies, "heavy physical work" exposure appeared to include other work-related physical factors (particularly lifting and awkward postures).

LIFTING AND FORCEFUL MOVEMENTS

Definition

Lifting is defined as moving or bringing something from a lower level to a higher one. The concept encompasses stresses resulting from work done in transferring objects from one plane to another as well as the effects of varying techniques of patient handling and transfer. Forceful movements include movement of objects in other ways, such as pulling, pushing, or other efforts. Several studies included in this review used indices of physical workload that combined lifting/forceful movements with other work-related risk factors (particularly heavy physical work and awkward postures). Some studies had definitions for lifting which include criteria for number of lifts per day or average amount of weight lifted.

Studies Reporting on the Association Between LBP and Lifting and Forceful Movements

Eighteen studies examined relationships between back disorders and lifting or forceful movements. Only one, Punnett et al. 1991 case-control study of back pain in auto workers, fulfilled the four evaluation criteria (Table 6-2, Figure 6-2). The majority (66%) had adequate participation rates; four defined outcomes using both symptoms and medical exam criteria. Blinding of investigators with regard to case/exposure status was not mentioned in most, but it could be confirmed in two papers and inferred (by study methodology) in two others. Seven studies used an exposure assessment that included observation or direct measurement; an additional nine obtained exposure information by self-report on questionnaire or interview. Only two relied on job title alone to characterize exposure.

Thirteen investigations were cross-sectional in design; three were case-control, and two were prospective. Eleven defined the health outcome by symptom report on interview or questionnaire.

Descriptions of seven studies which provided the most information regarding the relationship between low-back disorder and lifting and forceful movements follow. Detailed descriptions for all 18 investigations can be found in Table 6-6.

The Punnett et al. [1991] case-control study examined the relationship between back pain and occupational exposures in auto assembly workers. Back pain cases (n=95) were determined by symptoms at interview and medical examination; controls included those free of back pain. For all participants (or proxies in the same jobs), jobs were videotaped and work cycles were reviewed using a posture analysis system. Exposures included time spent in various awkward postures. Peak biomechanical forces were estimated for up to nine postures where a load weighing at least 10 lb was held in the hands. In multivariate analyses that adjusted for a number of covariates (age, gender, length of employment, recreational activities, and medical history), time in non-neutral postures (mild or severe flexion and bending) was strongly associated with back disorder (OR 8.09, 95% CI 1.4–44). Lifting was also associated with back disorder (OR 2.16, 95% CI 1.0–4.7). When the subset with physical medical findings was examined, associations were more pronounced. Although few study subjects were unexposed to all of the postures studied, a strong increase in risk was observed with both intensity and duration of exposure. It was not possible to determine the relative contributions of different awkward postures because all were highly correlated. Only participants' current jobs (for referents), or job when symptoms started (for cases) were analyzed; the study design thus assumed a short-term relationship between exposure and outcome (although length of time in job was also included in the models). The authors attempted to ensure that exposure preceded disease by identifying time of onset and measuring exposures in the job held just prior. The strong associations, after adjustment for covariates, are notable.

Burdorf et al. [1991] examined back pain symptoms in a cross-sectional study of male concrete fabrication workers and a referent group of maintenance workers. Back pain symptoms were assessed by questionnaire. Exposures were measured using the Ovako Working Posture Analysis System, which assessed postures for the back and lower limbs along with lifting load. Information on exposures in previous jobs was also collected. Concrete workers experienced significantly more back symptoms than referents (OR 2.8, 95% CI 1.3–6.0). Univariate results showed associations between back pain and both posture index and WBV in current job (correlations were presented). Lifting was not found to be associated with back pain (and exposure was found not to vary significantly across the six job categories examined in the study). In multivariate analyses adjusting for age, both posture index and WBV were significantly associated with back pain, with ORs of 1.23 (p=0.04) (for an ordinal scale of 6) and 3.1 (p=0.01) (dichotomous), respectively. These two measures were highly correlated and analyzed separately. Strengths of the study include use of a standard symptom questionnaire, high participation rates, an objective measure of exposure, and an attempt to clarify the temporal relation between exposure and outcome by excluding cases of back pain with onset before the present job.

Chaffin and Park [1973] carried out a prospective study of back complaints in 411 employees of four electronics manufacturing plants. The outcome included visits to the plant medical department because of back complaints over a one-year period. Exposure was assessed by evaluating 103 jobs with a range of manual lifting for lifting strength rating (LSR) and load weights. The LSR is a ratio of the maximum weight lifted on the job to the lifting strength, in the same load position, for a large/strong man. Results showed a strong increase in back complaint incidence with LSR for both males and females (with an approximate five-fold increase in risk comparing males in the highest and lowest LSR). A similar increase was observed for females, although there were no women in the highest exposure category. No dose-response was observed by frequency of lifts (a relatively high risk of back complaints was observed for the lowest exposure category). Covariates (age, weight, and stature) were examined and found not to contribute to back complaints. The prospective study design helped increase the likelihood that exposure preceded disorder. Study limitations include lack of information on participation rates and an outcome consisting of incident reports. Time of true onset was not ascertained, and it is possible that symptom onset preceded or coincided with exposure assessment despite the longitudinal study design. The detailed exposure assessment addressed only lifting as a risk factor; presence of other risk factors related to back disorders was not identified.

A case-control study of prolapsed lumbar disc was carried out using a hospital population-based design [Kelsey et al. 1984]. Cases (n=232) included individuals diagnosed with prolapsed lumbar disc; an equal number of controls matched on sex, age, and medical service were selected. Exposure was assessed using a detailed occupational history that was not described but presumably was obtained by interview. An association with work-related lifting without twisting the body was observed at the highest lifting level (25 lb or more) (OR 3.8, 95% CI 0.7–20.1). Twisting without lifting was associated with disc prolapse (OR 3.0, 95% CI 0.9–10.2); a combination of both risk factors had an OR of 3.1 (95% CI 1.3–7.5). The highest risk was observed for simultaneous lifting and twisting with straight knees (OR 6.1, 95% CI 1.3–27.9). Despite the fact that exposures were self-reported, these associations were notably strong. The potential existed for differential recall bias for cases and controls because study subjects were interviewed about work-related factors after case status was established. Interviewers may not have been blinded to case/control status.

In Liles et al. [1984] prospective study of 453 individuals working in jobs with manual material handling requirements, incidence of back injuries was examined with regard to lifting. The study group included those who lifted frequently (at least 25 lifts per day of not less than 4.53 kg, with exposure of at least two hours per day). The outcome included reported or recorded lifting injuries to the back. Lifting exposures were assessed until job change (up to a two-year period) using the Job Severity Index (JSI). The JSI is a measure of the physical stress level associated with lifting jobs and is a function of the ratio of job demands to the lifting capacities of the person performing the job. Information on weight, frequency of lifting, and task geometry is collected through comprehensive task analysis. When the study group (working in 101 jobs from 28 plants) was classified into 10 equal categories according to JSI, a dose-response relationship with injury was observed (RR 4.5, 95% CI 1.02–19.9 for total injuries, comparing category 10 to category 1). Study limitations included no statement relating to response rate or participant selection, no adjustment for confounders, and no statistical testing. The outcome definition specified that the back injury be lifting-related, which increased the likelihood that the outcome would be related to the exposure measured. The prospective designassured that measured exposures preceded injury onset. Other strengths included objective assessment of exposure.

Using an unusual cross-sectional study design, Marras et al. [1993, 1995] examined the relationship between low-back disorders and spinal loading during occupational lifting. A total of 403 jobs from 48 diverse manufacturing companies were assessed for risk of low-back disorder using plant medical department injury reports. Jobs were ranked into three categories according to risk, then assessed for position, velocity, and acceleration of the lumbar spine during lifting motions in manual materials handling using electrogoniometric techniques. Those in high-risk jobs averaged 226 lifts per hour, with an average load weight of 88.4 N. A combination of five factors distinguished between high- and low-risk jobs: lifting frequency, load moment, trunk lateral velocity, trunk twisting velocity, and trunk sagittal angle. The highest combination of exposure measures produced an OR of 10.7 (95% CI 4.9–23.6 in comparison to the lowest combined measures). In univariate analyses, the most powerful single variable was maximum moment (a combination of both weight of the object and distance from the body), which yielded a significant OR of 3.3 between low- and high-risk groups [Marras et al. 1995]. The study design was unusual in that the unit of analysis appeared to be the job rather than the individual. Neither participation rates nor total number of participants was stated. No information appeared regarding the proportions of individuals within jobs who were recruited for measurement of lifting motions. However, the unit of analysis was job, and each was characterized by measurement of at least one study subject. Effects of covariates were not addressed (multivariate analyses appeared to include only biomechanical variables). The study results emphasized the multifactorial etiology of back disorders, including contributions of lifting frequency, loads, and trunk motions and postures. The study design did not allow for examination of temporal relationships.

Walsh et al. [1989] examined the relationship between self-reported LBP and work-related factors in a population-based cross-sectional study of 436 English residents. LBP was ascertained by interview, as was lifetime occupational history (including exposures to standing, walking, sitting, driving, lifting, and using vibrating machinery). Exposures were ascertained either as of the birthday prior to onset of symptoms or by lifetime occupational history prior to onset of symptoms. Using the most recent job (as of the birthday prior to symptoms), driving was associated with symptoms in males (RR 1.7, 95% CI 1.0–2.9), as was lifting or moving weights of 25 kg or more (RR 2.0, 95% CI 1.3–3.1), when all exposures were considered in multivariate analyses. For women, lifting (RR 2.0, 95% CI 1.1–3.7) was associated with symptoms. When lifetime exposures were considered, lifting remained significantly associated for males (RR 1.5, 95% CI 1.0–2.4). Both sitting (RR 1.7, 95% CI 1.1–2.6) and use of vibrating machinery (RR 5.7, 95% CI 1.1–29.3, based on one case) were associated with symptoms in females. The multivariate analyses stratified on sex and adjusted for age and simultaneous work exposures. While information on symptoms and exposures was obtained crosssectionally, the authors attempted to construct a retrospective cohort design by gathering data on lifetime work exposures and back symptoms. While in the design lifetime exposures were cumulated only prior to disorder onset, it would not be expected that participants could recall these relationships accurately. Temporal relationships were unclear.

Strength of Association

The most informative studies included those that employed independent measures of exposure to assess lifting demands, as they provided the best contrast among levels of exposure and were subject to the least misclassification. A case-control study by Punnett et al. [1991] found an OR of 2.16 (95% CI 1.0–4.7) for the relationship between back pain (ascertained by symptoms and medical exam) and lifting, after adjusting for covariates (including awkward postures). In their 1973 investigation, Chaffin and Park found a strong increase in incidence of medical visits related to back problems with increased LSR (with an approximate five-fold increase in risk comparing males in the highest and lowest categories); they did not find a similar dose-response relationship for frequency of lifts. Marras et al. [1993, 1995] examined the relationship between low-back injury reports and spinal loading during lifting, and found an OR of 10.7 (95% CI 4.9–23.6) for simultaneous exposures to lifting frequency, load weight, two trunk velocities, and trunk sagittal angle. Both lifting and postures contributed to the high ORs. In Magora's [1972, 1973] studies of LBP and occupational physical efforts, the highest LBP rate was observed in those who lifted rarely. When LBP was ranked by level of sudden maximal effort, the highest rate was seen for those who did it often, with a dose-response for three categories (10.9, 11.3, and 18.0, respectively, with a RR of 1.65 [95% CI 1.3–2.1]) when comparing lowest to highest). Liles et al. [1984] found a significant association between incidence of back injuries related to lifting and lifting exposures as assessed by JSI: the RR was 4.5 (95% CI 1.02–19.9) comparing the highest and lowest exposure categories. Burdorf et al. [1991] found no association between back pain symptoms and lifting load (the latter did not vary across the six job categories examined in the study). Huang et al. [1988] conducted detailed ergonomic evaluations of two school lunch preparation centers with differing rates of musculoskeletal (including back) disorders. The center with higher disorder rates had greater lifting and other work-related demands. Unfortunately, the study was ecologic in design and did not link exposures and outcomes to calculate risk estimates for the study groups, although several areas for ergonomic intervention were identified.

Other studies assessed exposures by self-report on interview or questionnaire. Johansson and Rubenowitz [1994] examined low-back symptoms by index of manual materials handling (which included lifting and other risk factors). In neither white- nor blue-collar workers was LBP significantly associated with the index. In Kelsey's 1975 case-control study of herniated lumbar discs, cases and controls had similar histories of occupational lifting (RR 0.94, p=0.10). In a second case-control study of prolapsed lumbar disc, Kelsey et al. [1984] found that an association with work-related lifting without twisting was observed only at the highest lifting level (OR 3.8, 95% CI 0.7–20.1). A combination of both risk factors at moderate levels yielded an OR of 3.1 (95% CI 1.3–7.5). The highest risk was seen for simultaneous lifting and twisting with straight knees (OR 6.1, 95% CI 1.3–27.9). Svensson and Andersson [1989] found a significant association between lifetime incidence of LBP and lifting in univariate analyses (RR 1.2, p<0.05), but not in multivariate analyses. Holmström et al. [1992] found an association between one-year prevalence of LBP and an index of manual materials handling (OR 1.27, 95% CI 1.2–1.4), after adjusting for age. No association was observed in multivariate analyses. Toroptsova et al. [1995] found that LBP and lifting were related in univariate analyses (OR 1.4, p<0.05); no multivariate analyses were conducted. In the Walsh et al. [1989] examination of LBP and work-related factors, LBP was associated with lifting (in jobs just prior to injury) (RR 2.0, 95% CI 1.1–3.7), when age, sex, and all exposures were considered in multivariate analyses. When lifetime exposures were considered, lifting remained significantly associated for males (RR 1.5, 95% CI 1.0–2.4). In Burdorf and Zondervan's 1990 study, an OR of 5.2 (95% CI 1.1–25.5) was observed for LBP and frequent lifting among crane operators. No relationship was seen for the referent group of noncrane operators from the same plant (OR 0.70, 95% CI 0.14–3.5).

In a study that determined exposure status on the basis of job title, Videman et al. [1984] found slightly higher rates (not significant) of LBP in nursing aides than in qualified nurses. The authors stated that aides had higher workloads related to patient handling and lifting. Knibbe and Friele [1996] found that LBP rates were higher for registered nurses than for nursing aides, whom they stated had more lifting responsibilities (OR 1.2, p=0.04). After adjusting for hours worked, however, aides had the higher rate (RR 1.3, no statistical testing done). Undeutsch et al. [1982] examined back pain in baggage handlers, a group characterized by frequent bending, lifting, and carrying of loads. Although no exposures were estimated for this group, symptoms were significantly associated with length of employment after adjusting for age (p=0.035).

In the studies using more quantitative exposure assessments, strengths of association for the relationships between low-back disorder and lifting included estimates including a negative relationship [Magora 1972], no association [Burdorf et al. 1991], and several positive associations with ORs in the 2.2–10.0 range. One study found a positive relationship between sudden maximal efforts and LBP (OR 1.7) [Magora 1973]. Punnett et al. [1991] found a point estimate of 2.16 after adjusting for other covariates; Chaffin and Park [1973] found a strong relationship (OR 5) for LSR (but not lifting frequency); Marras et al. [1993, 1995] found that the highest risk of injury was related to lifting in combination with posture-related risk factors (OR 10.7). Liles et al. [1984] observed an OR of 4.5 for back injuries and the highest JSI. The investigation of school lunch preparers did not calculate risk estimates [Huang et al. 1988].

Studies that used subjective measures of exposure found point estimates including none [Johansson and Rubenowitz 1994; Kelsey 1975a,b; Videman et al. 1984] to a range including 1.3, 1.4, 2.0, 3.8, and 5.2 [Burdorf and Zondervan 1990; Holmström et al. 1992; Kelsey et al. 1984; Knibbe and Freile 1996; Toroptsova et al. 1995; Undeutsch et al. 1982; Walsh et al. 1989]. Although the Kelsey et al. [1984] exposure estimates were based on self-report, they showed important relationships between lifting and posture in multivariate analyses. While the OR for lifting alone was 3.8 (for the highest lifting level), the OR rose to 6.1 when postures related to twisting and bent knees were included in the model.

In summary, the articles reviewed provide evidence of a strong positive association between low-back disorder and lifting. Results from these and other studies emphasized the importance of awkward postures in the risk of low-back disorder.

Temporal Relationship

Two prospective studies assessed exposures prior to identification of back disorders. Both demonstrated positive associations between exposure and back disorder. Thirteen of the 18 studies were cross-sectional analyses. In two of these, investigators excluded cases of LBP with onset prior to the current job to increase the likelihood that exposure preceded disorder. A third cross-sectional study truncated self-reported exposures on the birthday preceding disorder onset. One case-control study truncated exposures prior to disorder onset. Of the four cross-sectional and case-control studies which attempted to address temporality, three found positive relationships between lifting and back disorder.

Consistency in Association

Although the 18 studies used varying designs, outcomes, and exposure assessment methods, they were fairly consistent in demonstrating a relationship between lifting and low-back disorder when objective measures of exposure were used to evaluate populations with high exposures. Results were less consistent when subjective exposure measures were utilized.

A NIOSH review of earlier publications related to patient lifting demonstrated results consistent with this review [Jensen 1990]. A comprehensive literature search evaluated all studies published between 1967 and 1987 that contained original research on nursing personnel and back problems. Of 90 studies, six were identified which distinguished between two or more groups of nurses with differing frequencies of patient handling and reported on back problems for each group. A weighted analysis of results from the six reports demonstrated an overall increase in back problems of 3.7 in those in the higher lifting frequency category.

Coherence of Evidence

Lifting and manual materials handling have been studied as risk factors for low back disorder for decades. Studies of workers' compensation claims have shown that manual material handling tasks, including lifting, are associated with back pain in 25%-70% of injuries [Cust et al. 1972; Horal 1969; Snook and Ciriello 1991]. Data from the 1994 Bureau of Labor Statistics annual Survey of Occupational Injuries and Illnesses demonstrated that the industry with the highest rate of time-loss injuries due to overexertion was nursing and personal care facilities (where employees are required to engage in frequent patient handling and lifting).

During lifting, three types of stress are transmitted through the spinal tissues of the low back: compressive force, shear force, and torsional force [Waters et al. 1993]. It has been suggested that disc compression is believed to be responsible for vertebral end-plate fracture, disc herniation, and resulting nerve root irritation [Chaffin and Andersson 1984]. In early biomechanical assessments, models showed that large moments are created in the trunk area during manual lifting. Static evaluations of the trunk demonstrated that lifting results in large compressive forces on the spine.

More recently, biomechanical investigations have focused on spine loading and disc tolerances associated with asymmetric loading of the trunk. In laboratory experiments, dynamic trunk motion components of lifting have been associated with greater spine loading. Increased trunk motion during lifting activities has been associated with increased trunk muscle activity and intra-abdominal measures, among other changes [Marras et al. 1995]. Some laboratory studies have shown that lateral shear forces make trunk motions more vulnerable to injury than in a compressive loading situation. There is also *in vitro* evidence that the viscoelastic properties of the spine may cause increased strain during increased speed of motion [Marras et al. 1995].

Current models for lifting-related musculoskeletal injury stress that biomechanical considerations comprise only part of the assessment of risk [Waters et al. 1993]. Other criteria include physiologic measures of metabolic stress and muscle fatigue and psychophysical considerations (the worker's perception of his/her lifting capacity, a combination of perceived biomechanical and physiologic attributes of the job). All three criteria are important in assessing risk across the full spectrum of job and individual worker variability.

Exposure-Response Relationships

Eight studies examined exposure-response relationships in some form. Of these, four found dose-response relationships between low-back disorder and objective measures of lifting [Chaffin and Park 1973; Liles et al. 1984; Marras et al. 1995; Punnett et al. 1991]; another found a dose-response between disorder and sudden maximal efforts [Magora 1973]. A study of baggage handlers found an association between back disorder and length of employment [Undeutsch et al. 1982]. Two studies found no dose-response relationship (using a posture analysis assessment and a manual materials handling index) [Burdorf et al. 1991; Johansson and Rubenowitz 1994].

The majority of studies which examined exposure-response relationships, and in particular those that utilized quantitative exposure measures, demonstrated these trends.

Conclusions: Lifting and Forceful Movements

There is strong evidence that low-back disorders are associated with work-related lifting and forceful movements. The five studies reviewed for this chapter which showed no association between lifting and back disorder used subjective measures of exposure, poorly described exposure assessment methodology, or showed little differentiation of exposure within the study group. The remaining 13 studies were consistent in demonstrating positive relationships, where those using subjective measures of exposure showed a range of risk estimates from 1.2 to 5.2, and those using more objective assessments had ORs ranging from 2.2 to 11. Studies using objective measures to examine specific lifting activities generally demonstrated risk estimates above three and found dose-response relationships between exposures and outcomes. For the most part, higher ORs were observed in high-exposure populations (e.g., one high-risk group averaged 226 lifts per hour with a mean load weight of 88 N. Evidence from other studies and reviews has also suggested that groups with high- frequency exposure to lifting of heavy loads, such as nursing staff, are at high risk of back disorder.

Most of the investigations reviewed for this document adjusted for potential covariates in analyses: two-thirds of the studies showing positive associations examined effects of age and gender. Nevertheless, some of the relatively high ORs that were observed were unlikely to be caused by confounding or other effects of lifestyle covariates. Several studies suggested that both lifting and awkward postures were important contributors to the risk of low-back disorder. The observed relationships are consistent with biomechanical and other laboratory evidence regarding the effects of lifting and dynamic motion on back tissues.

BENDING AND TWISTING (AWKWARD POSTURES)

Definition

Bending is defined as flexion of the trunk, usually in the forward or lateral direction. Twisting refers to trunk rotation or torsion. Awkward postures include non-neutral trunk postures (related to bending and twisting) in extreme positions or at extreme angles. Several studies focus on substantial changes from non-neutral postures. Risk is likely related to speed or changes and degree or deviation from non-neutral position. For the purposes of this review, awkward postures also included kneeling, squatting, and stooping. In most of the studies included in this review, awkward postures were measured concurrently with other work-related risk factors for back disorder.

Studies Reporting on the Association Between LBP and Awkward Postures

Twelve studies examined the relationship between low back disorder and bending, twisting, and awkward postures (Table 6-3, Figure 6-3). Most (nine) also examined the effects of occupational lifting. See the previous discussion of lifting and forceful movements. Nine studies were cross-sectional in design, two case-control, and one prospective.

Participation rates were adequate for 83% of the investigations (Table 6-3). Four studies assessed postures using objective measures (however, in the study by Magora [1972], details on their observation methods were not reported; the rest estimated exposures from interview or questionnaire responses). Health outcomes included low-back and sciatic pain symptoms, lumbar-disc prolapse, and back injury reports. In four investigations, outcomes were defined using both symptoms and medical examination criteria. Only one investigation, the Punnett et al. [1991] case-control study of back pain in auto workers, fulfilled the four evaluation criteria (Table 6-3, Figure 6-3).

Several other studies, while not meeting all of the four criteria, are particularly notable because they used objective measures of exposure assessment [Burdorf et al. 1991; Marras et al. 1993, 1995] or met more than one of the criteria [Holmström et al. 1992; Kelsey et al. 1984]. As discussed earlier, the physical examination criterion may be less important in low-back disorders because of the paucity of specific physical findings in most cases of low-back disorders.

Descriptions of five studies which offered the most information regarding the effects of bending, twisting, and awkward postures follow. Please note that there is some overlap with studies that examined lifting effects. Detailed descriptions of the 12 studies appear in Table 6-6.

The Punnett et al. [1991] case-control study examined the relationship between back pain and occupational exposures in auto assembly workers. Back pain cases (n=95) were determined by symptoms at interview and medical examination; controls included those free of back pain. For all participants or proxies in the same jobs, jobs were videotaped and work cycles were reviewed using a posture analysis system. Exposures included time spent in various awkward postures. Peak biomechanical forces were estimated for up to nine postures where a load weighing at least 10 lb was held in the hands. In multivariate analyses that adjusted

for a number of covariates (age, gender, length of employment, recreational activity and medical history), time in non-neutral postures mild or severe flexion and bending were strongly associated with back disorder (OR 8.0, 95% CI 1.4–44). In the same model, lifting was also associated (OR 2.16, 95% CI 1.0–4.7). When the subset with physical medical findings was examined, associations were more pronounced. Although few study subjects were unexposed to all of the postures studied, a strong increase in risk was observed with both intensity and duration of exposure. It was not possible to determine the relative contributions of different awkward postures because all were highly correlated. Only participants' current jobs (for referents) or jobs when symptoms started (for cases) were analyzed; the study design thus assumed a short-term relationship between exposure and outcome. Although length of time in job was also included in the models, the authors attempted to ensure that exposure preceded disease by identifying time of onset and measuring exposures in the job held just prior. The strong associations, after adjustment for covariates, are notable.

Burdorf et al. [1991] examined back pain symptoms in a cross-sectional study of male concrete fabrication workers and a referent group of maintenance workers. Back pain symptoms were assessed by questionnaire. Exposures were measured using the Ovako Working Posture Analysis System, which assessed postures for the back and lower limbs, along with lifting load. Information on exposures in previous jobs was also collected.

Concrete workers experienced significantly more back symptoms than referents (OR 2.8, 95% CI 1.3–6.0).

Univariate results showed associations between back pain and both posture index and WBV in current job. Correlations were presented showing lifting was not found to be associated with back pain or to vary significantly across the six job categories examined in the study. In multivariate analyses adjusting for age, both posture index and WBV were significantly associated with back pain, with ORs of 1.23 (p=0.04) (for an ordinal scale of 6) and 3.1 (p=0.001) (dichotomous), respectively. Those in the highest posture index category were steel benders, who spent an average of 47% of their time in bent back postures (compared to 12% for the lowest exposed group). The posture index and WBV measures were highly correlated and analyzed separately. Strengths of the study included use of a standardized symptom questionnaire, high participation rates and objective measure of exposure, and an attempt to clarify the temporal relation between exposure and outcome by excluding cases of back pain with onset before the present job.

Using an unusual cross-sectional study design, Marras et al. [1993, 1995] examined the relationship between low-back disorders and spinal loading during occupational lifting. A total of 403 jobs from 48 diverse manufacturing companies were assessed for risk of low-back disorder using plant medical department injury reports. Jobs were ranked into three categories according to risk then assessed for position, velocity, and acceleration of the lumbar spine during lifting motions in manual materials handling using electrogoniometric techniques. A combination of five factors distinguished between high- and low-risk jobs: lifting frequency, load moment, trunk lateral velocity, trunk twisting velocity, and trunk sagittal angle. The highest combination of exposure measures produced an OR of 10.7 (95% CI 4.9–23.6) (in comparison to the lowest combined measures). The study design was unusual in that the unit of analysis appeared to be job rather than individual. Neither participation rate nor total number of participants was stated. No information appeared regarding the proportions of individuals within jobs who were recruited for measurement of lifting motions. However, the unit of analysis was job, and each was characterized by measurement of at least one study subject. Effects of other covariates were not addressed (multivariate models appeared to include only biomechanical variables). The study results emphasize the multifactorial etiology of back disorders, including contributions of lifting frequency, loads, and trunk motions and postures. The study design did not allow for examination of temporal relationships.

A case-control study of prolapsed lumbar disc was carried out using a hospital population-based design [Kelsey et al. 1984]. Cases (n=232) included individuals diagnosed with prolapsed lumbar disc; an equal number of controls matched on sex, age, and medical service were selected. Exposure was assessed using a detailed occupational history (not described, but presumably obtained by interview). An association with work-related lifting, without twisting the body, was observed at the highest lifting level (OR 3.8, 95% CI 0.7–20.1). Twisting without lifting was associated with disc prolapse (OR 3.0, 95% CI 0.9–10.2); a combination of both risk factors had an OR of 3.1 (95% CI 1.3–7.5).

The highest risk was observed for simultaneous lifting and twisting with straight knees (OR 6.1, 95% CI 1.3–27.9). Despite the fact that exposures were self-reported, these associations were notably strong. The potential existed for differential recall bias for cases and controls, because study subjects were interviewed about work-related factors after case status was established. Interviewers may not have been blinded to case/control status.

Holmström et al. [1992] examined the relationship between LBP and work task activities in a cross-sectional study of male construction workers. One-year prevalence of LBP was ascertained by questionnaire. A sample of workers was clinically examined. Exposure relative to lifting, handling, and work postures was obtained by self-report. After adjustment for age, the index for manual material handling, which included lifting, was associated with LBP with a RR of 1.27 (95% CI 1.2–1.4). Stooping and kneeling postures showed a dose-response relationship with LBP, particularly severe LBP (with ORs 1.3, 1.8, and 2.6 in comparison to those with no stooping; ORs 2.4, 2.6, and 3.5 in comparisons to those with no kneeling, respectively). No association was observed with sitting. In multiple regression analyses, LBP was associated with stooping (p<0.001) and kneeling (p<0.01). While the authors attempted to adjust for some covariates (age, gender, and psychosocial factors) in analyses, they did not appear to examine simultaneous effects of physical work-related factors in a single model. The cross-sectional design could not ascertain the temporal relationships between exposure and disorder.

Strength of Association

The more informative studies included the Punnett et al's [1991] case-control investigation, which fulfilled the four evaluation criteria, plus several others that used independent exposure assessments. In the Punnett et al. study, multivariate analyses that adjusted for covariates demonstrated that time in non-neutral postures was strongly associated with back disorders (OR 8.09, 95% CI 1.4–44). In the same model, the OR for lifting was 2.2. Burdorf et al. [1991] found associations between posture index and back symptoms in both univariate and multivariate analyses: in multivariate analyses adjusting for age, the OR for posture index was 1.23 (p=0.04), for an ordinal scale of six levels. Posture index was highly correlated with WBV. However, the Kelsey et al's [1984] case-control study of prolapsed lumbar discs found that twisting without lifting had an OR of 3.0 (95% CI 0.9–10.2); in combination, the two had an OR of 3.1 (95% CI 1.3–7.5). The highest risk was observed for a combination of lifting, twisting, and straight knees (OR 6.1, 95% CI 1.3–27.9). In the Marras et al. [1993, 1995] cross-sectional study, back injuries were associated with spinal loading during lifting, which included simultaneous exposures to lifting frequency, load weight, trunk lateral velocity, trunk twisting velocity, and trunk sagittal angle. An OR of 10.7 (95% CI 4.9–23.6) was observed for the highest combination of exposure measures. Univariate ORs were 1.73 (95% CI 1.38–2.15) for trunk lateral velocity, 1.66 (95% CI 1.34–2.05) for trunk twisting velocity, and 1.60 (95% CI 1.31–193) for maximum sagittal flexion when comparing the high-and low-risk groups [Marras et al. 1993].

The other studies showed a range of point estimates. In univariate analyses, Magora [1972, 1973] found that for bending, the highest rate of LBP was observed for the rarely/never category. For twisting and reaching, the highest LBP rate was in the sometimes category. Johansson and Rubenowitz [1994] found no associations between low-back symptoms and bent or twisted work postures in blue- and white-collar workers. After adjustment for age and gender, however, extreme work postures were significantly associated with the outcome in blue-collar workers. Relationships were presented as partial correlations, thus preventing calculation of risk estimates. Riihimäki et al. [1994] observed that occupational exposure to twisted and bent postures were associated with incidence of sciatic pain in univariate but not multivariate analyses. No risk estimates were provided. In Svensson and Andersson's 1989 study of LBP in Swedish women, bending forward was associated with lifetime incidence in univariate (RR 1.3, $p<0.05$) but not multivariate analyses. The Masset and Malchaire [1994] univariate analyses demonstrated that trunk torsions were associated with LBP in steel workers (OR 1.55, $p<0.05$); no associations were shown in multivariate analyses. Toroptsova et al. [1995] demonstrated that LBP in the past year was associated with bending (OR 1.7, $p<0.01$) in univariate analyses (multivariate analyses were not conducted). Riihimäki et al. [1989a] observed a dose-response for sciatic pain and self-reported twisted or bent postures; the OR for the highest exposure category was 1.5 [95% CI 1.2–1.9]. Holmström et al. [1992] observed that stooping and kneeling postures were associated with LBP, particularly severe disorder, with ORs of 2.6 and 3.5 ($p<0.05$), respectively.

In summary, three of the four studies using more quantitative exposure assessments showed elevated risk estimates for the relationship between low-back disorder and bending, twisting, or awkward postures, with ORs ranging from 1.23 (for a scaled variable) to 8.09; the highest risk estimate, an OR of 10.7, was based on combined exposure to lifting and posture risk factors. Most of these were based on multivariate analyses that adjusted for covariates (usually age and gender). The remaining studies demonstrate risk estimates ranging from no association (in one study), 1.3–1.7 in univariate but not multivariate analyses, to a high of 3.5 in another study. Studies utilized a number of definitions for awkward postures, as noted**.**

Temporal Relationship

One prospective study assessed exposures prior to identification of back disorders. Results demonstrated positive associations in univariate but not multivariate analyses. [Riihimäki et al. 1994]. Nine of 12 studies were cross-sectional in design. In one of these, investigators excluded cases of LBP with onset prior to the current job to increase the likelihood that exposure preceded disorder. [Burdorf et al. 1991]. No association between exposure and back disorder was observed. One case-control study examined only exposures experienced in the job just prior to disorder onset [Punnett et al. 1991]. A strong association between exposure to awkward postures and back pain was observed.

Consistency in Association

Although the 12 studies used varying designs, outcomes, and exposure assessment methods, the studies using quantitative exposure measures were fairly consistent in demonstrating a moderate relationship between awkward postures and low-back disorder.

Coherence of Evidence

Nine of the 12 studies which examined posture effects also studied effects of lifting. Therefore, a discussion of coherence of evidence for the former relationship is similar to that found in the section on lifting and forceful movements. Forward flexion can generate compressive forces on the structures of the low back similar to lifting a heavy object. Similarly, rapid twisting can generate shear or rotational forces on the low back [Marras et al. 1995].

Exposure-Response Relationships

Six studies examined dose-response relationships between posture and low-back disorder. In one, no dose-response relationship was found between LBP and estimates for bending and twisting/reaching. In the other five studies, relationships were demonstrated between back injury and spinal loading score, LBP and posture index, sciatic pain and awkward postures, LBP and stooping, and low-back symptoms and kneeling.

Conclusions: Awkward Postures

The investigations that were reviewed provided evidence that low-back disorders are associated with work-related awkward postures. Results were consistent in showing increased risk of back disorder with exposure, despite the fact that studies defined disorders and assessed exposures in many ways. Several studies found risk estimates above three and dose-response relationships between exposures and outcomes. Many of the studies adjusted for potential covariates in their analyses, and a few examined the simultaneous effects of other work-related risk factors in analyses. Several studies suggested that both lifting and awkward postures were important contributors to risk of low back disorder.

WHOLE BODY VIBRATION (WBV)

Definition

WBV refers to mechanical energy oscillations which are transferred to the body as a whole (in contrast to specific body regions), usually through a supporting system such as a seat or platform. Typical exposures include driving automobiles and trucks, and operating industrial vehicles.

Studies Reporting on the Association Between LBP and Whole Body Vibration

Nineteen investigations addressed WBV as a risk factor for back disorder. Fifteen study designs were cross-sectional, two were cohort, one was case-control, and one had both cross-sectional and cohort components.

None of the 19 studies fulfilled all of the four evaluation criteria (Table 6-4, Figure 6-4). Participation rates were over 70% for 13 investigations. Seven used independent measures of exposure for estimation of WBV; in 10 studies, exposure information was obtained by questionnaire or interview. In two studies, exposure to WBV was based on job title alone. Health outcomes included symptom report of LBP, sciatica, or lumbago, sick leaves or disability retirements related to back disorders, and medically confirmed herniated lumbar disc.

Five of the nine studies which met two or more of the evaluation criteria used similar methodologies and offered the most information regarding the association between WBV and back disorder. Detailed descriptions for all 19 investigations can be found in Table 6-6.

Bovenzi and Betta [1994] examined the relationship between WBV and back disorder in a cross-sectional study of male tractor drivers. The unexposed group included male revenue inspectors and administration workers with no vibration exposure. Outcomes included various types of back symptoms reported by questionnaire. Vibration measures were obtained from a representative sample of tractors and linked to individual information on number of hours driven yearly (obtained by questionnaire). Self-reported exposures to postural loads were also obtained. In comparison to referents, tractor drivers demonstrated an OR of 3.22 (95% CI 2.1–5.2) for lifetime LBP. For LBP in the past year, the OR was 2.39 (95% CI 1.6–3.7). For LBP in the past year, ORs ranged from 2.31 to 3.04 by exposure levels for total vibration dose, equivalent vibration magnitude, and duration of exposure, after adjustment for covariates. In multivariate analyses, chronic LBP showed a dose-response relationship with total vibration dose (OR 2.00, 95% CI 1.2–3.4, for the highest category), equivalent vibration magnitude (OR 1.78, 95% CI 1.04–3.0, for the highest category), and duration of exposure (OR 2.13, 95% CI 1.2–3.8, for the highest category). Exposure-response relationships were observed for postural load categories, with ORs of 4.56 (95% CI 2.6–8.0) for LBP in the past year and 2.30 (95% CI 1.2–4.5) for chronic LBP (for the highest exposure categories). Multivariate analyses adjusted for age, body mass index, education, sports activity, car driving, marital status, mental stress, climatic conditions, back trauma and postural load (or vibration dose, depending upon the exposure examined).

Bovenzi and Zadini [1992] used a similar cross-sectional study design to examine low back symptoms in male bus drivers. Referents included maintenance employees who worked for the same company. Back pain symptoms were assessed by questionnaire. WBV was measured for a sample of buses used over the relevant time period. Cumulative vibration exposures were calculated using this information, along with questionnaire items related to work duration, hours, and previous exposures. In comparison to referents, bus drivers demonstrated an OR of 2.80 (95% CI 1.6–5.0) for lifetime LBP; the OR for LBP in the past year was 2.57 (95% CI 1.5–4.4). In multivariate analyses, the ORs for LBP in the previous year were 1.67, 3.46, and 2.63 for three total vibration dose categories. Similar trends were observed for other measures of vibration (equivalent vibration magnitude and total duration of exposure), and after exclusion of those with exposure in previous jobs. Statistically significantly increasing trends were observed for nearly all types of back symptoms by exposure level (to all three measures of vibration) after adjustment for covariates. Multivariate analyses adjusted for age, awkward postures, duration of exposure, body mass index, mental workload, education, smoking, sports activities, and previous exposures.

Three studies of WBV effects were conducted by the same group of Dutch investigators. The first examined back pain and WBV exposures cross sectionally in male helicopter pilots [Bongers et al. 1990]. A referent group of nonflying Air Force officers (with characteristics similar to pilots) was also included. Information on back symptoms was obtained by questionnaire. Vibration measures were assessed in two helicopters of each type used by the study group. Individual exposures were calculated by matching this with questionnaire items related to hours of flying time and types of helicopters flown. Information on exposure to bent/twisted postures was also obtained by questionnaire. In comparison to controls, ORs for pilots were elevated for a number of back symptoms: 9.0 (95% CI 4.9–16.4) for LBP and 3.3 (95% CI 1.3–8.5) for sciatica. All of the above were adjusted for age, height, weight, climate, bent and twisted postures, and feeling tense at work. In multivariate analyses, ORs for LBP were 13.8, 7.5, 6.0, and 13.4 for four categories for total flight time (in comparison to controls). ORs for LBP by total vibration dose were 12.0, 5.6, 6.6, and 39.5. By hours of flight time per day, ORs were 5.6, 10.3, and 14.4 for LBP. Although there was some concern that pilots with back pain may have dropped out of employment, risk estimates were high (particularly in analyses by exposure level). Transient back pain appeared to increase with daily exposure time, while chronic back pain appeared more associated with total flight time and total vibration dose.

In a second study by the same group, WBV exposures were examined in male tractor drivers and a referent group of inspectors and maintenance technicians [Boshuizen et al. 1990a,b]. Two investigations were conducted using the same population: a 1986 cross-sectional study of a cohort identified in 1975, and a cohort analysis of sick leaves and disability retirements due to back disorder through the same time period. For the cross-sectional analyses, information on back symptoms was obtained by questionnaire. Vibration was measured for a sample of vehicles and linked with questionnaire information related to types of vehicles driven, hours, and previous employment. Information regarding exposure to awkward postures was also collected. Results from the cohort analysis showed an incidence density ratio of 1.47 (95% CI 1.04–2.1) for a comparison of sick leaves due to back disorders in exposed and referent groups. An increase in sick leaves for disc disorders by vibration dose was observed, with an OR of 7.2 (95% CI 0.92–179) for the highest category. Cross-sectional study results demonstrated increases in LBP symptom prevalence by vibration dose category. Multivariate ORs increased by vibration dose (an OR of 2.8, 95% CI 1.6–5.0, for the highest category) and years of exposure (an OR of 3.6, 95% CI 1.2–11, for the highest category) after adjustment for duration of exposure, age, height, smoking, awkward postures, and mental workload.

Boshuizen et al. [1992] also conducted a cross-sectional study of back pain in fork-lift truck and freight container tractor drivers exposed to WBV. Referents included other employees working for the same shipping company, but with no vibration exposure. Back pain symptoms were assessed by questionnaire. Exposures were estimated by measurement of vibration in a sample of vehicles, combined with questionnaire responses. Cumulative exposures were calculated, truncating at time of symptom onset. Prevalence of back pain was higher in the exposed group than in referents: the RR for back pain was 1.4 ($p<0.05$); RRs for LBP and lumbago were 1.4 ($p<0.05$) and 2.4 ($p<0.05$), respectively, after adjusting for age. Differences in LBP were observed only in younger age groups after multivariate adjustment for mental stress, years of lifting, awkward postures, height, smoking, and hours of sitting. There was no association between total vibration dose and back pain (OR 0.99, 95% CI 0.85–1.2) or lumbago (OR 1.14, 95% CI 0.91–1.4). Only vibration in the 5 years immediately preceding symptom onset was significantly associated with back pain (OR 2.4, 95% CI 1.3–4.2) and lumbago (OR 3.1, 95% CI 1.2–7.9). It appeared that a healthy worker selection effect was operating, as differences in back pain were observed only for those in younger age groups.

Evaluation of the Causal Relationship Between Back Disorder and Whole Body Vibration

Strength of Association

Recent studies that included quantitative exposure assessments provided the most information regarding the relationship between WBV and back disorder [Bongers et al. 1988; Boshuizen et al.1990a, b; Bovenzi and Betta 1994; Bovenzi and Zadini 1992]. (Two other recent studies also described quantitative exposure assessments, but no results relating to these were presented [Burdorf et al. 1993; Magnusson et al. 1996]). In all five, ORs were calculated by levels of vibration exposure, expressed in several ways (usually including magnitude and duration of exposure). In the five studies, overall ORs comparing back pain in exposed and referent groups ranged from 1.4 [Boshuizen et al. 1992] to 9.5 [Bongers et al. 1990]. Analyses conducted by exposure level demonstrated stronger relationships. In Bovenzi and Betta’s 1994 study of tractor drivers, ORs for lifetime LBP were 3.79 for total vibration dose, 3.42 for equivalent vibration magnitude, and 4.51 for duration of exposure (for the highest exposure levels). For LBP in the previous year, ORs were 2.36, 2.29, and 2.74 for the highest levels of the same three exposure measures. In Bovenzi and Zadini’s 1992 study of urban bus drivers, the highest ORs for LBP were observed for intermediate rather than the highest exposure categories: 3.46 for total vibration dose, 3.77 for equivalent vibration magnitude, and 3.08 for total duration of WBV exposure. The Bongers et al. [1990] investigation of back pain in helicopter pilots demonstrated that the highest ORs for LBP were found in the highest categories for total flight time (OR 13.4, 95% CI 5.7–32), total vibration dose (OR 39.5, 95% CI 10.8–156) and hours of flight time per day (OR 14.4, 95% CI 5.4–38.4). A study of tractor drivers demonstrated LBP ORs of 2.8 (95% CI 1.6–5.0) for the highest total vibration dose and 3.6 (95% CI 1.2–11) for the highest exposure duration category [Boshuizen et al. 1990a]. In the same population, the OR for all sick leaves due to back disorder was 1.47, comparing exposed (95% CI 1.04–2.1) and referent groups [Boshuizen et al. 1990b]. For sick leaves related to intervertebral disc disorders, the highest OR was observed for the highest exposure category (OR 7.2, 95% CI 0.92–179). The Boshuizen et al. [1992] study of forklift truck and freight container tractor drivers showed no association between back pain and total vibration dose (OR 0.99, 95% CI 0.85–1.2) but did show an association for vibration in the preceding five years (OR 2.4, 95% CI 1.3–4.2). In this study the increase in LBP prevalence in the exposed group was only significant for those in younger age groups (an OR of 5.6 for those age 25-34) in multivariate analyses. In all five of these cross-sectional studies, ORs were calculated by vibration exposure category after adjusting for a number of covariates, as mentioned in the detailed study descriptions, above.

Other studies assessed both exposure and low-back disorder by interview or questionnaire. Burdorf and Zondervan [1990] observed no association between WBV exposure and LBP in crane operators in univariate analyses (OR 0.66, 95% CI 0.14–3.1); no associations were observed in multivariate analyses. Toroptsova et al. [1995] also found no association between LBP and vibration in their study (no definition for vibration was provided, but WBV was suggested). In the Riihimäki et al. 1994 prospective study, sciatic pain was associated with vibration in univariate but not multivariate models (no risk estimates were provided). While the definition for “vibration” was not clear, the authors suggested it could be interpreted as low-level WBV. The Masset and Malchaire [1994] cross-sectional study found that LBP was associated with vehicle driving (OR 1.2, p<0.001) in univariate analyses. Similar results were observed in multivariate analyses (OR 1.2, p<.005). Riihimäki et al. [1989a] observed an OR of 1.3 (95% CI 1.1–1.7) for longshoremen and earthmovers in comparison to a referent group with no vibration exposure. In the same study, no association was seen for annual car driving (OR 1.1, 95% CI 0.9–1.4). Walsh et al. [1989] found that driving (on job held prior to symptoms) was significantly associated with low-back symptoms in males (RR 1.7, 95% CI 1.0–2.9) after adjusting for age and other job exposures in multivariate analyses. Burdorf et al. [1991] found that WBV was significantly associated with back pain (OR 3.1, p=0.001) in multivariate analyses that adjusted for age. The Kelsey [1975a] case-control study found a significant association between herniated lumbar disc and time driving (OR 2.75, p=0.02), and more specifically, working as a truck driver (OR 4.7, p<0.02). Burdorf et al. [1993] investigation demonstrated an OR of 3.29 (95% CI 1.5–7.1) for crane operators and 2.51 (95% CI 1.5–5.4) for vibration-exposed straddle-carrier drivers after adjusting for a number of covariates. In a study of Danish salespeople, annual driving distance was associated with low-back symptoms [Skov et al. 1996]. A dose-response relationship was observed in multivariate analyses, with an OR of 2.79 (95% CI 1.5–5.1) for the highest category.

Four studies assessed exposures primarily by job title. Magnusson et al. [1996] observed an OR of 1.79 (95% CI 1.2–2.8) for bus and truck drivers in comparison to an unexposed referent group. In a study of crane operators, the exposed group demonstrated ORs of 2.00 (95% CI 1.1–3.7) for all intervertebral disc disorders and 2.95 (95% CI 1.2–7.3) for disc degeneration after adjustment for age and shift [Bongers et al. 1988]. An examination of risk estimates of disc degeneration by years of exposure showed the highest OR (5.73) in the highest exposure category. In the Johanning [1991] study of subway train operators, an OR of 3.9 (95% CI 1.7–8.6) was observed for sciatica. While not a primary focus of the Magora [1972, 1973] studies of LBP in eight selected occupations, it was observed that bus drivers had back pain rates similar to those of the comparison group of bankers (RR 1.19, 95% CI 0.8–1.7).

Thus, four out of five studies using quantitative exposure assessments demonstrated positive associations between back disorder outcomes and vibration exposures, with ORs ranging from 1.4 to 39.5. The fifth cross-sectional study found no overall association between exposure and back disorder but found associations in selected subgroups (which suggested that the study population was biased, as noted above). In all of these studies, risk estimates by exposure category were calculated after adjustment for many covariates.

In the remaining studies, risk estimates varied, including no association (n=3), ORs of 1.2, 1.7, and 2.8 for driving, an OR of 1.8 for truck or bus driving, an OR of 4.7 for truck driving, an OR of 1.3 for machine operation, ORs of 2.0, 2.95 and 5.73 for crane operation, an OR of 3.1 for WBV, and an OR of 3.9 for subway train operation.

In summary, the evidence from these investigations suggests a positive association between WBV and back disorder. Relationships were particularly strong for high-exposure groups where exposures were assessed using observational or measurement approaches.

Temporal Relationship

Three studies had prospective designs in which temporal relationships between outcome and exposure could be determined [Bongers et al. 1988; Boshuizen et al. 1990b; Riihimäki et al. 1994]. In two of these, clear positive relationships between back disorder and exposure were demonstrated [Bongers et al. 1988; Boshuizen et al. 1990b]. Twelve studies had a cross-sectional design that could not directly address temporality. However, three attempted to clarify relationships by excluding from analysis the cases with disorder onset prior to current job [Burdorf et al. 1991, 1993; Burdorf and Zondervan 1990]. A fourth cross-sectional study truncated self-reported exposures on the birthday preceding disorder onset [Walsh et al. 1989]. In these four investigations, positive relationships between back disorder and WBV were also observed.

Consistency in Association

Results with regard to the relationship between low back disorder and WBV were most consistent in the studies using observational or measurement approaches to exposure assessment. The strength of association was more variable in studies using job titles or questionnaires to assess exposures. The variability in the associations does not appear to be related to confounding exposures, since most studies adjusted for age, gender and at least several other confounders. Studies using more quantitative exposure measures were fairly consistent in showing the higher risk estimates.

In addition to the epidemiologic investigations that were reviewed for this document, many more were conducted in the 1960s though the 1980s. Others have summarized this evidence in earlier reviews. Hulshof and Veldhuijzen van Zanten [1987] concluded that, although studies varied in methodologies and quality, most showed a strong tendency toward a positive association between WBV exposure and LBP. Seidel and Heide [1986] stated that the literature they reviewed indicated an increased risk of spine disorders after intense long-term exposure to WBV. Bongers and Boshuizen [1990] conducted a meta-analysis of studies published through 1990 that examined the relationship between WBV and several back disorders. The overall OR for WBV exposure and degenerative changes of the spine was 1.5; the summary OR for LBP was also 1.5. These conclusions are consistent with the positive associations observed in the evidence reviewed above (although the studies published in the 1990s have tended to report larger ORs).

Other evidence for the relationship is provided by surveillance data. The U.S. population-based National Health Interview Survey, carried out in 1988, found that males employed as truck drivers and tractor equipment operators had a RR of 2.0 for back pain in comparison to all male workers [Guo et al. 1995].

Coherence of Evidence

Laboratory studies have shown that exposure to WBV causes spine changes that may be related to back pain. These include fatigue of the paraspinal muscles and ligaments, lumbar disc flattening, disc fiber strain, intradiscal pressure increases, disc herniation, and microfractures in vertebral end-plates [Wilder and Pope 1996]. Studies of acute effects have shown that the vertebral end-plate is the structure that is most sensitive to high WBV exposure, followed by the intervertebral disc [Wikström et al. 1994]. Experimental investigations have demonstrated that high exposures to vibration cause injuries such as degeneration and fracturing of the vertebral end-plate. With regard to intervertebral discs, several studies have suggested that vibration causes creep, an increase in intradiscal pressure resulting from compressive loading. Pressure peaks may cause ruptures in the superficial structure of the disc and changes in the nutritional balance that lead to degeneration. Thus, prolonged vibration exposure may cause spine pathology through mechanical damage and/or changes in tissue metabolism.

In addition to pathology of the vertebrae and intervertebral discs, vibration exposure has been shown to cause changes in electromyographic (EMG) activity in muscles of the lower back [Wikström et al. 1994]. For example, EMG experiments have demonstrated that lower back muscle exhaustion increases during WBV exposure in truck driving. Decreased stability of the lower back may result from slower muscle response, perhaps increasing the risk of injuring other structures.

Laboratory investigations have shown that other work-related factors, including prolonged sitting, lifting, and awkward postures, may act in combination with WBV to cause back disorder [Dupuis 1994; Wikström et al. 1994; Wilder and Pope 1996].

Exposure-Response Relationships

Five of six studies which carried out quantitative exposure assessment demonstrated exposure-response relationships between WBV and back disorder.

Bovenzi and Betta [1994] observed a dose-response between chronic LBP and total vibration dose, equivalent vibration magnitude, and duration of exposure. Bovenzi and Zadini [1992] found statistically significantly increasing trends for nearly all types of back symptoms by exposure level, after adjustment for covariates. Bongers et al. [1990] demonstrated increased ORs for sciatic pain and transient back pain with increasing hours of daily flight time. In their cohort of tractor drivers, Boshuizen et al. [1990b] observed an increase in risk of sick leaves for disc disorder by total vibration dose level.

In other studies, Bongers et al. [1988] found an increase in risk of disc degeneration by years of exposure to crane operation; Skov et al. [1996] found an increase in low-back symptoms with annual driving distance. Johanning [1991] found no association between years of employment as a subway train operator and back pain symptoms.

The majority of studies which examined back disorders by exposure level demonstrated dose-response relationships.

Conclusions: Whole Body Vibration

There is strong evidence of a positive association between exposure to WBV and back disorder. Of the 19 studies reviewed for this chapter, four demonstrated no association between WBV and back pain. Possible explanations for these results included use of subjective exposure assessments that perhaps resulted in misclassification of exposure status and, in one cross-sectional study, operation of a healthy worker selection effect (where those with higher exposures dropped out of the study group). The remaining 15 studies were consistent in demonstrating positive associations, with risk estimates ranging from 1.2 to 5.7 for those using subjective exposure measures, and from 1.4 to 39.5 for those using objective assessment methods. Most of the studies that examined relationships in high-exposure groups using detailed quantitative exposure measures found strong positive associations and exposure-response relationships between WBV and back pain. These relationships were observed after adjusting for age and gender, along with several other covariates (which, depending on the study, may have included smoking status, anthropometric measures, recreational activity, and physical and psychosocial work-related factors). This evidence is supported by results observed in many earlier epidemiologic investigations that have been summarized in other reviews.

Laboratory studies have demonstrated WBV effects on the vertebrae, intervertebral discs, and supporting musculature. Both experimental and epidemiologic evidence suggests that WBV may act in combination with other work-related factors such as prolonged sitting, lifting, and awkward postures to cause increased risk of back disorder.

It is possible that effects of WBV may depend on the source of exposure. For example, in the studies reviewed for this document, ORs were particularly high for helicopter pilots. It was not possible to determine differences for other types of vehicles (automobiles, trucks, and agricultural, construction, and industrial vehicles).

STATIC WORK POSTURES

Definition

Static work postures include isometric positions where very little movement occurs, along with cramped or inactive postures that cause static loading on the muscles. In the studies reviewed, these included prolonged standing or sitting and sedentary work. In many cases, the exposure was defined subjectively and/or in combination with other work-related risk factors.

Studies Reporting on the Association Between LBP and Static Work Postures

Ten studies examined relationships between low back disorder and static work postures, which may have included prolonged sitting, standing, or sedentary work. For none was static work posture the primary occupational exposure of interest. Instead, it was often one of many variables examined in larger studies of several or many work-related risk factors. Nine of the studies were cross-sectional in design; one was a case-control study.

None of the investigations fulfilled the four research evaluation criteria (Table 6-5, Figure 6-5). Participation rates were acceptable for 60%. For four, case definitions included both symptoms and medical examination criteria. Health outcomes included symptom report of back pain, sciatica, or lumbago, back pain as ascertained by symptoms and medical exam, herniated lumbar disc, and lumbar disc pathology. One study claimed to assess job-related exposures by observation; the nine others obtained information on static work postures by self-report on interview or questionnaire.

Below are descriptions of four of the more informative studies. Detailed descriptions for all 10 investigations are found in Table 6-6).

Burdorf and Zondervan [1990] carried out a cross-sectional study comparing 33 male crane operators with noncrane operators from the same Dutch steel plant, matched on age. Symptoms of LBP and sciatica were assessed by questionnaire. Activities in current and past jobs were assessed by questionnaire; exposures were rated according to level of heavy work, frequency of lifting, WBV, and prolonged sedentary posture. Crane operators were significantly more likely to experience LBP (OR 3.6, 95% CI 1.2–10.6). Among crane operators alone, the OR for heavy work was 4.0 (95% CI 0.76–21.2) after controlling for age, height, and weight. It was determined that this heavy work occurred in the past and not in current jobs. Among crane operators alone, the OR for frequent lifting was 5.2 (95% CI 1.1–25.5). The frequent lifting in crane operators was also determined to be from jobs held in the past. Among noncrane operators, history of frequent lifting exposure was not associated with LBP (OR 0.70, 95% CI 0.14–3.5). Among crane operators, univariate ORs for WBV and prolonged sedentary postures were 0.66 (95% CI 0.14–3.1) and 0.49 (95% CI 0.11–2.2), respectively. In multivariate analyses controlled for age, height, weight, and current crane work, associations with specific work-related factors were substantially reduced; the high prevalence of LBP in crane operators was explained only by current crane work. No measures of dose-response were examined. Limitations included a low response rate for crane operators (67%), with some suggestion that those with illness may have been underrepresented (perhaps underestimating the OR), and self-report of health outcomes and exposures. The investigators excluded cases of LBP with onset before the present job to increase the likelihood that exposure preceded disease.

Kelsey [1975b] carried out a hospital population-based case-control study of herniated lumbar discs and their relationship to a number of workplace factors, including time spent sitting, chair type, lifting, pulling, pushing, and driving. Cases were defined by symptoms, medical evaluation, and radiology; exposures were ascertained by interview (over lifetime job history). Cases (n=223) and controls (n=494 unmatched controls) had similar histories of job-related lifting (RR 0.94, p=0.10). Findings indicated that sedentary work (sitting more than half the time at work) was associated with disc herniation, but only for the age group 35 years and older (RR 2.4, p=0.01). (The RR for those less than 35 was 0.81). Disc herniation was also associated with time spent driving (RR 2.75, p=0.02) and, more specifically, with working as a truck driver (RR 4.7, p<0.02), suggesting a relationship with WBV. The study design had several potential limitations, including possible unrepresentativeness of the study population (because the group was hospital-based). As exposure information was obtained retrospectively, cases may have over-reported exposures thought to be associated with back problems. Strengths include a well-defined outcome and consistent results in comparisons to the two control groups.

Svensson and Andersson [1989] examined LBP in a population-based cross-sectional study of employed Swedish women. Information on LBP and sciatica was obtained by questionnaire, as were exposure-related items. Physical exposures included lifting, bending, twisting, other work postures, sitting, standing, monotony, and physical activity at work. Lifetime IRs varied by occupation, with ranges from 61%–83% in younger age groups and 53%–75% in older groups. After the study was completed, the authors noted that for these women, the highest lifetime incidence of LBP was not found in jobs with the highest physical demands. The measure for "physical activity at work" was also not significantly associated with LBP in univariate analyses. Bending forward (RR 1.3), lifting (RR 1.2), and standing (RR 1.3) were associated with lifetime incidence of LBP in univariate analyses (p<0.05). Sitting was not (OR 0.84, p=0.10). None of the measures of physical workplace factors were associated with lifetime incidence of LBP in multivariate analyses.

Videman et al. [1990] studied 86 males who died in a Helsinki hospital to determine the degree of lumbar spinal pathology. Disc degeneration and other pathologies were determined in the cadaver specimens by discography and radiography. Subjects' symptoms and work exposures (heavy physical work, sedentary work, driving, and mixed) were determined by interview of family members. In comparison to those with mixed work exposures, those with sedentary (OR 24.6, 95% CI 1.5–409) and heavy work (OR 2.8, 95% CI 0.3–23.7) had increased risk of symmetric disc degeneration. Similar relationships were seen for end-plate defects and facet joint osteoarthrosis. For most pathologic changes, sedentary work appeared to have a stronger relationship than heavy work. Back pain symptoms were consistently higher in those with any form of spinal pathology, although the difference was significant only for anular ruptures. This study was unusual in design in that it examined a combination of spinal pathological outcomes, symptoms, and workplace factors. However, participation in the study was dependent on obtaining information from family members; participation rates were not stated. While recall bias is often a problem in studies of the deceased, in this case it should have been nondifferential, if present.

Strength of Association

The ten studies were approximately equal in terms of information they provided relating to static work postures. Burdorf and Zondervan [1990] observed an OR of 0.49 (95% CI 0.11–2.2) for the univariate relationship between prolonged sedentary postures and LBP in crane operators. Holmström et al. [1992] found no association between LBP and sitting (in univariate or multivariate analyses). In the Magora [1972, 1973] cross-sectional investigation, the highest LBP rates were observed for those in the "rarely" category for variables related to sedentary postures, sitting, and standing. No dose responses were observed. In the Toroptsova et al. [1995] study of machine manufacturing workers, sitting, standing, and static work postures were not associated with LBP history in univariate analyses. No details were provided. In multivariate analyses, Masset and Malchaire [1994] found a nonsignificant association between LBP and seated posture (OR 1.5, p=0.09) in multivariate analyses. Svensson and Andersson's 1989 study of Swedish women found that standing was associated with lifetime incidence of LBP in univariate analyses (OR 1.3, p<0.05), but not in multivariate models. Sitting was not associated in univariate analyses (OR 0.84, p=0.10). Walsh et al. [1989] found that low-back symptoms were associated with lifetime occupational exposure to sitting in females only (RR 1.7, 95% CI 1.1–2.6) in multivariate analyses that considered other work exposures. Kelsey's 1975b case-control study demonstrated that sedentary work (sitting more than half the time at work) was associated with lumbar disc herniations, but only for those 35 and older (RR 2.4, p=0.01); the RR for those less than 35 was 0.81. In a study of salespeople, a dose-response was observed for sedentary work and low back symptoms. An OR of 2.45 (95% CI 1.2–4.9) was seen for the highest category after adjustment for covariates [Skov et al. 1996]. The Videman et al's [1990] study of cadavers found that those with histories of either sedentary or heavy work exposure had increased risk of symmetric disc degeneration (OR 24.6, 95% CI 1.5–409 and OR of 2.8, 95% CI 0.3–23.7, respectively). Similar results were seen for other disc pathologies. For most pathologic changes, sedentary work appeared to have a stronger relationship than heavy work.

In summary, most (n=6) risk estimates for variables related to static work postures, including standing and sitting, were not significantly different from one. Others found small to moderate significant increases in risk: ORs of 1.3 for standing, 1.7 for sitting (females only), and 2.4 and 2.5 for sedentary work. The Videman et al. [1990] cadaver study found high risks of disc pathology in those with a history of sedentary work. Study quality was similar across the range of point estimates observed.

Therefore, an estimate of the strength of association is difficult to determine. The magnitude cannot be estimated based on the available data.

Temporal Relationship

Eight of 10 studies were cross-sectional in design. Two of these attempted to use additional methodologies to increase the likelihood that exposure preceded disorder by excluding cases with onset prior to current job and truncating exposures prior to disorder onset. One found a positive relationship between prolonged sitting and LBP symptoms.

Consistency in Association

The studies showed poor consistency in estimation of the relationship between low-back disorder and static work postures, perhaps due to considerable differences in definition of exposure.

Coherence of Evidence

As mentioned elsewhere, LBP has been associated with mechanical forces causing an increased load on the lumbar spine [Waters et al. 1993]. Increased loading on the spine causes increased intervertebral disc pressures, which in turn, may be responsible for herniation and back pain. In laboratory experiments, disc pressure has been found to be substantially greater in unsupported sitting than in standing positions [Chaffin and Andersson 1984].

Studies reviewed for this document suggested relationships between back disorder and nonwork activities seemed to be consistent with the hypothesis that static

work postures might be associated with back disorder. Kelsey [1975a] observed that, in addition to sedentary work, amount of time spent sitting on weekends was associated with herniated discs. The finding that sedentary work was associated with herniated discs only in older age groups suggested that duration of exposure may be important and that a threshold may exist. Toroptsova et al. [1995] observed that back pain was lower in those who engaged in sports activity, perhaps suggesting that greater muscle strength prevents back pain**.**

Several authors offered explanations for the lack of associations they observed. It was pointed out that perception of "sedentary" is subjective and that many jobs that investigators (or subjects) considered to include prolonged static postures may actually have allowed considerable movement throughout the day (such as office workers). Other "sedentary" groups (such as industrial sewing machine operators) may be forced by work schedules to maintain static postures for long periods. It is important to have a true range of exposure if differences in associated disorders are to be detected.

Exposure-Response Relationships

Three studies addressed dose-response relationships, two of which did not demonstrate any trends. Magora [1972, 1973] found the highest risk of LBP in the lowest exposure categories for sedentary postures, sitting, and standing. Videman et al. [1990] found a high rate of lumbar disc pathology in those with histories of sedentary and heavy work, with relationships stronger for sedentary work. A dose-response for LBP symptoms and sedentary work was observed by Skov et al. [1996].

Conclusions: Static Work Postures

Ten studies examined the relationship between low-back disorder and static work postures. In most cases, this exposure was not of primary interest but was one of many potential workplace risk factors that were included in analyses. Static work posture was defined in several ways, including sedentary work and work-related sitting and standing. Exposure information was ascertained by interview for nine of 10 studies. The strength of association could not be easily estimated because a large proportion of point estimates did not differ statistically significantly from unity. As a whole, the results from these studies provide inadequate evidence that a relationship exists between static work postures and low-back disorder.

ROLE OF CONFOUNDERS

As mentioned above, back disorder is multifactorial in origin and may be associated with both occupational and nonwork-related factors and characteristics. The latter may include demographics, leisure time activities, history of back disorder, and structural characteristics of the back [Garg and Moore 1992]. The relative contributions of these covariates may be specific to particular anatomic areas and disorders. For example, a recent study of identical twins demonstrated that occupational and leisure time physical loading contributed more to disc degeneration of the upper than the lower lumbar region [Battié et al. 1995]. For both anatomic areas, age and twin effects (genetic influences and early shared environment) were the strongest identifiable predictors for this particular health outcome.

Psychosocial factors, both work- and nonwork-related, have been associated with back disorders. These relationships are discussed at length in Chapter 7 and Appendix B.

In the studies reviewed for this document, gender and age effects were addressed in most (86% and 74%, respectively). Approximately 40% addressed work-related psychosocial factors. In addition to these, many studies addressed other potential confounders in their analyses.

Table 6-1. Epidemiologic criteria used to examine studies of low back MSDs associated with heavy physical work

Study (first author and year)	Risk indicator (OR, PRR, IR or *p*-value)*,†	Participation rate $70%	Physical examination	Investigator blinded to case and/or exposure status	Basis for assessing back exposure to heavy physical work
Met at least one criterion:					
Åstrand 1987	2.3†	Yes	Yes	No	Job titles or self-reports
Bigos 1991b	No association	No	No	NR†	Observation or measurements
Burdorf 1991	No risk estimate§	Yes	No	No	Observation or measurements
Clemmer 1991	2.2†, 4.3†	Yes	No	NR	Job titles or self-reports
Heliövaara 1991	1.9, 2.5†	Yes	Yes	No	Job titles or self-reports
Hildebrandt 1995	1.2†	Yes	No	No	Job titles or self-reports
Hildebrandt 1996	No association	Yes	No	No	Job titles or self-reports
Johansson 1994	No association	Yes	No	NR	Job titles or self-reports
Leigh 1989	1.5†	Yes	No	NR	Job titles or self-reports
Masset 1994	No association	Yes	No	NR	Job titles or self-reports
Partridge 1968	1.2	Yes	Yes	No	Job titles or self-reports
Riihimäki 1989b	1.0	Yes	No	NR	Job titles or self-reports
Ryden 1989	2.2†	Yes	No	NR	Job titles or self-reports
Svensson 1989	No association	Yes	No	NR	Job titles or self-reports
Videman 1984	1.1	Yes	No	NR	Job titles or self-reports
Videman 1990	2.8, 12.1†	NR	Yes	NR	Job titles or self-reports
Met none of the criteria:					
Bergenudd 1988	1.8†	No	No	NR	Job titles or self-reports
Burdorf 1990	4.0	No	No	NR	Job titles or self-reports

*Odds ratio (OR), prevalence rate ratio (PRR), or incidence ratio (IR).

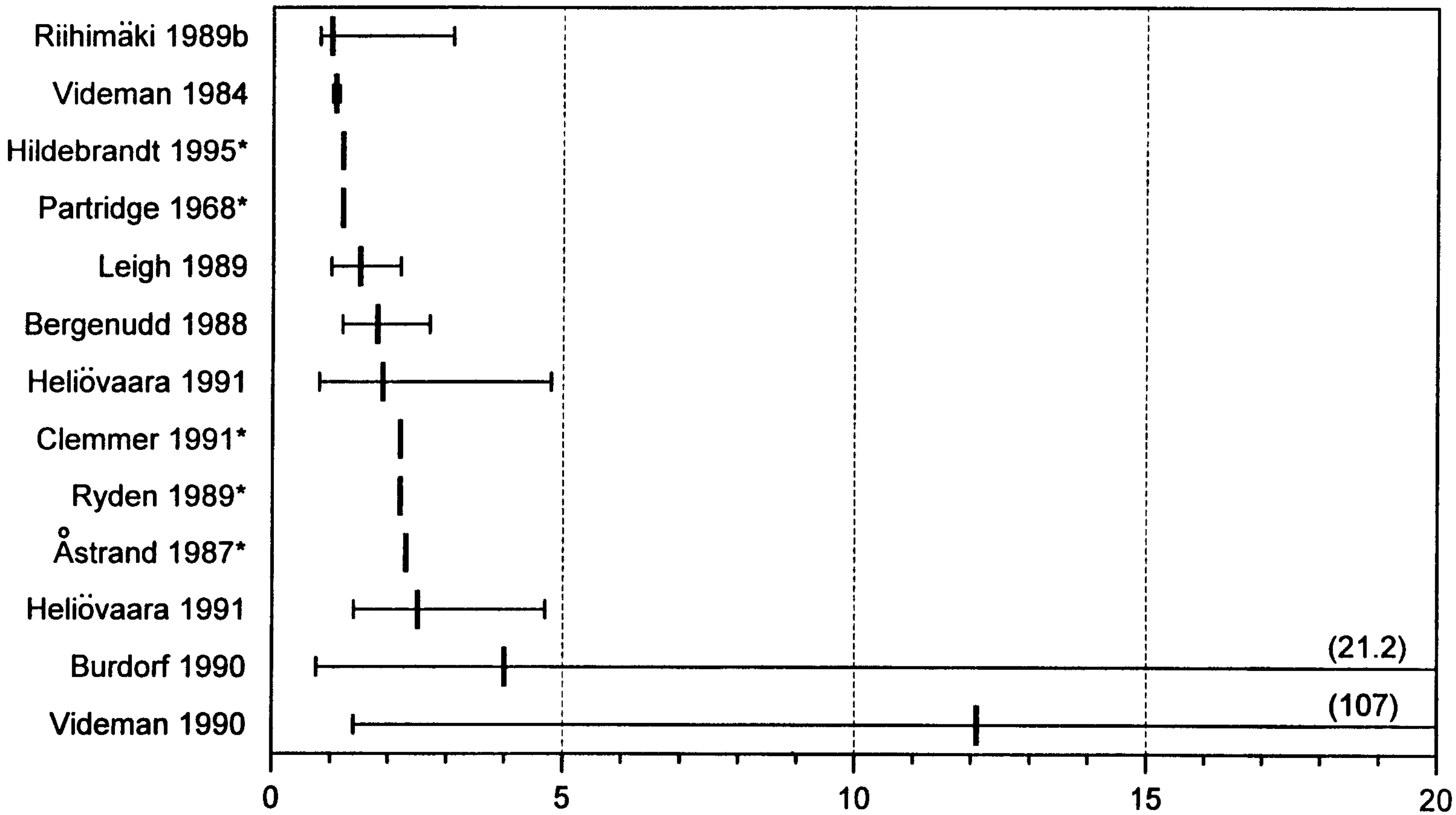
†Indicates statistical significance.

‡Not reported.

§Significant associations found in univariate but not multivariate results.

Figure 6-1. **Risk Indicator for Low-Back MSDs and Heavy Physical Work**

(Odds Ratios and Confidence Intervals)



* Risk factor reported without confidence limits.
Note: One study indicated a statistically significant association without reporting odds ratios. Five studies found no association. See Table 6-1.

Table 6-2. Epidemiologic criteria used to examine studies of low back MSDs associated with lifting and forceful movements

Study (first author and year)	Risk indicator (OR, PRR, IR or *p*-value)*,†	Participation rate $70%	Physical examination	Investigator blinded to case and/or exposure status	Basis for assessing back exposure to lifting and forceful movements
Met all four criteria:					
Punnett 1991	2.2†	Yes	Yes	Yes	Observation or measurements
Met at least one criterion:					
Burdorf 1991	No association	Yes	No	No	Observation or measurements
Chaffin 1973	Approx. 5†	NR	No	NR	Observation or measurements
Holmström 1992	1.3§	Yes	Yes	Yes	Job titles or self-reports
Huang 1988	No risk estimate	Yes	No	NR	Observation or measurements
Johansson 1994	No association	Yes	No	NR	Job titles or self-reports
Kelsey 1975b	0.94	Yes	Yes	NR	Job titles or self-reports
Kelsey 1984	3.8	Yes	Yes	NR	Job titles or self-reports
Knibbe 1996	1.3	Yes	No	No	Job titles or self-reports
Liles 1984	4.5†	NR	No	No	Observation or measurements
Magora 1972	No association, 1.7†	NR	No	NR	Observation or measurements
Marras 1995	10.7†	NR	No	NR	Observation or measurements
Svensson 1989	1.2§	Yes	No	NR	Job titles or self-reports
Toroptsova 1995	1.4†	Yes	Yes	NR	Job titles or self-reports
Undeutsch 1982	No risk estimate	NR	Yes	NR	Job titles or self-reports
Videman 1984	No association	Yes	No	NR	Job titles or self-reports
Walsh 1989	1.5†, 2.0†	Yes	No	NR	Job titles or self-reports
Met none of the criteria:					
Burdorf 1990	0.70, 5.2†	No	No	NR‡	Job titles or self-reports

*Odds ratio (OR), prevalence rate ratio (PRR), or incidence ratio (IR).

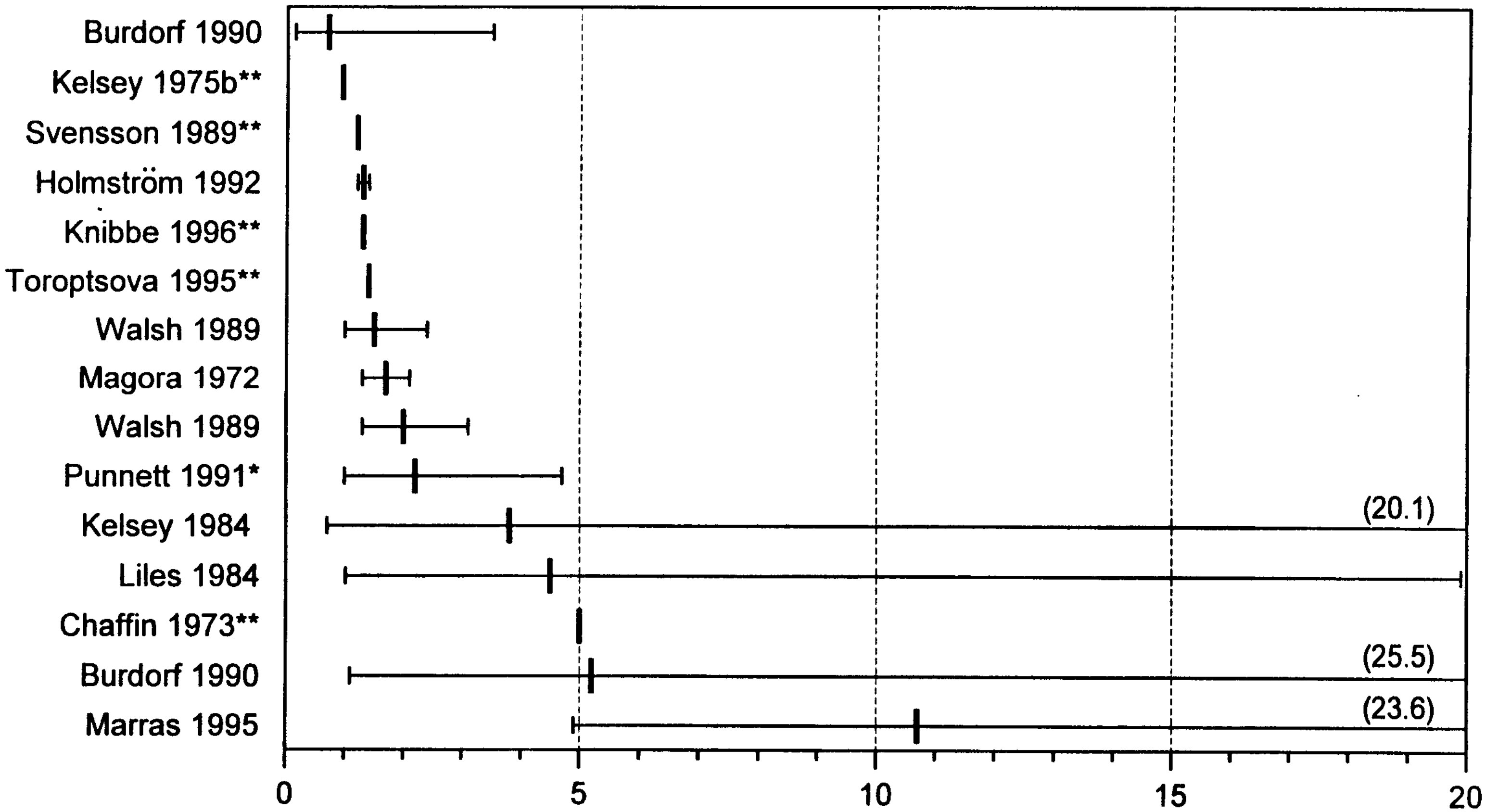
†Indicates statistical significance.

‡Not reported.

§Significant associations found in univariate but not multivariate results.

Figure 6-2. **Risk Indicator for Low-Back MSDs and Lifting and Forceful Movements**

(Odds Ratios and Confidence Intervals)



* Studies which met all four criteria.

**Risk factor reported without confidence limits.

Note: Four studies found no association. Two studies reported results without reporting risk estimates. See Table 6-2.

Table 6-3. Epidemiologic criteria used to examine studies of low back MSDs associated with bending, twisting, or awkward postures

Study (first author and year)	Risk indicator (OR, PRR, IR or *p*-value)*,†	Participation rate $70%	Physical examination	Investigator blinded to case and/or exposure status	Basis for assessing back exposure to bending, twisting, or awkward postures
Met back criteria:					
Punnett 1991	8.09†	Yes	Yes	Yes	Observation or measurements
Met at least one criterion:					
Burdorf 1991	1.2†	Yes	No	No	Observation or measurements
Holmström 1992	2.6†, 3.5†	Yes	Yes	Yes	Job titles or self-reports
Johansson 1994	NR†,‡	Yes	No	NR	Job titles or self-reports
Kelsey 1984	3	Yes	Yes	NR	Job titles or self-reports
Magora 1972, 1973	No association	NR	No	NR	Observation or measurements
Marras 1993, 1995	10.7†	NR	No	NR	Observation or measurements
Masset 1994	No association§	Yes	No	NR	Job titles or self-reports
Riihimäki 1989b	1.5†	Yes	No	NR	Job titles or self-reports
Riihimäki 1994	No association§	Yes	No	NR	Job titles or self-reports
Svensson 1989	No association§	Yes	No	NR	Job titles or self-reports
Toroptsova 1995	1.7†	Yes	Yes	NR	Job titles or self-reports

*Odds ratio (OR), prevalence rate ratio (PRR), or incidence ratio (IR).

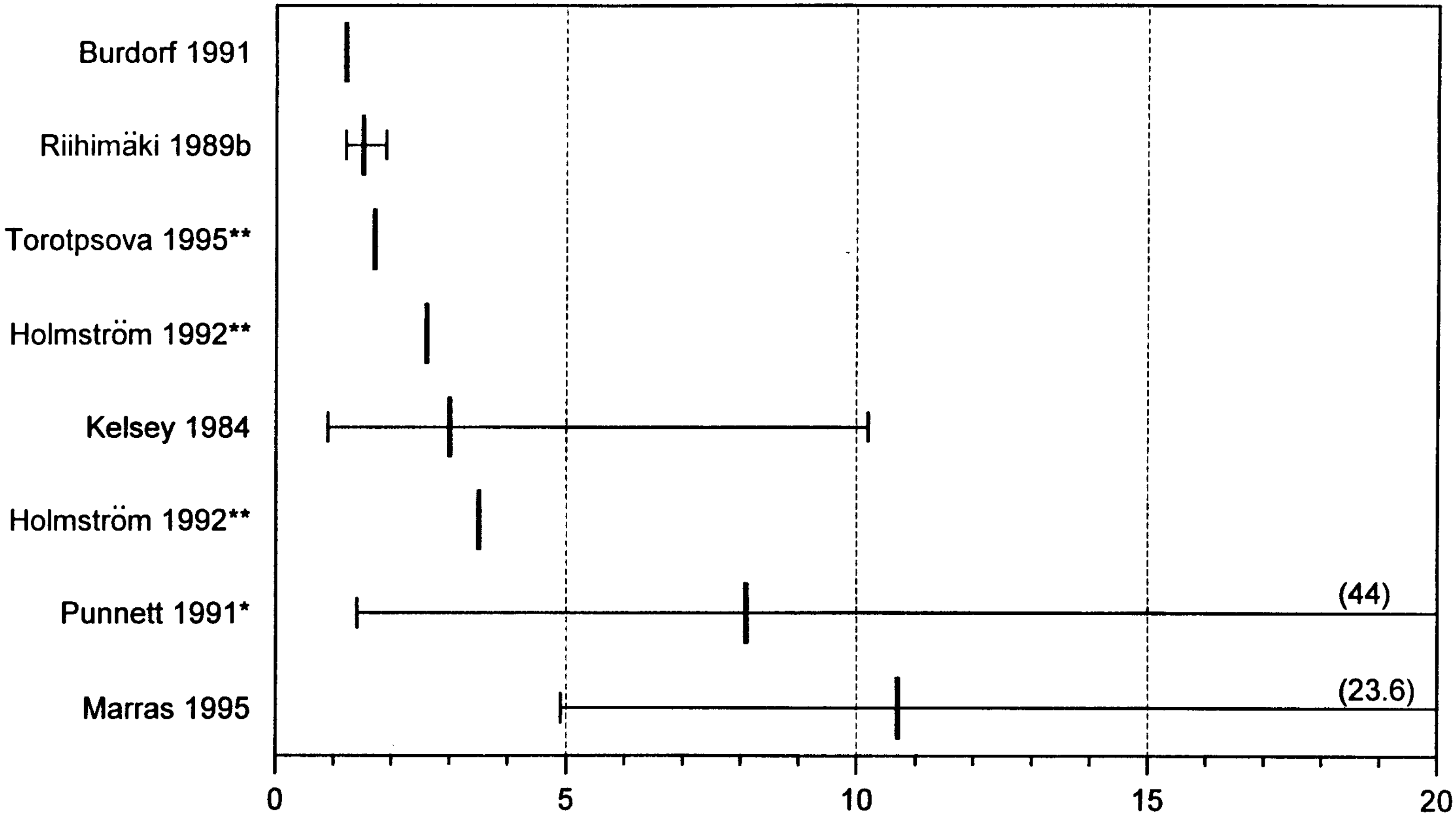
†Indicates statistical significance. If reported with NR, a significant association was reported without a numerical value.

‡Not reported.

§Significant associations found in univariate but not multivariate results.

Figure 6-3. **Risk Indicator for Low-Back MSDs and Bending, Twisting, and Awkward Postures**

(Odds Ratios and Confidence Intervals)



* Studies which met all four criteria.
**Risk factor reported without confidence limits.
Note: Four studies found no association. One study indicated statistically significant association without reporting odds ratio. See Table 6-3.

Table 6-4. Epidemiologic criteria used to examine studies of low back MSDs associated with whole-body vibration

Study (first author and year)	Risk indicator (OR, PRR, IR or *p*-value)*,†	Participation rate $\geq$70%	Physical examination	Investigator blinded to case and/or exposure status	Basis for assessing back exposure to lifting and whole-body vibration
Met at least one criterion:					
Bongers 1988	2.0†–5.7	Yes	Yes	NR‡	Job titles or self-reports
Bongers 1990	3.3–39.5†	Yes	No	NR	Observation or measurements
Boshuizen 1990a, 1990b	1.5–3.6†	Yes	No	NR	Observation or measurements
Boshuizen 1992	0.99	Yes	No	NR	Observation or measurements
Bovenzi 1992	2.6†	Yes	No	NR	Observation or measurements
Bovenzi 1994	2.4–4.6†	Yes	No	NR	Observation or measurements
Burdorf 1991	3.1†	Yes	No	No	Job titles or self-reports
Burdorf 1993	2.5–3.3†	Yes	No	NR	Observation or measurements
Kelsey 1975b	2.8†, 4.7†	Yes	Yes	NR	Job titles or self-reports
Magnusson 1996	1.8†	NR	No	NR	Observation or measurements
Magora 1972	1.2	NR	No	NR	Observation or measurements
Masset 1994	1.2†	Yes	No	NR	Job titles or self-reports
Riihimäki 1989a	1.3†	Yes	No	NR	Job titles or self-reports
Riihimäki 1994	No association	Yes	No	NR	Job titles or self-reports
Toroptsova 1995	No association	Yes	Yes	NR	Job titles or self-reports
Walsh 1989	1.7†	Yes	No	NR	Job titles or self-reports
Met none of the criteria:					
Burdorf 1990	0.66	No	No	NR	Job titles or self-reports
Johanning 1991	3.9†	No	No	NR	Job titles or self-reports
Skov 1996	2.8†	No	No	NR	Job titles or self-reports

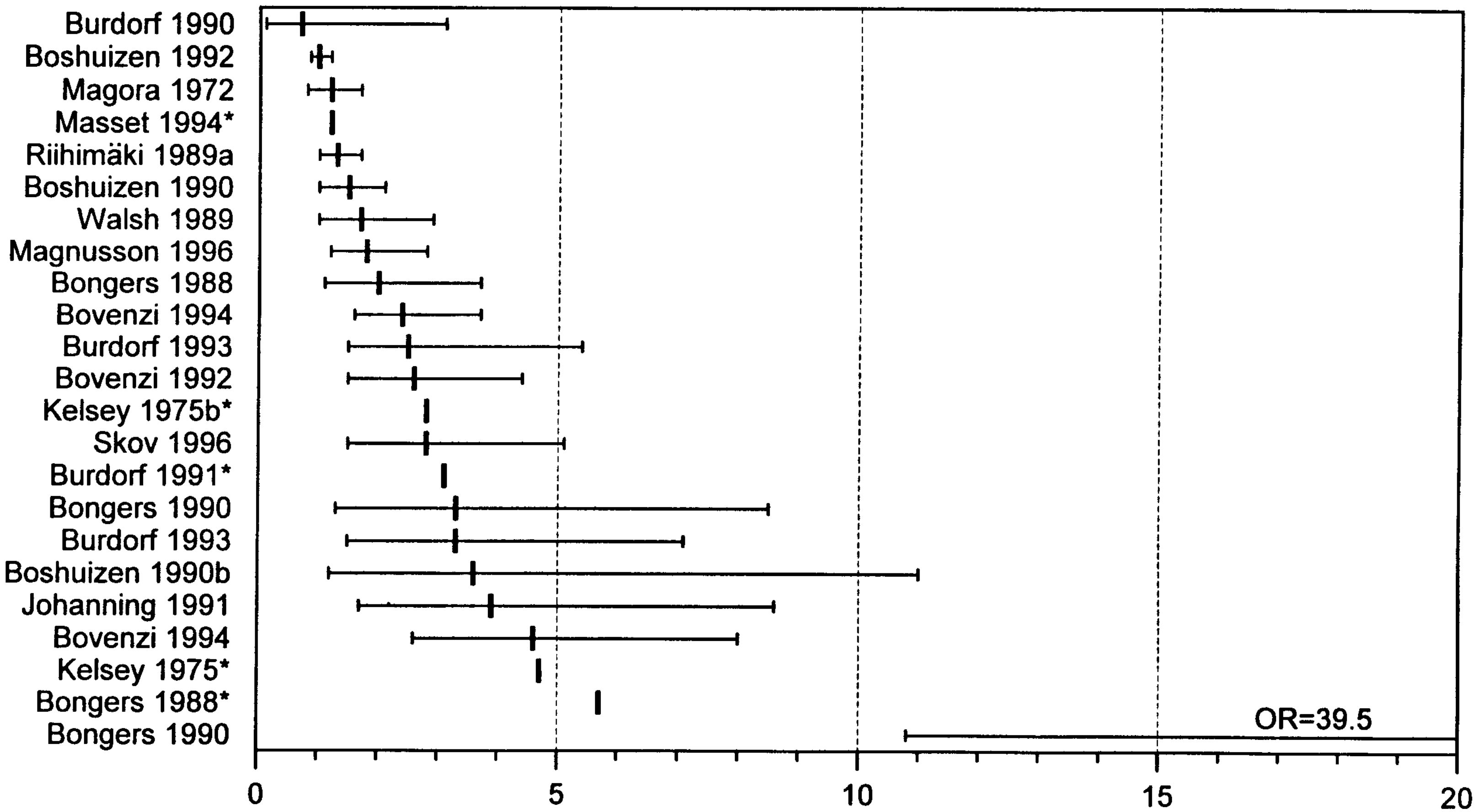
*Odds ratio (OR), prevalence rate ratio (PRR), or incidence ratio (IR).

†Indicates statistical significance.

‡Not reported.

Figure 6-4. **Risk Indicator for Low-Back MSDs and Whole-Body Vibration**

(Odds Ratios and Confidence Intervals)



* Risk factor reported without confidence limits.
Note: Two studies found no association. See Table 6-4.

Table 6-5. Epidemiologic criteria used to examine studies of low back MSDs associated with static work postures

Study (first author and year)	Risk indicator (OR, PRR, IR or *p*-value)*, †	Participation rate $70%	Physical examination	Investigator blinded to case and/or exposure status	Basis for assessing back exposure to static work postures
Met at least one criterion:					
Holmström 1992	No association	Yes	Yes	Yes	Job titles or self-reports
Kelsey 1975b	0.81, 2.4†	Yes	Yes	NR	Job titles or self-reports
Magora 1972, 1973	No association	NR	No	NR	Observation or measurements
Masset 1994	1.5	Yes	No	NR	Job titles or self-reports
Svensson 1989	1.3§	Yes	No	NR	Job titles or self-reports
Toroptsova 1995	No association	Yes	Yes	NR	Job titles or self-reports
Videman 1990	24.6†	NR	Yes	NR	Job titles or self-reports
Walsh 1989	1.7† (females)	Yes	No	NR	Job titles or self-reports
Met none of the criteria:					
Burdorf 1990	0.49	No	No	NR	Job titles or self-reports
Skov 1996	2.45†	No	No	NR	Job titles or self-reports

*Odds ratio (OR), prevalence rate ratio (PRR), or incidence ratio (IR).

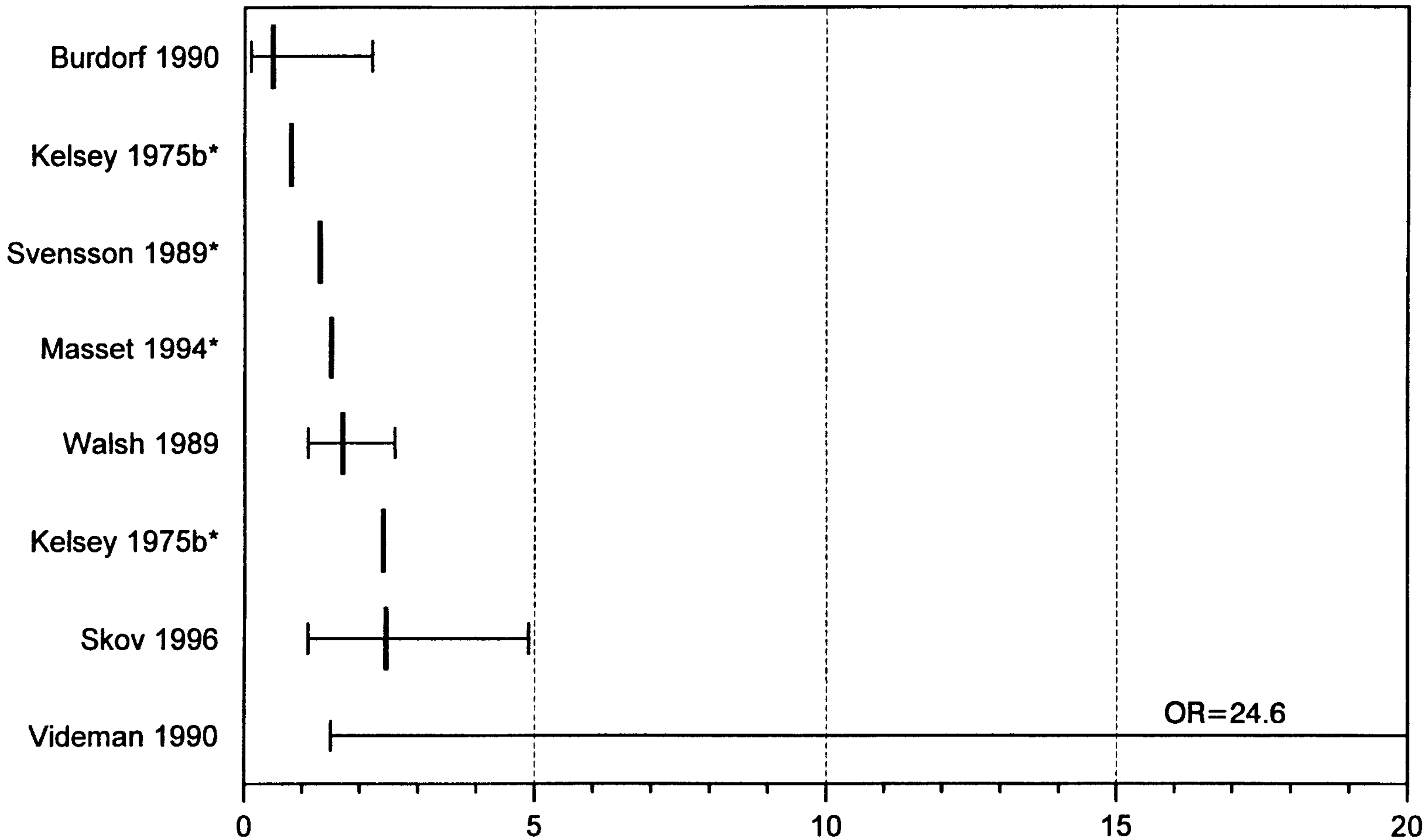
†Indicates statistical significance.

‡Not reported.

§Significant associations found in univariate but not multivariate results.

Figure 6-5. **Risk Indicator for Low-Back MSDs and Static Work Postures**

(Odds Ratios and Confidence Intervals)



* Risk factor reported without confidence limits.

Note: Three studies found no association. See Table 6-5.

Table 6-6. Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Åstrand 1987 Åstrand and Isacsson 1988	Cross-sectional, 1987 Retro-spective 22 years follow up, 1988	391 male employees in a Swedish pulp and paper industry located at one of 4 sites: Mill 1, Mill 2, Mill 3, and Head Office.	Outcome: Medical, psychological and social indicators. Questionnaires on social and psychological factors; medical examination of thoracic and lumbar spine. Exposure: Based on the type of work performed at each job site. All mill work jobs were judged as heavy; all office/clerk jobs were judged as light. Some worker movement between office/clerk jobs and mill work, based on health status.	29.4 % of manual workers reported back pain in response to: "Do you often have back pain?"	12.9% of clerks reported back pain in response to same question.	 Duration of employ-ment:1.2 Neuro-ticism: 2.8	*p*=0.002 1.0-1.5 1.4-5.4	Participation rate: 82.5%. The proportion of backs evaluated as abnormal by physical examination was 16%, similar to U.S. data collected in 1971. 66% of group with back abnormalities reported back pain. Psychosocial work factors did not show any significant association with back pain. The working conditions of back pain sufferers were changed because of their reduced working capacity, which tends to offset differences in prevalence of back pain between groups doing heavy work and control populations. Results support Magora's findings that heavy work over time is associated with increased back pain. Back pain was associated with occupation, low education, duration of employment, and neuroticism. In follow-up study, a "healthy worker effect" was documented.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Bergenudd and Nilsson 1988	Longitudinal	323 males and 252 females; all participants in Malmo, Sweden, Longitudinal Study since 1938.	Outcome: Back pain not tracked by exam. "Attended" for exam but BP based only on self assessment and questionnaire, 1983. Exposure: Exposures and occupations tracked by questionnaires since 1942. Work classified into 3 categories of heaviness based on 10 years work. (1) Light physical work: white collar. (2) Moderate: Nurses, shop assistants, bakers, and light industry. (3) Heavy: Carpenters, bricklayers, and heavy industry.	Point prevalence: LBP males: 28% females: 30% 5% prevalence of sciatica In heavy or moderate work (LBP): males: 32.4% females: 38.9%	LBP in unexposed males: 21.4% females: 23.9%	All: 1.83 Females: 2.03 Males: 1.76	1.2-2.7 1.1-3.7 1.01-3.1	Participation rate: 67% in questionnaire and health survey from 830 individuals living in Malmo. Not controlled for confounders. Exposures rated from job title. Weak support for occupational factors in causation. Some support for workload causing symptoms. Moderate or heavy physical demands had more back pain; then light physical demand group (*p*<0.01) statistically significant only in females. Those with back pain had fewer years of education and were less satisfied with their working conditions. There was no difference in the relationship between family, relatives, or friends.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Bigos et al. 1986a	Retro-spective cohort morbidity (15-month follow-up)	Aircraft manufacturer employees in 33 job classifications (n=31,200).	Outcome: Report of low back injury. Exposure: 33 job classifications.	Highest LB injury rates in mechanics Rate=38.2	Lowest LB injury rates in electronic technicians and tool grinders Rate=NS	Highest to lowest compari-son is in range of 5 to 7 (exact numbers not reported)		Participation rate: 100% (includes all records). Exact rates by job titles not reported. Authors state that differences by job title are difficult to interpret because of overlapping confidence intervals.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Bigos et al. 1991b	Prospective	3,020 aircraft assembly workers; 1,613 involved in work perception and psychosocial portion of study.	Outcome: A case was defined as a subject reporting an acute industrial back injury. Subjects answered series of questionnaires: On demographic and psychosocial factors, a cardiovascular questionnaire, and a take-home questionnaire on psychosocial and individual factors (see comments). Subjects had physical examination to assess physical attributes: Lifting strength, aerobic capacity, and flexibility. Exposure: Based on questionnaire data of work and home activities. Also "All jobs employing >19 workers analyzed for heavy and tiring tasks in terms of maximal loads." Also analyzed "perceived physical exertion" as potential risk factor.	8% to 9% of workers reported an acute industrial back injury.	N/A	Lack of enjoyment of job tasks: OR=1.7 MMPI: tend towards somatic complaint or denial of emotional distress: OR=1.37 Prior back pain: OR=1.7	1.3-2.2 1.1-1.7 1.2-2.5	Participation rate: 43% of the original number of workers solicited 54% of participants returned questionnaire with Minnesota Multiphasic Personality Inventory (MMPI); 75% participated in some part of the study. Of volunteers, respondents and non-respondents were similar. Employees' work exposure not as well documented as psychosocial factors. Take home questionnaire had 566 question Minnesota Multiphasic Personality Inventory (MMPI), family function questionnaire (APGAR), Health locus of control (HLOC). Other information included medical history, previous back discomfort or problem, and previous back injury claims in prior 10 years. Study did not investigate actual presence of back symptoms or specific disorders; subjects followed for three years and became a case if they: (1) reported to medical department, (2) filed an incident or report, (3) filed an industrial insurance claim. Authors state that results may not apply as strongly to cases of severe symptoms or in work involving heavy job requirements (study performed in a manufacturing industry where "job tasks do not tend to be extremely stressful" for the back.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Bongers et al. 1988	Retro-spective cohort (January, 1975-December 1984)	Dutch, male, steel workers (n=1,405)	Outcome: Disability pension for back-related disorder. Exposure: Job title and duration of employment. Measurements of vibration in cranes but not used in this study.	Crane operators (n=743)	Floor workers in same departments (n=662)	Incidence Density Ratios All back disorders: 1.32 Interverte-bral disc disorders: 2.00 Degenera-tion of interverte-bral disc: 2.95 COX regression: IDR for displace-ment of disc: 2.46 IDR for degenera-tion of inteverte-bral disc: 3.28	 0.84-2.1 1.1-3.7 1.2-7.3 1.2-12.5	Participation rate: $70%. Adjusted for nationality, shiftwork, age, and calendar time. ORs likely are underestimated because of slight vibration exposure of the control group and potential health-based selection of the exposed group before start of the follow-up period. The combination of exposure to W.V., unfavorable postures, and adverse climatic conditions is the probable cause of the back disorders.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Bongers et al. 1990	Cross-sectional	Dutch, male, helicopter aircrew and non-flying air force officers	Outcome: Back symptoms, by questionnaire. Exposure: Hr of flight time, types of helicopters flown, and time spent in bent or twisted postures were obtained by questionnaire. Vibration measurements were taken in two helicopters of each type used in the study. Cumulative exposures were obtained by combining questionnaire and measurement data.	Dutch helicopter pilots and aircrew observers (n=163)	Non-flying air force officers (297)			Participation rate: $70%. Adjusted for age, height, weight, climate, bending forward, twisted postures, and feeling tense at work. Prevalence of transient back pain, in particular, was higher for exposed than referent group. Prevalence of transient back pain increased with daily exposure time. Chronic back pain increased with total flight time and total vibration dose. Postures of pilots were constrained due to cockpit conditions. Selection bias possible in that pilots with back trouble could have dropped out of employment.
				Back pain, 68%;	17%	8.0	4.5-14.3	
				LBP, 55%;	11%	9.0	4.9-16.4	
				Lumbago, 13%;	9%	2.6	1.1-6.0	
				Sciatica, 12%;	6%	3.3	1.3-8.5	
				Pattern alternating, 41%	6%	9.5	4.8-18.9	

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	Referent group	RR, OR, or PRR	95% CI	Comments
Boshuizen et al. 1990a,b	Cross-sectional follow-up of a cohort identified in 1975. Also, includes entire cohort in examination of sick leave and disability follow-ups.	Employees of two Dutch companies performing land reclamation and inspection of roads, dikes, and building sites. Several workers operate vehicles. The cross-sectional study included 577 workers, and the cohort study 689.	Outcome: Back pain symptoms were obtained by questionnaire in the cross-sectional study, and back-related sick leave and disability retirement information was collected in the cohort study. Exposure: Vehicle vibration information was combined with questionnaire data regarding vehicle types driven, awkward postures maintained, hr of work, and previous jobs held.	Sick leave for all back disorders		1.47	1.04-2.1	Participation rate: 79%. ORs corrected for duration of exposure, age, height, smoking, awkward postures, and mental workload. Association greater with duration of exposure than magnitude.
				LBP prevalence: by vibration dose, 4 categories		RR: 19.1, 29.4, 28.03, 8.1		
				By vibration, 3 categories		1.80, 1.78, 2.8		
				By years of exposure 3 categories		2.44, 2.50, 3.60		
				Sick leave by vibration dose, 4 categories		1.0, 0.97, 1.51, 1.45		
				Dose of 5 years, all back disorders		1.13 COX regress. adj. for age		

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence				Comments
				Exposed workers	Referent group	RR, OR, or PRR	95% CI	
Boshuizen et al. 1992	Cross-sectional	Male employees of six Dutch shipping companies (n=452).	Outcome: Back pain symptoms by questionnaire Exposure: Measurement of vibration in sample of vehicles combined with questionnaire responses to calculate cumulative dose (before symptom onset.	Fork-lift truck and freight tractor drivers (n=242).	Employees of the same companies without vibration exposure (n=210)			Participation rate: $70%. Adjusted for age, mental stress, years lifting > 10 kg and twisting spine, height, smoking, looking backwards, and hr sitting. Authors suggested that a healthy-worker effect was operating in that older drivers were subject to health-based selection. Psychosocial factors were not addressed, except for “mental stress from work”.
				Prevalence (age standardized:				
				Back pain, 48%	34%		*p*=<0.05	
				LBP, 41%	30%		*p*=<0.05	
				Lumbago, 19%	8%		*p*=<0.05	
				Cox regression: Back pain and total dose:		0.99	0.85-1.2	
				Lumbago and total dose:		1.14	0.91-1.4	
				Vibration exposure in last 5 years and back pain:		2.4	1.3-4.2	
				and lumbago:		3.1	1.2-7.9	
				Age and prevalence of LBP (multivariate OR):				
				25-34		5.6	Õ	
				35-44		1.96	Õ	
				45-54		0.68	Õ	

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

				MSD prevalence				
Study	**Study design**	**Study population**	**Outcome and exposure**	**Exposed workers**	**Referent group**	**RR, OR, or PRR**	**95% CI**	**Comments**
Bovenzi and Zadini 1992	Cross-sectional mail survey	Male bus employees working in Trieste	Outcome: Back-pain symptoms from questionnaire (rev. Nordic). Exposure: WBV measured. Cumulative exposures estimated from measurements plus questionnaire results (duration of work, previous exposures, etc.).	234 bus drivers	125 maintenance workers working for same bus company			Participation rate: $70%. Adjusted for age, awkward posture, duration of exposure, BMI, mental load, education, smoking, sport activities, previous jobs at risk for back pain and duration of employment. Does not address sedentary nature of work (states sitting is poorly correlated with LBP unless in combination with WBV). Psychosocial: adjusted for "mental load" (no risk estimate provided). Results were similar after excluding those with WBV exposure in previous jobs from analyses.
				Univariate results: lifetime prevalence of LB symptoms, 83.8%;	66.4%	3.12	1.8-5.3	
				LBP, 36.3%;	15.2%	2.80	1.6-5.0	
				Previous 12 months: LB symptoms, 82.9%	65.6%	2.99	1.8-5.1	
				LBP, 39.7%;	20.0%	2.57	1.5-4.4	
				Dose-response for total vibration and lifetime LBP;		4.05	1.8-9.3	
				Dose-response for 12-mo. LBP.		3.25	1.5-7.0	

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Bovenzi and Betta 1994	Cross-sectional	Tractor drivers, aged 25-65, working in Italy (n=1155) and male revenue officers engaged in inspection and administrative work (n=220).	Outcome: Survey questionnaire (modified Nordic) Exposure: Vibration levels were measured for a representative samples of tractors. Information on awkward postures gained from questionnaire. Number of hr operating yearly estimated from tractor maintenance records. Cumulative exposures estimated by combining the information.	Tractor drivers	Revenue officers			Participation rate: 91.2% for exposed and 92.2% for unexposed.
				Univariate: Back Pain: 86.1%	57.3%	1.83	1.1-3.0	Multivariate analyses adjusted for age, BMI, education, sport activity, car driving, marital status, mental stress, climatic conditions, back trauma, and postural load.
				LBP Lifetime: 81.3%	42.3%	3.22	2.1-5.2	
				12-month LBP, 71.7%	36.8%	2.39	1.6-3.7	
				Dose-response (highest categories) Lifetime LBP and tot. vib. dose;		5.49	3.6-8.5	Relationships reported between vibration exposure and back pain, with clearest dose-responses for chronic LBP outcome.
				Chronic LBP and tot. vib. dose;		2.63	1.7-4.10	Independent effects observed for postural load and vibration.
				Lifetime prevalence LBP and duration of exposure: 5-15 years 16-25 years >25 years		3.08 3.03 4.51	1.88-5.07 1.80-5.12 2.43-8.34	Results were similar after excluding those with WBV exposure in previous jobs from analyses.
				Lifetime prevalence LBP and total vibration dose (years m^2/s^4) <15 15-30 >30		2.79 3.44 3.79	1.70-4.58 2.05-5.77 2.20-6.53	

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	Referent group	RR, OR, or PRR	95% CI	Comments
Burdorf and Zondervan 1990	Cross-sectional	33 male crane operators and 30 male non-crane operator control subjects matched for age. Employed for $ one year.	Outcome: Back pain assessed by questionnaire (Nordic). Pain in lower back in the last 12 months.	61% of crane operators had back pain	27% of controls had back pain	3.6	1.2-10.6	Participation rate: 67% of crane operators and 100% of controls.
			Exposure: Defined by job title and questionnaire items: heavy physical work, lifting, WBV, and sedentary postures (current and past).	Risk Factors:				Control workers carried out more moderate or heavy work, lifting, walking, and standing than crane operator in past.
				Heavy work		4.02	0.76-21.2	Physical demands are not significant in multivariate analyses.
				Frequent lifting		5.21	1.10-25.5	
				Whole body vibration		0.66	0.14-3.1	Controlled for age, height, and weight.
								Crane operators with long work absences over-represented among non-responders.
								Results indicate that the current job of crane operator is associated with reports of onset of back pain.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence				Comments
				Exposed workers	Referent group	RR, OR, or PRR	95% CI	
Burdorf et al. 1991	Cross-sectional prevalence study	114 concrete workers compared to 52 maintenance engineers (controls). All male.	Outcome: Back pain symptoms assessed by questionnaire. Back pain defined as pain which continued for $ a few hr during the past 12 months. Exposure: Assessed by task analysis and OVAKO working posture analysis system (OWAS) observation method. Eleven postures of importance for occupational strain on the back were used. For each job, two or three workers were chosen at random. Index for postural load constructed using ordinal scale for rating the average proportion of poor back postures. Six jobs were ranked by index.	59% of concrete workers had back pain	31% of controls had back pain	2.80 age adjusted and controlled for back pain from previous job Model 1 Postural index OR=1.23 Model 2 Whole body vibration OR=3.1	1.31-6.01 *p*=0.04 *p*=0.001	Participation rate: 95% concrete workers; 91% maintenance males. Workload related to prevalence of back pain. Postural load, bending and twisting, as well as whole body vibration causal factors. Questionnaire included previous employment history, risk factors in present and previous jobs. Univariate analysis controlled for confounders using Mantel-Haensel chisquare. Age, height, and weight not significant factors. Age controlled for in logistic regression. 30% with back pain had symptoms >30 days. Concrete workers spent significantly more time in bent and/or twisted postures. Postural index and whole body vibration significantly correlated (0.48, *p*<0.001). Therefore, authors designed two separate logistic regression models. Prolonged standing or sitting not found to be risk factors.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Burdorf et al. 1993	Cross-sectional	Crane operators, saddle-carrier drivers and office workers aged 25-60, working in a large transport company (n=275).	Outcome: Back pain symptoms, by questionnaire. Exposure: Postures assessed with OWAS, WBV measured in sample of each group, and past work exposures estimated by questionnaire.	Crane operators (n=94) and saddle-carrier drivers (n=95) Multivariate analyses: Crane operators Straddle-carrier drivers	Office workers (n=86)	 3.29 2.51	 1.52-7.12 1.2-5.4	Participation rate: $70%. Adjusted for age and confounders (history of heavy work, exposure to WBV (y/n), history of work requiring prolonged sitting, cold and drafts, working under severe pressure, job satisfaction, height, weight, duration of total employment were considered). Risk estimates were not presented by exposure categories, despite quantitative assessment. Risk estimates reflect simultaneous exposure to WBV, static postures, and awkward postures. Only persons with no complaints of low back pain before starting their current jobs were included in analyses.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Chaffin and Park 1973	Prospective with approx. 1 year follow-up	5 plants in large electronics company. n=411 individuals (279 males and 132 females).	Outcome: Visit medical department because of low back complaint. Exposure: 103 jobs evaluated for Lifting Strength Rating (LSR) and lifting frequency.	Overall back rate, annual 7.2/100 FTEs (25 total back injuries)				Participation rate: Not reported. Age, weight, stature not associated with low back injuries. A strong positive trend is indicated in the incidence rate data as the LSR increases.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Clemmer et al. 1991	Retro-spective cohort	Offshore drilling workers. 14,518,845 worker-hr over 1979 to 1985 (7,259 FTEs), 4,765 total injuries.	Outcome: Back-injury cases reported on standard forms with mention of "rheumatogical crux" for which the agent of injury was mechanical energy excluding other body sites. Exposure: Based on job title.	543 cases of low back injuries. 7.5/100 Roustabouts, floorhands, and derrick workers, low-back strains rate: 6.92	Control room and maintenance 3.18	RR=2.2		Participation rate: Not reported. Workers performing the heaviest physical labor had highest number of injuries and highest rates. Controlling for "job," age significantly associated with back strain in workers performing heaviest length of employment work not associated with back pain. Job was best predictor of lost time. Back injuries largely from falls. 75% of back strains precipitated by pushing, pulling, or lifting.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Deyo and Bass 1989	Cross-sectional	From the NHANES-II national survey of 27,801 individuals, 10,404 files of adults age 25 or older who had a physical examination were reviewed and 1,134 who met the case definition were selected for this study. The mean age of the subjects was 48.3 years and half (51.7) were females.	Outcome: Low-back pain within the past year with $ one episode of near daily pain for $ two weeks. Exposure: Smoking and obesity, personal characteristics.	Prevalence of LBP in current smokers: 10.7%.	Prevalence of LBP current non-smokers: 10.2%		Not significant	Participation rate: Not reported. Lifestyle factors, including smoking and obesity, are risk factors for low-back pain.
				Ever smoked vs. LBP: 10.9%	9.6%	1.13	Significant	The attributable risk for smoking was 1.3 cases/100 persons.
				50 pack years vs. LBP: 14.1%	9.6%	1.47	Significant	Smoking risk increases steadily with cumulative exposure and with degree of maximal daily exposure.
				BMI vs LBP, Highest quintile: 14.8%	Lowest quintile: 8.5%	1.70	Significant	A stronger association exists between back pain and smoking in younger subjects than among those >age 45.
						Odds ratio each increment		There is a steady increase in back pain prevalence with increasing obesity, but this elevates most strikingly in the highest 20% of body mass index (levels over 29.0 kg/sq m).
				LOG REGRESSION:				
				Obesity		1.12	p<0.0006	
				Smoking		1.05	p<0.0006	
				Chronic cough		1.36	p<0.0006	
				Activity		1.22	p<0.0006	
				Education		0.84	p<0.0006	
				Age		1.01	p<0.0006	The association between obesity and LBP could be confounded by other unmeasured lifestyle differences between the obese and non-obese so that obesity is just a marker for a true causal factor or factors.
				Working		0.8	NS	

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Heliövaara et al. 1991	Cross-sectional	2,727 males and 2,946 females (30 to 46 years) with history, symptoms, or findings indicating musculoskeletal disease.	Outcome: LBP interview and tests at medical mobile clinic with uniform criteria. Low-back syndrome: Symptoms during the preceding month and major pathologic finding on physical exam (fingertip-floor distance >25 cm at flexion, rotation restricted to 25 degrees or less, objective signs of scoliosis of 20 degrees or more, Lumbar Lordosis, Ladegue's test positive at 60 degrees or less, or severe abnormality. Sciatica: Symptoms radiating down leg and findings of Lumbar nerve root compression. Exposure: Based on self-administered questionnaire; index for occupational physical stress and occupational mental stress.	Prior traumatic injury increased risk of LBP and, sciatica and, low back syndrome Work load index and, sciatica and, low back syndrome Stress index and, sciatica and, low back syndrome	No prior injury	2.5 2.6 2.4 3.1 2.4 2.0	1.9-3.3 2.1-3.1 1.0-5.7 1.7-5.7 1.7-3.5 1.5-2.6	Participation rate: 93% in screening. Physical and mental stress loads related to both sciatica and LBP. Controlled for age and gender. Body mass index, alcohol consumption, work-related driving, parity, and height were not associated with LBP. Diabetes had a significantly decreased prevalence of LBP (OR=0.4 CI 0.3-0.8). There was no statistical difference in LBP between sexes; sciatica significantly more prevalent among males. No association between smoking and sciatica. Significant association between smoking and LBP in both older and younger males, but only older females. Significant association between LBP and osteoarthritis, mental disorders, and respiratory disease.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

				MSD prevalence				
Study	Study design	Study population	Outcome and exposure	Exposed workers	Referent group	RR, OR, or PRR	95% CI	Comments
Hildebrandt 1995	Cross-sectional	From the Dutch population; a sample of 8,748 workers from three surveys on successive years.	Outcome: Back pain cases defined by symptom questionnaire ("yes" to "back pain quite often") and responses to interviewer. Exposure: Based on job title classification of work demands; four categorical exposure variables: trade branch, trade class, professional branch, and professional class.	29.6% (2,327) of heavy workers reported back pain "quite often." Rates of LBP: Construction: 35%; Truckers: 31%; Plumbers: 31%.	23.9% of sedentary workers reported back pain "quite often."	*p*<0.05 OR=1.2	õ 1.33-1.55	Participation rate: "Population sampled was representative of Dutch population." Unable to calculate. Workers performing non-sedentary work at highest risk. Rates increase with age for males, to age 54, and for females to age 64. Controlled for age and gender by stratification. Professions with high prevalence of back pain on average were characterized by physically demanding work with dynamic components. Data originally collected for screening of health and medical consumption, therefore less specific exposure variables—only job titles. However, there may be less potential for information bias because respondents did not then focus exclusively on back pain and work-relatedness. Conclusion: In non-sedentary work, both males and females have higher prevalence rates than those who work in sedentary jobs.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Hildebrandt et al. 1996	Cross-sectional	436 male workers in five maintenance departments of a steel company, compared to 396 non-sedentary workers also exposed to heavy workloads.	Outcome: Low back pain cases defined by symptom questionnaire ("yes" to low back pain in last 12 months). Exposure: Assessed by questionnaire. Workers placed into one of 18 groups based tasks performed "often" or "predominantly." Tasks assigned a score on four indices: (1) physical workload, (2) psychosocial workload, (3) poor climate, and (4) vibration.	Prevalence: 1-year; LBP: 53%	Reference group had high physical exposures.	õ	õ	Participation rate: Varied from 60% to 80% in different departments. Reference group characterized by high levels of exposure to adverse working conditions. Poor selection of referents. Prevalence rates adjusted for age differences between groups. Task groups with high prevalence rates of low back symptoms also associated with high exposures to unfavorable working conditions. Rates work groups (within units) according to self-reported exposures but does not cross-tab these with LBP.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Holmström et al. 1992	Cross-sectional	1,773 randomly sampled construction workers (male).	Outcome: (1) LBP history from postal questionnaire. Back pain defined as pain, ache, or discomfort in lower back, including gluteal regions with or without radiating pain into leg/s experienced sometime, often, or very often during past year, (2) $ for 1 to 7 days, (3) with any degree of functional impairment. A sample of workers had clinical exam: Active spinal mobility test, springing test, straight leg raising, interspinal and paraspinal palpation from T11 to S1, combined extension and lateral flexion while standing and passive lumbar flexion and extension while lying on one's side. Exposure: Based on questionnaire data reporting of task activity.	1-year prevalence rate LBP 54%; 1-year prevalence for severe LBP 7%.				Participation rate: 76%. Examined medical records for nonrespondents; same as for respondents. Information included individual and employee-related factors, disorders in locomotor system, physical workload, and psychosocial factors. Examiners blinded to case and exposure status. Multiple logistic regression models used; separate models for individual, manual materials handling, and working postures. In univariate analysis, no relationship with daily traveling time, leisure activity, or height and weight. Construction tasks such as bricklaying or carpentry did not affect LBP. Stress index reflected a high achiever person. Longer duration of stooping and kneeling was associated with LBP in all age groups (dose-response). Only severe LBP related to smoking.
				Lifting freq: >1/5 min	<1/5	1.12	*p*<0.001	
				Stooping: >4 hr	seldom	1.29	1.1-1.5	
				Kneeling: > 4 hr	seldom	1.24	1.1-1.4	
				Stress: high		1.6	1.4-1.8	
				Anxiety: high		1.3	1.1-1.4	

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Huang et al. 1988	Cross-sectional	Subjects consisted of all 24 female full-time workers from school lunch center A and 20 female full-time workers from center B. All 42 workers completed a symptom, health and work history questionnaire and 20 from each center also participated in a physical examination. Six workers from center B declined to participate for personal reasons unrelated to the purpose of the study.	Outcome: Symptoms relating to upper limbs, trunk and lower limbs during the previous month were solicited from a questionnaire, while clinical findings of pain during movements, muscle tenderness, signs of CTS, signs of epicondylitis, and signs of tenosynovitis were documented in a physical examination. Exposure: Ergonomic risk factors included handling heavy objects, holding constrained postures, too much stooping, repetitive use of arms and hands, and poor equipment layout. NLE used to evaluate manual lifting tasks.	Consistently constrained postures: 17 workers (70.8%) Poor equipment layout: 18 workers (75%) Consult physician: 17 workers (70.8%) Muscle tenderness: 5.1 +/- 5.6 Signs of tenosynovitis: 6 workers (30%) Upper back pain:	 3 workers (15%) 3 workers (15%) 5 workers (25%) 0.8 +/-2.3 1 workers (5.0%)	N/A	*p*<0.05 *p*<0.01 *p*<0.01 *p*<0.01 *p*<0.05 significant	Participation rate: All 42 workers completed a symptom, health, and work history questionnaire and 20 from each center also participated in a physical examination. Six workers from center B declined to participate for personal reasons unrelated to the purpose of the study. Center A had a significantly higher prevalence of musculoskeletal complaints, more clinical findings, and greater medical treatment experience than those in center B. The ratio of the actual lifting load to the Action Limit was also larger in center A than in center B. No significant difference was found between the centers for low back pain. Study design was ecologic. Health outcomes and exposures were examined separately for two centers. Information was not combined for individual participants.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Johanning 1991; Johanning et al. 1991	Cross-sectional mail survey	Employees of the New York City transit system (n=584)	Outcome: Back-pain symptoms in past year, by questionnaire survey. Exposure: Job title. Although, WBV measures were taken for the exposed group, no analyses were presented.	Subway train operators (n=492)	Subway control tower operators (n=92)			Participation rate: Not reported. Controlled for age, gender, job title, employment duration.
				Any back pain, 41%	25%	PRR=1.11	1.04-1.19	Study groups are stable working populations with low turnover rates.
				Sciatic pain		3.9	1.7-8.6	Exposed and unexposed groups are similar with regard to demographics and job histories. Workers with a history of back problems or previous WBV exposure were excluded from the study. Duration of employment not associated with risk. Exposure data was not associated with outcome data in these articles. Vibration measures showed high lateral and vertical acceleration levels.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Johansson and Rubenowitz 1994	Cross-sectional	Subjects were 241 blue-collar (39% females) and 209 white-collar (35% females) workers from eight diversified metal industry companies in Sweden. The participation rate was approximately 90%. Eighty-seven percent of the blue-collar and 95% of the white-collar workers had >2 years experience in their current jobs.	Outcome: Low-back symptoms during the past 12 months as self-reported on the Nordic Musculoskeletal Questionnaire (NMQ), which was supplemented with an additional question regarding the work-relatedness of the symptoms. Exposures: Individual and employee-related variables related to the psychosocial work environment and the physical workload (sitting, manual materials handling, lifting).	Prevalence of low-back symptoms =0.43 (CI 0.37-0.50) for blue-collar workers, which reduced to *p*=0.32 (CI 0.26-0.39) when solely work-related symptoms were considered.	Prevalence of LB symptoms =0.42 (CI 0.35-0.49) among wt. collar workers, which reduced to *p*=0.18 (CI 0.11-0.24) when solely work-related symptoms were considered.	PRR=1.76	1.25-2.47	Participation rate: The participation rate was approximately 90%. Eighty-seven percent of the blue-collar and 95% of the white-collar workers had >2 years experience in their current jobs. Among blue-collar workers 12 of 15 correlation tests regarding workload factors and work-related symptoms were not significant. Among blue-collar workers 10 of 15 partial correlation tests (adjusted for the effects of age and sex) regarding psychosocial job factors and work-related musculoskeletal symptoms were significant. Among blue-collar workers 7 of 15 partial correlation tests regarding psychosocial job factors and musculoskeletal symptoms, according to the NMQ, were significant. Among white-collar workers none of the relationships between the five psychosocial factors and low-back symptoms were significant, whether or not work-related. Calculations of associations based on the NMQ, without an effort to determine the work-relatedness of symptoms, could have a powerful effect-masking result.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Kelsey 1975b	Case-control	Cases were obtained from a population in the age range 20 to 64 years residing in the New Haven SMSA who had lumbar X-rays taken during the period June 1971 through May 1973 at the three hospitals in the area and at the office of two of the private radiologists in New Haven. A total of 217 pairs (89 females and 128 males) was obtained for the comparison of cases and matched controls. For the analysis of cases and unmatched controls, there were 223 cases (91 female and 132 males) and 494 controls (225 females and 269 males).	Outcome: Herniated lumbar intervertebral discs were the outcomes of interest in this study. Three levels of herniated disc were classified: Surgical cases, probable cases, and possible cases. Exposure: Occupation, years of employment, amount of time worked, amount of time spent sitting, type of chair, lifting, pushing, pulling, carrying, lifting frequency, and weight of objects lifted were the exposures of interest.	Sitting >half the time:				Participation rate: 79% cases; 77% controls.
				<35 years	Equal	RR=0.81		
				>35 years	Fewer	RR=2.40	*p*=0.01	Results were similar for two control groups (less strong for unmatched controls).
				Time driving: >half vs. herniation	Fewer	RR=2.75	*p*=0.02	Study design subject to nondifferential recall problems (with regard to case/control status).
				Occupation: Truck driver vs. herniation	Fewer	RR=4.67	*p*=0.02	The association between sedentary occupations, especially those which involve driving, and herniated lumbar discs exists in both sexes and in comparisons between cases and both control groups.
				Lifting vs. herniation	Equal	RR=0.94	*p*=0.10	The strength of this association in those aged 35 and older and the lack of association in those who are under that age suggest that a certain amount of time in sedentary occupations is necessary for an effect to be seen. This study gave no evidence of an increased risk for herniated lumbar discs among males who did lifting on their jobs, and little indication of this among the females. Chance could explain the slight tendency toward significance in the female subjects.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Kelsey et al. 1984	Case-control	Persons in the age range of 20 to 64 years who had lumbar X-ray films or myelograms taken during 1979 to 1981, in one of three hospitals, one neurosurgical private practice, or two orthopaedic private practices in the New Haven and Hartford, CT areas. 232 matched case-control pairs.	Outcome: Status determined on the basis of an interview, diagnostic tests performed by interviewers, and data recorded in medical records. Cases classified as "surgical" cases, "probable" cases, and "possible" cases. Control group composed of persons without known prolapsed disc admitted to the same medical services for conditions not related to the spine. Cases and controls all with recent (within 1 year) disease onset. Exposure: Exposure to activities performed on the current job assessed by interview and questionnaire.	N/A	N/A	Lifting: >11.3 kg >25/day: OR=3.5 Lifting: > 11.3 kg >5/day and twisting the body half the time: OR=3.1 Lifting: >11.3 kg while twisting body with the knees almost straight: OR=6.1 Carrying: >11.3 kg 5 to 25/day: OR=2.1 Carrying: >11.3 kg >25 per/day: OR=2.7	1.5-8.5 1.3-7.5 1.3-27.9 1.0-4.3 1.2-5.8	Participation rate: 72% cases; 79% controls. All case categories combined in case-control analyses (same results observed for all categories). Controls matched with cases on sex, age and hospital service. Frequent twisting alone did not affect the risk of prolapsed disk, while twisting with lifting had a detrimental effect. Study design subject to nondifferential recall problems (with regard to case/control status).

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

				MSD prevalence				
Study	**Study design**	**Study population**	**Outcome and exposure**	**Exposed workers**	**Referent group**	**RR, OR, or PRR**	**95% CI**	**Comments**
Knibbe and Friele 1996	Cross-sectional (study intended to provide baseline data for longitudinal study).	355 females employed as community nurses or community nurse auxiliaries by the home care organization of the city of Rotterdam.	Outcome: Questionnaire, developed from Nordic questionnaire for musculoskeletal disorders, mailed to nurses. Exposure: Questionnaire asked (1) if nurses could describe any work tasks they considered physically demanding, and (2) whether the onset of back pain was related to a specific work situation. Also job title: Community nurses vs. Auxiliaries.	Lifetime LBP prevalence: 87% 1-year LBP prevalence: 66.8% Auxiliaries: 61.2 1-week LBP prevalence: 20.6% Prevalence of sick leave due to back pain in previous 3 months: 9.7%	N/A	õ Back pain in last 7 days, community nurses vs. community nurse auxiliary: OR=0.84 Backpain in previous 12 months; community nurses vs. community nurse auxiliary: OR=1.54	õ 0.49-1.45 0.97-2.47	Participation rate: 94%. Males and pregnant females excluded from sample. 89.9% of nurses described situations they considered physically demanding. 82.1% of tasks described involved patient transfers. Static load on the back was mentioned in 23.2% of descriptions. Prevalence appeared to decrease with age. Cross-sectional study design prevented investigators from determining whether observation was due to selection effect or due to experience. Rates for community nurses and auxiliaries do not reflect significant differences in hrs worked/week (30.7 vs. 26.2). Adjusted for hrs worked OR is 1.3 (auxiliaries higher). Authors state that auxiliaries are responsible for more lifting activities.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	Referent group	RR, OR, or PRR	95% CI	Comments
Leigh and Sheetz 1989	Cross-sectional	959 working males and 455 working females in the United States employed >20 hr/week.	Outcome: LBP based on national survey of working conditions. Question: "Is the trouble with back or spine in past year?"	1-year LBP past prevalence: 19.4% males 20.7% female	Managers and Professional			Participation rate: Not reported. (Probably to national survey).
								Workers in jobs requiring "lots of physical effort and lots of repetitive work report more back pain.
		(U.S. Department of Labor QES Survey respondents.)	Exposure: Defined by job title and questionnaire on work conditions, including workload.	Occupations:				
				Farmers	Managers	5.17	1.57-17.0	
				Clerical	Managers	1.38	0.85-2.25	Exposure information based on self report and job title.
				Operator	Managers	2.39	1.09-5.25	
				Service	Managers	2.67	1.26-5.69	Health outcome did not distinguish between upper and lower back pain.
				Job demands: High	Low	1.68	1.05-2.90	
				Smoker	Non smoker	1.48	1.00-2.19	Gender, race, obesity, height, and repetitious work are not significantly associated with back pain.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Liles and Deivanayagan 1984	Prospective	28 companies, 63 jobs in study 1, 38 in study 2. Selected jobs with frequent lifting requirements; manual handling requirements. Study 1: 220 males; 24 females. Study 2: 165 males; 44 females.	Outcome: Lifting injury to back, as recorded or reported. Exposure: Jobs rated by Job Severity Index for lifting (observation, use of records for calculation). Each individual followed until job change (up to 2 years). Total of 529 FTEs divided equally into 10 SI levels.	Total injuries: Injury rate for the highest job severity index category: 17.1 injuries/100 FTES	Total injuries: Injury rate for the lowest job severity index category: 3.8 injuries/ 100 FTES	RR=4.5		Participation rate: Not reported (all volunteers). Dose response for lifting injuries by JSI. No adjustment for confounders. Outcome defined as lifting injuries. Not distinct from exposure.
				Disability injury rate for the highest job severity index category: 11.4 lost time injuries/100 FTES	Disability injury rate for the lowest job severity index category 3.0 lost time injuries/100 FTES	RR=3.0		
				Severe injury rate for highest job severity index category: 120.8 days lost/number of lost time injuries	Severe injury rate for the lowest job severity index category 3.0 days lost/number of lost time injuries	RR=40		

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Magnusson et al. 1996	Cross-sectional	Bus drivers, truck drivers, and sedentary workers recruited in the state of Vermont and Gothenburg, Sweden	Outcome: Back pain symptoms, by questionnaire. Exposure: Ergonomic exposures, by questionnaire and vibration level measurements according to ISO standards. Long-term vibration exposure calculated as product of daily exposure and years driving.	Bus drivers (n=111) and truck drivers (n=117)	Sedentary workers (n=137)			Participation rate: Not reported. ORs do not appear to be from multivariate analyses including other covariates, except as stated. Quantitative exposure measures are not used in analyses that are presented.
				Driving		1.79	1.16-2.75	
				Freq. lifting		1.55	1.01-2.39	
				Heavy lifting		1.86	1.2-2.8	
				Long-term vibration exposure		2.0	0.98-4.1	
				Vibration and freq. lifting		2.1	0.8-5.7	
				Vibration and heavy lifting		2.06	1.3-3.3	

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Magora 1972	Cross-sectional	A previous article (1970) described the process for selecting 3,316 individuals from 8 occupations for inclusion into this study.	Outcome: The outcome variable, low-back pain, was defined in a previous article [1970]. Symptoms by self-report. Exposure: The physical activities studied in this investigation were sitting, standing, weight lifting, and weight lifting technique.	The exposed group consisted of workers from 8 occupations. The selection process was described in an earlier article by the same author [1970].	The controls consisted of 2887 individuals from 8 occupations. The selection process was described in an earlier article by the same author [1970].		NR	Participation rate: Not reported. The use of two hands to lift a load, and especially holding the load away from the body, are related to a higher incidence of LBP. The lifting risk factors are magnified when completing unaccustomed tasks. Rarely sitting reported to be associated with LBP. Standing less than 4 hr daily reported to be associated with LBP. Variable sitting and standing reported to be protective.
				Sitting > 4 hr day:				
				Often:		0.95	0.8-1.14	
				Sometimes:		0.09	0.05-0.14	
				Rarely:		3.20	2.69-3.8	
				Standing Variable:				
				< 4 hr daily		2.38	1.99-2.85	

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence				Comments
				Exposed workers	Referent group	RR, OR, or PRR	95% CI	
Magora 1973	Cross-sectional	A previous article (1970) described the process for selecting 3,316 individuals from 8 occupations for inclusion into this study by observation and interview.	Outcome: The outcome variable, low-back pain, was defined in a previous article (1970). Exposure: The physical activities studied in this investigation were bending, rotation, reaching, sudden maximal efforts, and the number and type of work breaks, by observation, and interview.	The exposed group consisted of workers from 8 occupations. The selection process was described in an earlier article by the same author (1970). Among those with LBP: Bending: Often: 14.5% Sometimes: 3.4% Rarely: 23.2% Spine rotation: Often: 12.1% Sometimes: 22.0% Rarely: 10.3% Sudden maximal efforts: Often: 18.0% Sometimes: 11.3% Rarely: 10.9%	The controls consisted of individuals from 9 occupations. The selection process was described in an earlier article by the same author (1970). Among controls: Bending: Often: 85.5% Sometimes: 96.6% Rarely: 76.8% Spine rotation: Often: 87.9% Sometimes: 78% Rarely: 89.7% Sudden maximal efforts: Often: 82% Sometimes: 88.7% Rarely: 89%	Sudden maximal physical efforts were found to be related to a high incidence of LBP. Sudden maximal efforts and LBP: 1.65	Not reported 1.3-2.1	Participation rate: Not reported. It appears that sudden maximal efforts, especially if unexpected, play an important role in the causation of LBP. Many of the physical causative factors, such as bending or rotation, found by other investigators to be related to a high incidence of LBP are actually sudden maximal efforts incidentally carried out at that moment in a certain position of the spine. While most bending, twisting, and reaching motions required by each occupation are knowingly carried out, sudden maximal physical efforts are characterized by their unexpectedness. This may actually trigger LBP through sudden strain of soft tissues, possibly caught in a condition or posture < optimal for this kind of effort.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Marras et al. 1993 Marras et al. 1995	Cross-sectional	403 industrial jobs from 48 manufacturing companies: e.g., automobile assembly, food processing, lumber and wood, construction, metal and paper production, printing, and rubber production. No data provided on the number of workers in study.	Outcome: Existing medical and injury records in each industry were examined for each job to determine if workers on those jobs had reported work-related low-back disorders. The result yielded an outcome measure of "LBD risk," which was a normalized rate of work-related LBD. Exposure: A triaxial electrogoniometer was worn by workers to record position, velocity and acceleration of the lumbar spine while workers lifted in either "high" or "low" risk jobs. Workplace and individual characteristics were recorded. High risk exposed was >12% injury rate, yielding 111 high risk jobs, while 124 jobs were low risk, serving as the control group.	Maximum load moment: 73.65 Nm Sagittal mean velocity: 11.74 E/sec Maximum weight: 104 N 23.3 lb	23.64 Nm 6.55 E/sec Maximum weight: 37 N 8.3 lb	5.17 3.33 3.17	3.19-8.38 2.17-5.11 2.19-4.58	Participation rate: Numbers and proportions of those sampled by job group. No information on number of individual participants. Study provides linkage between epidemiologic measures of injury (i.e., "probabilities of high-risk LBD group membership") and select biomechanical and task factors for repetitive lifting jobs. Study illustrates multi-factored nature of injury risk, but it does not indicate the risk of LBD. Quality and accuracy of injury and medical records are unknown. Inaccuracies or underreporting would affect the accuracy of the model. Exposure assessors may not have been blinded to risk status of jobs they were evaluating.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Masset and Malchaire 1994	Cross-sectional	Steel workers (n=618). All male and all under 40 years of age.	Outcome: Interview-based checklist and questionnaire: Back pain defined for three periods: (1) during lifetime, (2) past 12 months, and (3) past 7 days by the question, "Did you have any problems in the lower back?" Exposure: Interview-based exposure assessment using checklist: postures and movements of the trunk, efforts, physical and psychosocial environment (monotony, responsibility), vehicular driving and exposure to whole body vibration.	Lifetime LBP prevalence for all workers: 66% 1-year LBP prevalence for all workers: 50% 1-week LBP prevalence: 25% Prevalence of sciatica was low: 2-3%	N/A	Õ Vehicle driving: 1.15 Heavy efforts of the shoulder: 1.62 Seated posture: 1.46	 <0.005 <0.01 0.09	Participation rate: 90%. Low back fatigue accounted for 25% LBP cases. No objective measure of workload. Stratified by age and exposure risk level. Ergonomic redesign prior to study, reduced ergonomic hazards. Physical workload, posture, movements of the trunk, repetition, negative perception of working environment, exposure to WBV, not associated with back pain. Information obtained included demographics, height, weight, medical history, personality, and social status (smoking, sports, satisfaction with family and occupation, abnormal fatigue, temper, headache, depressive tendency, present and past working environment. All long-lasting sick workers excluded from study; may cause survivor bias. Back "fatigue" separated from "back pain." This cross-sectional study was first part of a prospective study. Heavy efforts with shoulders were strongly correlated with LBP.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Partridge and Duthie 1968	Cross-sectional	206 male civil servants (clerical workers), age 15 to 64 years, and 171 male dock workers, age 25 to 64 years.	Outcome: Low-back pain (including lumbar disc disease, pelvic girdle pain, and leg pain). Participants attended an interview at which time a medical and social questionnaire was administered and a medical examination was performed. Complaints classified into 8 categories. Exposure: Based on job title (civil servant or docker).	Dockers: current rheumatic symptoms: 43.2% Low-back pain, 61 dockers (Standardized Ratio (SR) by age 106.1)	Civil servants: current rheumatic symptoms: 34.5% Low-back pain, 33 civil servants (SR 90.4)	RR=1.27	0.98-1.64	Participation rate: 95.7% for dockers and 91.0% for civil servants. Analyses corrected for age. Overall complaint rates did not differ between occupations, despite differences in physical effort requirements. Older civil servants complained of more neck/shoulder pain than dockers of a similar age. Difference attributed to static working postures involving the neck and shoulder. Among civil servants, only 5 weeks (16.1%) of sickness absence in previous year due to back pain. Among dockers, 75 weeks (68%) of work lost attributed to lumbar disc disease and backache. Authors conclude that there is a positive correlation between the heaviness of work and time lost due to back complaints, even if the complaint rate in different occupations does not vary significantly. Medical examiners probably not blinded to exposure status.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Punnett et al. 1991	Case-referent (retro-spective)	219 automotive assembly workers. 95 cases compared to 124 referents without back pain.	Outcome: Back pain cases: (interview and exam) defined as workers who filed new reports of back disorders at plant during a 10-month period. Back pain in interview defined as history of $ 3 episodes or $ one episode lasting $ one week within the year preceding the date of the interview. Physical exam consisted of active, passive, and resisted motions concentrating 11 ranges of motion of the back. Referents: No report of back disorders. Exposure: Based on video analysis of job postures and bio-mechanical data	84% (185)	20 workers unexposed	Non-neutral postures: 4.9 Mild flexion: 5.7 Severe flexion: 5.9 Time in non-neutral posture: 8.09 Lift 44.5N: 2.16 Age (years): 0.96 Back injury: 2.37	1.4-17.4 1.6-20.4 1.6-21.4 1.5-44.0 1.0-4.7 0.9-1.0 1.3-4.3	Participation rate: 84%. Healthy worker effect. Of the 124 referents, only 20 workers were unexposed to all awkward postures. Back disorders were found to be associated non-neutral trunk postures. 69% of subjects in job <5 years. Questionnaire involved demographics, work history, medical history, and non-occupational activities. Analyses controlled for gender, age, length of employment, recreational activity, medical history, and maximum weight lifted in study job. Exposure variable for non-neutral posture: The sum of the duration spent in non-neutral postures as a continuous variable. A strong trend found for increasing length of exposure and risk of back disorders to both mild and severe trunk flexion. Only current job analyzed: Assumes short-term relationship between outcome and exposure (however, also included duration of employment variables).

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Riihimäki et al. 1989a	Cross-sectional mail survey	Longshoremen, earth moving equipment operators (WBV), carpenters (heavy physical work), and office workers (sedentary work) (n=2,223)	Outcome: Back pain symptoms, by questionnaire. Exposure: Job title and questionnaire responses regarding work history, physical work factors, and work stress.	Longshoremen (n=542), earth movers (n=311), and carpenters (n=696)	Office workers (n=674)			Participation rate: $70%. Longshoremen and earthmovers combined in analysis (machine operators).
				Sciatic pain and machine operators		1.3	1.1-1.7	After adjustment for age, duration of employment was not associated with symptoms in any group.
				Sciatic pain and carpenters		1.0	0.8-1.3	Of the three back symptoms, sciatica, lumbago, and LBP, sciatica discriminated the best among occupational groups.
				Sciatica and twisted or bent postures		1.5	1.2-1.9	
				Sciatica and annual driving		1.1	0.9-1.4	All three exposed groups were exposed to $ one work-related risk factor for back disorder.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Riihimäki et al. 1989b	Cross-sectional	216 concrete workers compared to 201 house painters (all male), age-matched. Restricted to workers with 5 years work experience and to workers <55 years.	Outcome: Radiographically detectable degenerative changes in lumbar region. Exposure: Based on job title (article refers to Wickström [1985] evaluation of concrete reinforcement workers).	Grade 2 to 3 disc problem: 27.8% concrete workers Back problems: 55% Sciatic: 53%	Grade 2 to 3 disc problem: 15.4% house painters Back problems: 45% Sciatic: 39%	N/A Occupa-tion effect of concrete work: OR=1.8 Age: OR=6.5 Spondy-lophytes Occupa-tion effect of concrete work: OR=1.6 Age: OR=14.9	*p*=0.001 1.2-2.5 1.7-26 1.2-2.3 2.3-95	Participation rate: 84% concrete workers and 86% house painters. Examiners (radiologists) blinded to case or exposure status. Age, self-reported back accidents, body mass index, height, and smoking controlled for in analysis. Height, weight, smoking no effect on degenerative X-ray changes. Negative bias for occupational factor due to healthy worker effect. Positive bias due to recall for identifying accidents as risk factors. Individual exposure data not available for workers. Radiographically detectable degenerative changes associated with sciatic pain (1.0, 1.4, 1.9) for three grades of degeneration (not for LBP or lumbage). No hypotheses regarding specific risk factors. Exposure assessed by job title only.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	RR, OR, or PRR	95% CI	Comments
Riihimäki et al. 1994 Pietri-Taleb et al. 1995	Prospective (3-years)	Machine (heavy equipment) operators (688), carpenters (533), and office workers (591). All males.	Outcome: Based on 2 Postal questionnaires; LBP=Low-back symptoms in preceding 7 days, 12 months, and lifetime. Sciatic pain = pain radiating to leg/s.	22% machine operators	14% office workers	1.4	0.99-1.87	Participation rate: For follow-up: 81% machine operators, 79% carpenters, and 89% office workers.
				24% carpenters		1.5	1.1-2.1	Questionnaire included age, level of education, annual car driving, weekly physical exercise, occupational exposure, and history of other back problems.
			Exposure: Based on specific occupation: Machine operators were exposed to static loads, low-level, whole body vibration. Carpenters exposed to dynamic physical work. Office workers were sedentary workers.	Physical exercise > once a week	Maximum physical exercise once a week.	1.26	1.0-1.6 ($p<0.06$)	Questionnaires administered in 1984 and 1987. Separate logistic regression models created for specific occupation.
				Smokers and ex-smokers	Non-smokers	1.29	0.98-1.7 $p<0.06$)	History of other types of low back pain predicted sciatica in all groups.
			Questionnaire asked amount of twisted or bent postures, pace of work, monotonous work, problems with co-workers or superiors, draft, cold, vibration.	History of lower back pain: Mild LBP; Severe LBP	None	2.7 4.5	1.7-4.2 2.7-7.6 ($p<0.001$)	Monotonous work, problems with co-workers or supervisors, and high-paced work were not associated with sciatica three-year cumulative Incident Rate. Article examines only sciatic pain.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Ryden et al. 1989	Case-control	Cases consisted of 84 employees with back injuries and 168 controls (matched triplets). Mean age was 34 and 83.3% were female. Cases: Employees with injuries from job-related activities that occurred during the working day, not based on individual lost time from the job or workers' compensation. The incidence rate at the work site during the study period was 29/1,000 in 1983, 29/1,000 in 1984 and 33/1,000 in 1985. Controls selected from the same population by age, sex, and department. For each case, two controls were selected from a list of all employees, stratified by department. Matching for age was done within a 5-year span.	Outcome: Reported work-related low-back injuries while employed at the site of the study during the time period of 1983 through 1985. Exposures: History of previous back injury at work, work shift, heavy work, lifting, bending, slipping, self-reported low-back pain or "slipped disc," and individual risk factors.		Low-back pain: OR=2.27	Previous back injury: OR=2.13 Working day shift: OR=2.23 Low back pain: OR=2.27 Self-report slip disc: OR=6.20	1.07-4.24 1.28-3.89 1.25-4.12 2.64-14.57	Participation rate: Not reported. Disadvantages of the design include: a lack of detailed information that could have helped to focus on selected risk factors. For example, knowledge of pack-years rather than only number of cigarettes smoked/day would have been valuable, if available, as would more specific information on body build, including percent body fat and fitness level, rather than using height/weight and self-reported exercise level. Advantages of the design included economy, time savings, flexibility, and the analysis of a large group of risk factors simultaneously. Immediate reporting of injuries, including the nature of the injury and pertinent data regarding where and how the injuries occurred, is essential to efforts both to reduce injuries and to rehabilitate those who are injured. Cases and controls were (over) matched on occupation risk factors. Could not examine these effects. Those working day shift felt to have greater physical demands.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Schibye et al. 1995	Longitudinal	Follow-up of 303 sewing machine operators at nine factories representing different technology levels who completed questionnaire in 1985. In April 1991, 241 of 279 traced workers responded to same questionnaire.	Outcome: Based on Nordic Questionnaire: pain in the last 12 months in the low back (last 7 days). Exposure: Assessed by questions regarding: (1) type of machine operated, (2) work organization, (3) workplace design, (4) units produced/day, (5) payment system, and (6) time of employment as a sewing machine operator.	Prevalences of LBP in Sewing jobs: 12-month: LBP: 1985=38% 1991=47% Prevalences 1-week: LBP: 1985=23% 1991=25%				Participation rate: 1985: 94%; 1991: 86%. All participants were females. 77 of 241 workers still operated a sewing machine in 1991. 82 workers had another job in 1991 among those 35 years or below, 77% had left job; among those above 35 years 57% left job. 20% reported musculoskeletal symptoms as the only reason for leaving job. Healthy worker effect. Another 13% said symptoms were part of the reason. No significant changes in prevalences among those employed as sewing machine operators from 1985 to 1991; significant decrease in those who changed employment. As many as 50% of respondents reported a change in the response to positive or negative symptoms from 1985 to 1991. This was due to a decrease in the risk factors: e.g., decreased in output and hrs worked/week. Article examines only neck/shoulder area in detail (no exposure analyses for back outcome).

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Skov et al. 1996	Cross-sectional	1,306 Danish salespersons	Outcome: Musculoskeletal symptoms, by questionnaire. Exposure: Self-reported driving distance, time in sedentary work, lifting of heavy loads, psychosocial job characteristics.	Danish salespersons (n=1,306) Annual driving distance Sedentary work (% of worktime)	No unexposed group included	Annual driving distance, highest category: OR=2.79 Sedentary work (% of worktime) highest category: OR=2.45	1.5-5.1 1.2-4.9	Participation rate: Not reported. Covariates considered in multivariate analyses included age, sex, height, weight, smoking, work-related psychosocial variables, lifting, leisure time sports activities. No unexposed group was included.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Skovron et al. 1994	Cross-sectional	4,000 random-stratified sampled adults in Belgium; a bicultural country, uniform health care system; 48% male. Population-based telephone survey.	Outcome: Based on back pain symptom reporting from structured interviews. Back pain defined by question "Have you ever had back pain?" Cases restricted to those subjects currently working. Exposure: Based on interview data: occupation and working status, "Are you satisfied with work" question..	Point prevalence LBP: 33% Lifetime prevalence: 59% Among workers occupation: Work dissatisfaction: Female gender: Increasing age:		 NS 2.4 2.16 2.0	 p=0.02 p=0.001 p=0.001	Participation rate: 86%. Information included age, gender, social class, habitat, language, working status, occupation, work satisfaction, lifestyle factors, and family history. Logistic regression models controlled for age, and gender; interaction tested. First episode of back pain not associated with work satisfaction. Language influence reporting of first time occurrence and history of back pain but not severity of impairment as expressed as daily back pain. Uniform health care assured equal access and reporting. Results suggest that work satisfaction is not a cause of LBP, but it intervenes in the expression of LBP.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Svensson and Andersson 1989	Cross-sectional	Random sample of 1,760 38 to 64-year-old females from Goteborg, Sweden. At the time of the investigation, 14 females could not be located. Approximately 80% of the final sample of 1,746 females participated in the study.	Outcome: Low-back pain (LBP) was defined as all conditions of pain, ache, stiffness, or fatigue localized to the lower back. All episodes of LBP were included in the study, as determined by questionnaire. Exposure: Variables included working hr, working hr/week, amount of overtime, lifting, frequency of forward bending and twisting, work posture, possibility to change work posture, need to concentrate, monotony, satisfaction with work tasks, possibility to take rest breaks, worried and tense after work, fatigued at the end of the work day, and education. Exposed and unexposed were determined by questionnaire responses.			Univariate analysis found significant correlations between LBP and 5 exposures in ages 50-64 years: More bending, lifting, standing, higher degree of worry, and exhaustion at the end of the work day.	$p<0.05$ $p<0.01$ $p<0.01$ $p<0.01$ $p<0.0001$	Participation rate: Approximately 80% of the final sample of 1,746 females participated in the study. The analysis of correlations between the occurrence of LBP and the different variables describing work history, work environment, and stress was restricted to wage-earning females only (sick-listed included). No significant differences existed between the two age groups concerning the incidence and prevalence rates of LBP. However, several parameters indicated that the LBP in the older age group was more severe. Several of the correlations in the univariate analysis, when tested in the covariate analysis, were found to be dependent on other confounding factors. The findings in the present study stress the importance of psychological factors in relation to low-back pain. These factors are probably not only related to the individual's personality but also to the type of work and the environment at the workplace. Medical examiners discussed questionnaires with participants—not blinded.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Toroptsova et al. 1995	Cross-sectional	701 random-stratified sampled employees of a Russian machine building plant 47% male.	Outcome: LBP history from structured interviews. Back pain defined as pain lasting in area below 12th rib and above gluteal folds. All persons with LBP complaints examined by rheumatologist. Exposure: Based on interview data: Work, sports, and personal factors. 10 industrial factors examined: Lifting, standing, sitting, walking, vibration, static work, postures, repetitive work, and bending.	Frequent trunk flexion Frequent lifting required in job	No trunk flexion Occasional lifting (2 or less/day)	1.66 1.43	*p*<0.01 *p*<0.05	Participation rate: 88%. Analysis did not control for confounders. Information included personal data, family status, education, profession, anthropometric data, smoking, sport activity, and professional factors. Lifetime prevalence: 48%. Prevalence higher among older workers and smokers >10/day. Back pain decreased in group >55 years. The year of retirement for females. No association with sitting or standing postures, walking, vibration, static work postures, and repetitive work.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Undeutsch et al. 1982	Cross-sectional	366 male cargo transport workers at a large airport. (Baggage handlers).	Outcome: Standardized interview administered to all workers to detect subjective previous and present back symptoms. Clinical orthopaedic examination administered to 134 workers to detect objective findings. Exposure: Data on work experience in the present occupation was collected. No other exposure data collected.	Prevalence of previous back complaints: 56% Prevalence of present back symptoms: 66% Prevalence of objective back findings at examination: 70%	N/A	N/A	N/A	Participation rate: Not reported (46% of target population included). Current back symptoms positively correlated with height, age, and length of experience in transport work. Among workers with present symptoms, symptoms occurred most frequently during lifting of loads (75%) and while in bended body positions (61%). Changing body position (71%) and absence of work for one or more days were relieving factors for back symptoms. Comparison of interview and clinical exam results show interview to be a suitable screening method for clinical back pain (sensitivity=86%, specificity=31%). Significant association between length of transport work and back symptoms (*p*=0.035) adjusted for age. No heterogeneity with regard to exposure.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Videman et al. 1984	Cross-sectional	562 nurses and 318 nursing aides in Finland, all of them females.	Outcome: Based on results from a pre-tested questionnaire and from health information obtained from the local Pension Registers that were used to identify nurses who had been pensioned due to ill health during a 4-year period immediately preceding the mailing of the questionnaire. Exposure: Based on self-assessments from data obtained using a mailed questionnaire that included nine questions on physical loading factors at work and seven questions on work history and occupation. Jobs were reclassified as heavy, intermediate, and light based on results of questionnaire items dealing with workload.	85% of aides had $ one "life-time" episode of LBP and their point prevalence was 50% for LBP. Sciatica: 43% life-time prevalence. Aides had twice the lifting, bending and rotation.	79% of nurses had experienced $ one "life-time" episode of LBP; point prevalence was 41% for LBP Sciatica: 38% life-time prevalence	$ one "life-time" episode of LBP: 1.1	1.01-1.14	Participation rate: 88% nurses; 85% nurses aides. Workers with back pain were employed in heavy jobs on average 1 year longer than those with no previous LBP. Musculoskeletal disorders as a cause of disability increased with age; the 30-years risk for 25-years old aides was 3.4 times greater than for the nurses; similar results for sciatica with a risk of 4.5 times greater for the aides than nurses. The prevalence of LBP and sciatic symptoms in both nurses and in aides are high and similar to the results found in Britain. Physical workload related to patient handling was mainly responsible for the differences in LBP and sciatica rates between the aides and nurses. The finding was most evident under the age of 30 years. Non work-related factors, such as childbirth, also contributed to the adverse back conditions. Study lacks a good unexposed population since both nurses and aides were exposed to varying degrees of risk factors for LBP and sciatica. Workers with LBP were in heavier jobs for longer time than those without LBP.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

				MSD prevalence				
Study	Study design	Study population	Outcome and exposure	Exposed workers	Referent group	RR, OR, or PRR	95% CI	Comments
Videman et al. 1990	Cross-sectional	From a Finnish workforce of 86 males who had worked in four distinct occupational groups: Sedentary, Mixed, Driving, and Heavy. Criteria for inclusion: Deceased below the age of 64 who had been employed before death and the subjects' family able to provide working information. Exclusion criteria were long illnesses or a diseased state, such as cancer or infectious disease.	Outcome: Objective radiologically and discography-based pathologic criteria from the cadaver spines of the study population. Degree of degeneration was outcome measure, i.e., annular ruptures. Information on symptoms was obtained from family members. Exposure: Type of work, based on work history reports from family; classification of work based on heaviness, driving, and sedentary jobs. Classification based on physically heaviest occupation held for $ 5 years.	54% of heavy workers had LBP often, and 36% had sciatica 50% of drivers had LBP often, and 29% of them had sciatica Heavy physical load vs. not: OR=2.8 Sedentary vs. not: OR=24.6 (symmetric disc degeneration)	10% of sedentary workers had LBP often, and 19% had sciatica 29% of mixed group had LBP often, and 10% had sciatica	Heavy vs. Mixed: 2.7 Driving vs. Mixed: 2.3 Sciatica: NS	1.1-6.2 0.8-6.2	Participation rate: Not reported. Strength: First study linking pathologic data with history of occupation and physical loading factors. Weakness: Do not know the temporal pattern in development of the pathologic changes. Possible selection bias due to potential differential rates between work groups in leaving jobs because of degenerative diseases. Two important findings: Sedentary or heavy work contribute to the development of pathologic findings in spine. Severity of back pain was related to the heaviness of work, i.e., work factors responsible for development of pathologic changes and for the production of pain. Back pain more common with physically more loading occupations; *p*<0.001. Similar but weaker trend between loading and sciatica; *p*=0.03. General: *p*<0.01 between groups for back pain; and *p*<0.07 for sciatica. Relationships were observed between report of symptoms and disc pathology; also, exposures and disc pathology.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	Referent group	RR, OR, or PRR	95% CI	Comments
Walsh et al. 1989	Cross-sectional	A postal questionnaire was sent to a random sample of 267 males and 268 females in the age range of 20 to 70 who lived in Whitchurch, England. Four hundred, thirty-six questionnaires were returned, giving an overall response rate of 81%.	Outcome: Self-reported low-back pain, by interview. Exposure: Standing or walking for > 2 hr; sitting for > 2 hr; driving a car or van for > 4 hr; driving a truck, tractor or digger; lifting or moving weights of 25kg or more by hand; or using hand held vibrating machinery were the exposures of interest. Lifetime occupational history obtained by interview.	Lifetime incidence of LBP was 63%.				Participation rate: 436 questionnaires were returned, giving an overall response rate of 81%. The association with use of vibrating machinery among females (repetitive risk=5.7) was based on only one exposed case. Cases of low-back pain were ascertained solely on the basis of reported symptoms. Successive birth cohorts reported the development of low-back pain at any given age with increasing frequency. Driving a car for >4 hr a day was associated with low-back pain in males but not with low-back pain in females. Authors believe the data give strong support for a role of regular heavy lifting in the etiology of low-back pain and add weight to the evidence implicating occupational driving as a risk factor. At the same time, however, they suggest that such activities account for only a small proportion of the total burden of low-back pain in the general population. Author's estimates of the fraction of disease attributable to heavy lifting and car driving are 14 and 4%, respectively, leaving a substantial proportion of cases unexplained. Authors attempted to recreate a retrospective cohort design; asked participants to remember dates and jobs and LBP. Questionable recall for temporal relationships.
				Recent Occup. Activity:				
				Males				
				Driving>4hr/d		RR=1.7	1.0-2.9	
				Lifting 25kg		RR=2.0	1.3-3.1	
				Females				
				Lifting 25kg		RR=2.0	1.1-3.7	
				Lifetime Occup. Activity:				
				Males				
				Lifting 25kg		RR=1.5	1.0-2.4	
				Females				
				Sit >2hr/d		RR=1.7	1.1-2.6	
				Vib. machine		RR=5.7	1.1-29.3	
				Risk of unremitting LBP:				
				Males				
				Lifting 25kg		RR=5.3	1.3-20.9	
				Females				
				Lifting 25kg		RR=2.9	0.8-10.2	

CHAPTER 7

Work-Related Musculoskeletal Disorders and Psychosocial Factors

SUMMARY

While the etiologic mechanisms are poorly understood, there is increasing evidence that psychosocial factors related to the job and work environment play a role in the development of work-related musculoskeletal disorders (MSDs) of the upper extremity and back. Though the findings of the studies reviewed are not entirely consistent, they suggest that perceptions of intensified workload, monotonous work, limited job control, low job clarity, and low social support are associated with various work-related musculoskeletal disorders.

As some of these factors are seemingly unrelated to physical demands, and a number of studies have found associations even after adjusting for physical demands, the effects of these factors on MSDs may be, in part or entirely, independent of physical factors. It is also evident that these associations are not limited to particular types of jobs (e.g., video display terminal work [VDT]) or work environments (e.g., offices) but, rather, seem to be found in a variety of work situations. This seems to suggest that psychosocial factors may represent generalized risk factors for work-related MSDs. These factors, while statistically significant in some studies, generally have only modest strength.

At present, two of the difficulties in determining the relative importance of the physical and psychosocial factors are: (1) psychosocial factors are usually measured at the individual level, while physical factors are more often measured at the group (e.g., job or task) level and often by methods with limited precision or accuracy and (2) “objective measures" of aspects of the psychosocial work environment are difficult to develop and are rarely used, while objective methods to measure the physical environment are more readily available. Until we can measure most workplace and individual variables with more comparable techniques, it will be hard to determine precisely their relative importance.

INTRODUCTION

There is considerable confusion regarding the contribution of psychosocial factors to musculoskeletal illness and injury. Because of this, it is examined in this separate section of the report. Unlike the more finite (and generally more familiar) range of physical factors (e.g., force, repetition, and posture), the concept of psychosocial factors includes a vast array of conditions. Indeed, the term “psychosocial” is commonly used in the occupational health arena as a catchall term to describe a very large number of factors that fall within three separate domains: (1) factors associated with the job and work environment, (2) factors associated with the extra-work environment, and (3) characteristics of the individual worker. Interactions among factors within each of these domains constitute what is referred to as a “stress process,” the results of which are thought to impact upon both health status and job performance [Bongers and deWinter 1992; ILO 1986; Sauter and Swanson 1996; WHO 1989].

Included in the domain of job and work environment are a host of conditions, sometimes referred to as "work organization factors," which include various aspects of job content (e.g., workload, repetitiveness, job control, mental demands, job clarity, etc.); organizational characteristics (e.g., tall versus flat organizational structures, communications issues); interpersonal relationships at work (e.g., supervisor-employee relationships, social support); temporal aspects of the work and task (e.g., cycle time and shift work); financial and economic aspects (e.g., pay, benefit, and equity issues); community aspects (e.g., occupational prestige and status). These work and job environment factors are often thought of as demands, or "risk factors," that may pose a threat to health [Hurrell and Murphy 1992]. Extra-work environment parameters typically include factors associated with demands arising from roles outside of work, such as responsibilities associated with a parent, spouse, or children. Finally, individual worker factors are generally of three types [Payne 1988] corresponding to: genetic factors (e.g., gender and intelligence); acquired aspects (e.g., social class, culture, educational status); and dispositional factors (e.g., personality traits, and characteristics and attitudes such as life and job satisfaction).

PSYCHOSOCIAL PATHWAYS

The purpose of this discussion is to summarize research evidence linking work-related psychosocial factors, as described above, to MSDs of the neck, shoulder, elbow, hand/wrist, and back. It should be recognized at the outset, however, that the linkages between work-related psychosocial factors and health outcomes of all varieties are often complex and influenced by a multitude of conditions. In particular, both personal and situational characteristics may lead to differences in the way individuals exposed to the same job and work environment perceive and/or react to the situation [Hurrell and Murphy 1992]. Recent theoretical models of the relationship between psychosocial factors and MSDs [Bongers et al. 1993; Sauter and Swanson 1996] clearly reflect the complexity and multifactorial nature of the problem.

In general, four plausible types of explanations have been suggested to account for associations between work-related psychosocial factors and MSDs [Bergqvist 1984; Bongers et al. 1993; Bernard et al. 1993; Sauter and Swanson 1996; Sauter et al. 1983; Ursin et al. 1988]. First, psychosocial demands may produce increased muscle tension and exacerbate task-related biomechanical strain. Second, psychosocial demands may affect awareness and reporting of musculoskeletal symptoms, and/or perceptions of their cause. Within this second explanation may fall the "perverse incentive" view, in which societies may provide workers with systems (such as workers' compensation) that may lead to overreporting of MSD symptoms [Frank et al. 1995]. Third, initial episodes of pain based on a physical insult may trigger a chronic nervous system dysfunction, physiological as well as psychological, which perpetuates a chronic pain process. Finally, in some work situations, changes in psychosocial demands may be associated with changes in physical demands and biomechanical stresses, and thus associations between psychosocial demands and MSDs occur through either a causal or effect-modifying relationship.

The research evidence reviewed in the following discussion is organized into two separate sections. The first section includes studies of disorders of the neck, shoulder, elbow, hand and wrist which are discussed under the rubric of “upper extremity disorders.” This convention was adopted because many of the studies utilize measures which combine symptoms associated with several upper extremity body areas (e.g., neck and shoulder), and it is therefore not possible in reviewing these studies to isolate the effects of the psychosocial variables under consideration on more specific areas. The second section examines studies of back disorders. Associations reported in this review are statistically significant in nearly all cases (at the $p<0.05$ level and frequently also at the $p<0.01$ level). Where possible, odds ratios (ORs) are also reported.

The studies examined in this review are summarized in Tables 7-1 and 7-2. In interpreting the studies reviewed, it is necessary to be aware that, in general, researchers have not used standardized methods for assessing psychosocial factors in relationship to MSDs. Thus, individual psychosocial factors assessed by investigators vary from study to study. Moreover, even when work-related psychosocial factors (e.g., workload , job control, social support, job satisfaction, etc.) included by various investigators are the same or similar, they may be measured by different methods and different kinds of scales which can vary in psychometric quality. These methodological limitations complicate the process of drawing definitive conclusions regarding the literature as a whole and when comparing results between studies, one must take these differences into account.

UPPER-EXTREMITY DISORDERS (NECK, SHOULDER, ELBOW, HAND AND WRIST)

Individual and Extra-Work Environment Factors

A variety of psychosocial factors associated with both the individual worker and extra-work environment have been linked to upper extremity MSDs [Sauter and Swanson 1996; Bongers and deWinter 1992; Bongers et al. 1993]. These factors have included such conditions as depression and anxiety [Helliwell et al. 1992], symptoms of psychological distress [Leino 1989], and home problems [Karasek et al. 1987]. The connection between factors of this nature and the job and work environment, however, is unclear. While affective problems (such as anxiety and depression) and symptoms of distress may certainly be a consequence of the work situation, they may also be causally related to non-work circumstances only. Likewise, while extra-work environment conditions (e.g., “home problems") may be exacerbated by the work situation (e.g., shift work) their “work-relatedness” remains unclear. Because of the uncertainty regarding the work-relatedness of these individual and extra-work environment factors (and because discussions can be found in other sources), only the individual psychosocial factor, job dissatisfaction, is examined here.

Job Dissatisfaction

A number of studies suggest associations between low levels of satisfaction with work and upper extremity musculoskeletal symptoms and disorders. Tola et al. [1988], for example, in a study of 1,174 machine operators, 1,054 carpenters, and 1,013 office workers, found an association (OR 1.2) between job dissatisfaction and neck and shoulder physical findings or symptoms, after adjusting for confounders. Likewise, Hopkins [1990] reported a positive association between job dissatisfaction and musculoskeletal symptoms. However, low job satisfaction was not found to predict neck and shoulder problems one year later in a study of 154 Finnish workers [Viikari-Juntura et al. 1991a]. Likewise, in a study of 273 nursing aids employed in a geriatric hospital [Dehlin and Berg 1977] job satisfaction was found to be unrelated to reports of ever having cervical pain.

Job and Work Environment Factors

Intensified Workload

One of the factors most consistently associated with upper extremity MSDs has been the perception of an intensified workload, as measured by indices of perceived time pressure, workload, work pressure, and workload variability. Pot et al. [1987], for example, in a cross-sectional study of 222 VDT operators, found high levels of perceived time pressure associated with the reporting of upper extremity musculoskeletal complaints. Kompier [1988] found perceived time pressure to be associated with upper extremity complaints (in the preceding 12 months) among some 158 male bus drivers. Likewise, Takala et al. [1991], in a longitudinal study of 351 female bank cashiers, reported a positive association between perceived time pressure and symptoms of the neck and shoulder after adjusting for postural load. Theorell et al. [1991], however, in a sample of some 206 workers from six occupations, found that perceived time pressure was not significantly correlated with neck or shoulder symptoms.

Positive associations with upper extremity disorders have also been found in studies using measures of perceived work pressure and workload. High levels of perceived workload, for example, were found to be positively associated with musculoskeletal symptoms in the Pot et al. [1987] and Theorell et al. [1991] studies (which adjusted for physical demands such as lifting and awkward postures) reported above. Kvarnström and Halden [1983], in a case control study of 112 cases and 112 age- and sex-matched controls from an engineering firm, found sick leave due to fatigue or shoulder muscle soreness to be positively associated with high perceived workload. Karasek et al. [1987], in a study of 8,700 full-time members of the Swedish white collar labor union federation, found perceived workload to be positively associated with musculoskeletal aches as measured by a combination of several questions (OR 1.1 for males, 1.2 for females). Likewise, Sauter et al. [1983], in a study of 248 VDT users, found perceived workload and demands for attention to be associated with neck, back, and shoulder discomfort after adjusting for a wide variety of variables denoting physical demands. Bernard et al. [1993], in a study of 1,050 newspaper employees, found perceived increased workload demands (increased time working under deadline and increased job pressure) to be positively associated with neck, shoulder, and hand-wrist symptoms. Similarly, Hales et al. [1994], in a study of 553 telecommunications workers, found increased work pressure to be associated with neck (OR 1.2) and upper extremity (OR 1.1) disorders, as defined by physical examination and questionnaire. Ryan and Bampton [1988], using a total sample of 143 data processors, compared 41 individuals reporting a number of neck symptoms to 28 reporting very few neck symptoms (middle group left out) and found a positive association between symptom reports and reports of having to push themselves (OR 3.9). Ekberg et al. [1994] compared 109 workers who consulted a physician for new musculoskeletal neck and shoulder disorders with 637 controls and found a positive association (OR 3.5) with rushed work pace. Houtman et al. [1994], in a representative sample of 5,865 workers in the Netherlands, found reported high work pace associated with muscle or joint symptoms (OR 1.3) after adjusting for physical stressors and modifying personal characteristics. However, Dehlin and Berg [1977] in the study described above, found no relationship between reports of high perceived physical and psychological demands and reports of ever having pain in the cervical region. Finally, Houtman et al. [1994], in a representative sample of 5,865 workers in the Netherlands, found reported high work pace associated with muscle or joint symptoms (OR 1.29) after adjusting for physical stressors and modifying personal characteristics.

Variability in workload (surges in workload) has also been linked to upper extremity disorders. The studies by Hales et al. [1994] of 553 telecommunication workers and Hoekstra et al. [1994] of some 108 teleservice representatives, found perceived workload variability to be associated with elbow (OR 1.2) and neck (OR 1.2) disorders, but not with shoulder or hand disorders.

Monotonous Work

Monotonous work has been positively linked to the prevalence of upper extremity symptoms in various studies. In a study of 143 data processors, Ryan and Bamptom [1988] found that self-reports of “being bored most of the time” were highly (OR 7.7) associated with neck symptoms. Likewise, Linton [1990], in a study of approximately 22,200 Swedish workers undergoing a screening examination by the occupational health care service, found that monotonous work was positively associated with neck/shoulder pain (OR 2.3) during the preceding year. Ekberg et al. [1994], in the study described above, found an association between “low quality work” (lacking stimulation and variation) and neck and shoulder problems (OR 2.6). Similarly, Kvarnström and Halden [1983] in the case control study described above, found monotonous work to be associated with sick leave due to fatigue or tenderness in the shoulder muscles. Finally, Hopkins [1990] in a study of around 280 clerical workers found high levels of boredom to be associated with musculoskeletal symptoms (in any part of the body) during work hours.

Job Control

Numerous studies have reported positive associations between limited job control or autonomy at work and upper extremity problems. These include neck symptoms [Ryan and Bamptom 1988, OR 3.9; Hales et al. 1994, OR 1.6], neck/back/shoulder symptoms [Sauter et al. 1983; Theorell et al. 1991], musculoskeletal aches [Karasek et al. 1987], and muscle/joint symptoms [Hopkins 1990; Houtman et al. 1994]. The study by Pot et al. [1987], however, failed to support this relationship.

Job Clarity

A number of studies, including those of Ryan and Bamptom [1988], Karasek et al. [1987], and Ekberg et al. [1994], have shown positive associations between reports of role ambiguity (uncertainty about job expectations) and upper extremity disorders (particularly neck disorders). Similarly, uncertainty regarding job future was found to be predictive of neck and shoulder discomfort [Sauter et al. 1983] and elbow, neck, and hand/wrist symptoms [Hales et al. 1994].

Social Support

Limited social support from supervisors and coworkers has been found to be positively associated with a variety of upper extremity symptoms. The studies by Pot et al. [1987], Kompier [1988], Hopkins [1990], Sauter et al. [1983], and Hales et al. [1994], all support a positive association. Linton [1990] reported a positive association between neck symptoms and limited support from supervisors. Ryan and Bampton [1988] reported an effect of limited support from coworkers (OR 6.7), but not supervisors, on neck symptoms, while Kvarnström and Hagberg [1983] reported an effect of limited support from supervisors but not coworkers on sick leave due to shoulder muscle symptoms. Dehlin and Berg [1977], however, found no effect of social support on neck/shoulder symptoms, while Theorell et al. [1991] found no effect of social support at work on neck and shoulder symptoms or symptoms of the other joints (with or without adjustment for physical load). Likewise, Karasek et al. [1987] found no significant association between musculoskeletal aches and social support at work.

Summary and Conclusions for Upper Extremities

Overall, the epidemiologic studies of upper extremity disorders suggest that certain psychosocial factors (including intensified workload, monotonous work, and low levels of social support) have a positive association with these disorders. Lack of control over the job and job dissatisfaction also appear to be positively associated with upper extremity MSDs, although the data are not as supportive.

The evidence for the relationship between psychosocial factors and upper extremity disorders appears to be stronger for neck/shoulder disorders or musculoskeletal symptoms in general than for hand/wrist disorders. This stronger association for neck/shoulder disorders may be due to the following reasons: the large number of studies performed in the Nordic countries which have focused more on the neck/shoulder MSD health outcome than a hand/wrist outcome; many of the neck/shoulder studies included numerous psychosocial variables in their models, whereas studies of hand/wrist MSDs have not, as a rule, included as extensive psychosocial variable testing (therefore the variables are absent from the risk factor models); and the fact that most of the studies with extensive psychosocial scales were in office settings, where physical factors may be less important than psychosocial factors in their relationship with MSDs. This finding can be contrasted with studies in heavy industrial settings, where higher exposure to physical factors may have played a greater role than psychosocial factors in the development of MSDs. Also, pathophysiologic processes resulting from adverse psychosocial and work organization factors may exert a greater effect on the neck/shoulder musculature to produce increased muscle tension and strain than on the hand/wrist region.

BACK DISORDERS

Individual and Extra-Work Environment Factors

As with upper extremity disorders, a host of psychosocial factors associated with the individual worker (e.g., personality and psychological status) and extra-work environment (e.g., living alone) have been linked to back pain and disability [Bongers et al. 1993]. As the "work-relatedness" of these factors is unclear and because they have been examined by others (e.g., Bongers [1993]), with the exception of job dissatisfaction discussed above, they will not be extensively reviewed in this report. In general, these studies show clear associations between measures of psychological distress or dysfunction and self-reported back pain. However, the temporal relationship between psychological factors and musculoskeletal symptoms/ disorders remains unclear. One possibility is that psychological distress is simply a consequence of chronic low back pain, with no etiologic role in the development of the disorder. Alternatively, it is possible that psychological factors may have some etiologic role in the transition from an employee with a history of back pain to the status of an unemployed patient with chronic back pain, due to fear of re-injury, or other factors which would make it impossible to perform the job [Feyer et al. 1992].

While there are a number of prospective studies of low back pain and individual physical factors, there appear to be only a few prospective studies that incorporate individual and extra-work environment psychosocial factors. Bigos et al. [1991b] defined, in a 4-year study of 3,020 hourly wage earners at an aircraft manufacturing plant, an outcome as reporting a back pain complaint to the company medical department, filing a back-related incident report, or filing an industrial insurance claim. The psychosocial assessment included personality traits, as measured by the Minnesota Multiphasic Personality Inventory (MMPI), and limited information on family support, health locus of control, and work social support. One question about enjoyment of tasks in the job was also included. Of the 37 variables used to evaluate the role of social support, health locus of control, and personality traits, three were found to be significant in a multivariate analysis. They were Scale 3 of the MMPI [tendencies towards somatic complaints or denial of emotional distress (relative risk [RR]=1.4), dissatisfaction with work (RR=1.7), and prior back pain (RR=1.7)]. Although significant, these variables explained only a small fraction of the back pain reports in this population. The number of back pain reports was three times higher in the group with the highest scores on these three variables compared with the group with the lowest scores, although only 9% of the work force was in the highest risk group. Because this study focused on the reporting of back pain complaint and not the actual development of back pain, it would be a mistake to generalize the results to workers developing back pain. This study suggests that individual premorbid personality traits only explain a small fraction of work-related lower back problems.

Job Dissatisfaction

Job dissatisfaction has been associated with back disorders in both longitudinal and cross-sectional investigations. Bergenudd and Nilsson [1988], studying some 575 residents of Malmo for over 19 years, found job dissatisfaction to be associated with self-reported back pain. As described above, Bigos et al. [1991b] found a positive association between job dissatisfaction and workers filing compensation claims for back injury. Here, subjects who stated that they "hardly ever" enjoyed their job tasks were 2.5 times more likely to report a back injury than those who "almost always" enjoyed their job tasks. However, as Frank et al. [1995] point out, some reviewers have argued that the airplane manufacturing jobs with the highest levels of dissatisfaction were also the most physically demanding. Frank et al. [1995] also noted that, unfortunately, the extent of the interaction is difficult to assess because of the limited measurement of workplace biomechanical exposures in the Bigos et al. studies [1986a,b; 1991a,b]. While psychosocial and psychological factors were assessed at the individual level, workplace biomechanical factors were assessed only at the group level. Biering-Sorensen et al. [1989], in a one-year follow-up mail survey study of some 928 inhabitants of Denmark (which adjusted for confounders such as previous back pain), also found no association of back pain with job dissatisfaction. Because information was limited to the use of mailed survey questionnaires, no workplace biomechanical factors were measured in this study either.

The cross-sectional study by Dehlin and Berg [1977] of nursing aids described earlier found an association between dissatisfaction and self-reported back symptoms. However, this study did not adjust for confounders. Likewise, Magora [1973] in a mailed survey study of Israeli workers in 8 occupational categories found job satisfaction to be associated with reports of sick leave due to low back pain. This study also did not adjust for potential confounders. Svensson and Anderson [1989], in a cross-sectional study of 1,746 Swedish residents, found an association after adjustment. However, in a cross-sectional study by Åstrand [1987] of 391 male Swedish paper company workers (clerks and manual workers), no association was found between dissatisfaction and back disorders, as assessed by symptoms and physical examination after confounder adjustment.

Job and Work Environment Factors

Intensified Workload

A number of studies have reported associations between perceptions of intensified workload, as measured by reports of time pressure and high work pace, and self-reports of back pain. Heliövaara et al. [1991] in a study of approximately 5,600 Finns, found a composite measure (containing items on perceived time pressure at work, monotony, and fear of mistakes) to be associated (OR 2.0) with back disorders (defined by interview and physical examination) after adjusting for potential confounders, including physical load and previous back pain. Lundberg et al. [1989] found perceived time pressure to be associated with perceived back load among 20 workers on a Swedish assembly line. In a similar vein, Houtman et al.

[1994], in the study of 5,865 Dutch workers across all occupations reported above, found an association (OR 1.21) between reporting high work pace and self-reported back pain (but not chronic back pain problems, defined as back pain for more than three months or at least three times in the study period) (OR 1.2). Magora [1973], in the study of Israeli workers described above, found high levels of concentration to be associated with reports of sick leave due to low back pain (OR 2.9). However, Åstrand [1987], found no association between "hustling" and "nerve wracking work" and back pain in male paper company workers.

Monotony

Several studies described above [Heliövaara et al. 1991; Houtman et al. 1994] have reported associations between perceived monotony and reports of back complaints. Svensson and Anderson [1983], in a study of 940 male residents of Goteborg, Sweden, between the ages of 40 and 47, similarly found monotonous work (rated "absolutely" or "unacceptably" boring) to be associated with back complaints. This relationship remained after adjusting for several physical factors. However, Svensson and Anderson [1989] found no relationship between monotony and back pain complaints among Swedish women in a multivariate analysis which included measures of job and task satisfaction. Similarly, in the Houtman et al. [1994] study, controlling for a combination of physical stressors (dangerous work, heavy physical load, noise at work, dirty work, and bad smell at work) reduced the magnitude of the relationship (for back complaints, the OR decreased from 3.90 to 3.46.) The authors suggest that this may be because monotonous work is often work which is also either short-cycled or involves a high static (postural) load.

Job Control

In the study of teleservice operators cited above, Hoekstra et al. [1994], after controlling for a number of individual and work-related factors, found perceived job control at work to be inversely associated with back disorders (OR 0.6), that is, the less perceived job control at work, the higher the odds of back disorders. Likewise, as noted above, Sauter et al. [1983] found that low job control was related to neck, back, and shoulder discomfort.

Social Support

Bigos et al. [1991b] found a significant univariate relationship between limited social support at work and back trouble. However, this association was found to be nonsignificant by the investigators when included in a multivariate analysis.

Summary and Conclusions for Back Disorders

In general, the studies reviewed suggest an association between back disorders and perceptions of intensified workload as measured by indices of both perceived time pressure and workload. Despite the considerable differences in the types of methods used to assess both the independent and dependent variables, four of the five studies that explicitly included measures of intensified workload found significant associations. It is also noteworthy that all four of these studies attempted to control or adjust for potential covariates. Five of the seven studies that assess job dissatisfaction also found positive associations with back disorders. While this evidence is clearly suggestive, Biering-Sorensen et al. [1989] found no association in a large-scale one-year follow-up study; while Åstrand [1987] likewise found no evidence of an association among 391 paper workers. Limited support for an association between back disorders and low job control is also evident, while the evidence for a relationship between monotonous work and back disorders is mixed. Only one study examined the relationship between social support and back disorders and found only weak evidence for an association.

Overall Conclusions

While the etiologic mechanisms are poorly understood, there is increasing evidence that psychosocial factors related to the job and work environment play a role in the development of work-related MSDs of the upper extremity and back. Though the findings of the studies reviewed are not entirely consistent, they suggest that perceptions of intensified workload, monotonous work, limited job control, low job clarity, and low social support are associated with various work-related MSDs. As some of these factors are seemingly unrelated to physical demands, and a number of studies have found associations even after adjusting for physical demands, the effects of these factors on MSDs may be, in part or entirely, independent of physical factors. It is also evident that these associations are not limited to particular types of jobs (e.g., VDT work) or work environments (e.g., offices) but, rather, seem to be found in a variety of work situations. This observation seems to suggest that psychosocial factors may represent generalized risk factors for work-related MSDs. These factors, while statistically significant in some studies, generally have only modest strength.

At present, two of the difficulties in determining the relative importance of the physical and psychosocial factors are the following: (1) psychosocial factors are usually measured at the individual level, while physical factors are more often measured at the group (e.g., job or task) level and often by methods with limited precision or accuracy, and (2) “objective measures” of aspects of the psychosocial work environment are difficult to develop and are rarely used, while objective methods to measure the physical environment are more readily available. Until we can measure most workplace and individual variables with more comparable techniques, it will be hard to determine precisely their relative importance in the causation of MSDs.

Table 7–1. Summary of studies examining psychosocial factors and upper extremity disorders (neck, shoulder, elbow, hand, and wrist)

	Methods					Associations with UE outcomes					
Study	**Worker group (particip. rate)**	**Design**	**Psychosocial factor assessment**	**MSD outcome assessment**	**Covariate adjust-ments**	**Job/task dissat.**	**Int. wkld.**	**Mono. work**	**Low job control**	**Low job clarity**	**Low social supp.**
Bernard et al. 1993	1,050 newspaper workers (93%)	Cross-sectional	Self-report questionnaire with job stress scales	MSD case definition based on questionnaire			+		+		
Dehlin and Berg 1977	233 nursing aides (85%)	Cross-sectional	Self-report questionnaire—7 scales	Interviews—pain/ache symptoms		o	o				o
Ekberg et al. 1994	109 workers vs. 637 controls	Cross-sectional (case-control)	Self-report—modified Nordic questionnaire	MD consults for MSD disorders			+			+	
Hales et al. 1994	553 telecom-munications workers	Cross-sectional	Self-report questionnaire with job stress scales	Disorders based on symptom questionnaire and MD exam	Controlled for extra job factors		+		+	+	
Hoekstra et al. 1994	108 teleservice workers (95%)	Cross-sectional	Self-report job stress questionnaire	MSD case definition based on self-report questionnaire			+				
Hopkins 1990	291 keyboard operators and other clerical groups	Cross-sectional	Self-report questionnaire—items from habits of living questionnaire	Questionnaire symptoms		+		+	+	+	

See footnotes at end of table.

(Continued)

Table 7–1(Continued). Summary of studies examining psychosocial factors and upper extremity disorders (neck, shoulder, elbow, hand, and wrist)

	Methods					Associations with UE outcomes					
Study	Worker group (particip. rate)	Design	Psychosocial factor assessment	MSD outcome assessment	Covariate adjust-ments	Job/task dissat.	Int. wkld.	Mono. work	Low job control	Low job clarity	Low social supp.
Houtman et al. 1994	5,865 workers—general population	Cross-sectional	Self-report work-living questionnaire	Symptoms questionnaire	Physical stressors — personal character-istics		+		+		
Karasek et al. 1987	8,700 white collar labor union members (87%)	Cross-sectional (random sample)	Self-report questionnaire	Questionnaire—musculoskeletal aches			+		+	+	+
Kompier 1988	158 male bus drivers (73%)	Cross-sectional	Self-report questionnaire	Self report questionnaire—complaints and sick leave			+				+
Kvarnstrom and Halden 1983	224 fabrication workers	Cross-sectional (case-control)	Structured interview questionnaire	Disorders from medical and sick absence records			+	+			+/o
Linton 1990	22,200 workers—general population	Cross-sectional	Self-report work environment questionnaire and habits of living questionnaire	Pain				+			+
Pot et al. 1987	222 VDT operators	Cross-sectional	Structured interview questionnaire	Complaints—structured interview			+/+		o		+

See footnotes at end of table.

(Continued)

Table 7–1(Continued). Summary of studies examining psychosocial factors and upper extremity disorders (neck, shoulder, elbow, hand, and wrist)

	Methods					Associations with UE outcomes					
Study	**Worker group (particip. rate)**	**Design**	**Psychosocial factor assessment**	**MSD outcome assessment**	**Covariate adjust-ments**	**Job/task dissat.**	**Int. wkld.**	**Mono. work**	**Low job control**	**Low job clarity**	**Low social supp.**
Ryan and Bampton 1988	143 data processors	Cross-sectional (high vs. low symptoms)	Self-report questionnaire—items from work environment scale	Symptoms based on MD interview and exam			+	+	+	+	+/o
Sauter et al. 1983	248 VDT users and 85 non-users (90%)	Cross-sectional	Self-report questionnaire—work environment scale items	Questionnaire—discomfort scale	Physical work demands (adj.)		+		+	+	+
Takala et al. 1991	351 bank cashiers	Longi-tudinal	Self-report questionnaire	Questionnaire—muscle symptoms	Postural load (adj.)		+				
Theorell et al. 1991	207 workers in 6 occupations	Cross-sectional	Self-report questionnaire	Questionnaire—muscle tension symptoms	Physical load (adj.)		+/o		+		o
Tola et al. 1988	1,174 machinists; 1,034 carpenters; 1,013 office workers (67% to 76%)	Cross-sectional	Mailed questionnaire—worker characteristics	Symptoms in last 12 months; questionnaire and interview		o					

+ = Significant association found.
o = No significant association found.
+/+ = Two different measures of factor (e.g., time pressure and workload) found significant.
+/o = Mixed results (on factor significantly associated; second factor not significantly associated).

Table 7–2. Summary of studies examining psychosocial factors and back disorders

	Methods					Associations with back disorders				
Study	Worker group (participation rate)	Design	Psychosocial factor assessment	MSD outcome assessment	Covariate adjust-ments	Job dissat.	Int. wkld.	Mono. work	Low job control	Low social supp.
Åstrand 1987	391 workers in paper-pulp industry	Cross-sectional	Questionnaire—questions on work conditions	Interview and MD exam—back pain abnormalities		o	o			
Bergenudd and Nilsson 1988	575 55-year-old city residents (96%)	Longi-tudinal	Interview and mailed questionnaire	Interview reports of back pain		+				
Biering-Sorenson et al. 1989	928 persons—general population (82%)	Longi-tudinal	Mail questionnaire	Questionnaire—back pain in last 12 months		o				
Bigos et al. 1991b	3,020 male aircraft plant employees (54% with all data)	Longi-tudinal	Questionnaire—Personality Inventory (MMPI), other questions	Back problems—medical reports, insurance claims	Control for prior back problems	+				o
Dehlin and Berg 1977	233 nursing aides (85%)	Cross-sectional	Questionnaire—7 scales, 52 items	Interview—reported pain/ache symptoms		+				
Heliövaraa et al. 1987	5,600 workers—general population (92%)	Cross-sectional	Questionnaire—scale assessing combined hurried work, monotonous work, tight work schedules	MD exam and interview—back disorders	Physical load, prior back problems	Combined +	+ (Combined)			

See footnotes at end of table.

(Continued)

Table 7–2 (Continued). Summary of studies examining psychosocial factor and back disorders

	Methods					Associations with back disorders				
Study	Worker group (participation rate)	Design	Psychosocial factor assessment	MSD outcome assessment	Covariate adjust-ments	Job dissat.	Int. wkld.	Mono. work	Low job control	Low social supp.
Hoekstra et al. 1994	108 teleservice workers (95%)	Cross-sectional	Job stress questionnaire	MSD case definition based on questionnaire data	Individual work factors				+	
Houtman et al. 1994	5,865 workers—general population	Cross-sectional	Questionnaire—work living questionnaire survey	Questionnaire symptoms	Physical stressors; personal character-istics		+	+		
Lundberg et al. 1989	20 male assembly line workers	Cross-sectional	Ratings of time pressure during 2-hr work period	Back load ratings during 2-hr work period			+			
Magora 1973	3,316 workers in 8 occupations	Cross-sectional (low pain vs. controls)	Questionnaire—ratings of job aspects and satisfaction	Questionnaire—reports of low-back pain and sick leave due to low-back pain	Analyses stratified by occupation	+	+			
Sauter et al. 1983	248 VDT users; 85 non-users (90%)	Cross-sectional	Questionnaire—work environment scale survey	Questionnaire—reports of discomfort	Physical work demands				+	
Svensson and Anderson 1983	940 males—general population	Cross-sectional	Questionnaire—perceptions of stress, boredom	Interview report of back pain	Physical work demands—life and job satisfaction			+		

See footnotes at end of table.

(Continued)

Table 7–2 (Continued). Summary of studies examining psychosocial factor and back disorders

Study	Methods					Associations with back disorders				
	Worker group (participation rate)	Design	Psychosocial factor assessment	MSD outcome assessment	Covariate adjust-ments	Job dissat.	Int. wkld.	Mono. work	Low job control	Low social supp.
Svensson and Anderson 1989	1,746 females ages 38–64—general population	Cross-sectional	Questionnaire—items on job and task satisfaction	Interview—reports of back pain	Physical workload	+		o		

\+ = Significant association found.
o = No significant association found.

REFERENCES

Åaras A [1994]. Relationship between trapezius load and the incidence of musculoskele-tal illness in the neck and shoulder. Int J Ind Ergonomics *14*(4):341–348.

Abenhaim L, Suissa S [1988]. Economic scope of occupationally-induced back pain. Institute de recherche en sante et en securite du travail du Quebec. Quebec, Canada: IRSST, Research Summary No. 66.

AFL-CIO [1997]. Stop the pain. Washing-ton, DC: AFL-CIO.

Alexander and Alexander [1996]. 1996 U.S. risk management survey. New York, NY: Alexander and Alexander, Inc.

Allender E [1974]. Prevalence, incidence, and remission rates of some common rheumatic diseases or syndromes. Scand J Rheumatol *3*:145–153.

Alterman T, Shekells RB, Vernon SW, Burau KD [1994]. Decision latitude, psy-chologic demand, job strain and coronary heart disease in the Western Electric study. Am J Epidemiol *139*(6):620–627.

Amadio PC [1995]. De Quervain's disease and tenosynovitis. In: Gordon SL, Blair SJ, Fine LJ, eds. Repetitive motions disorders of the upper extremity. Rosemont, IL: American Academy of Orthopaedic Surgeons, pp. 435–448.

Amano M, Gensyo U, Nakajima H, Yatsuki K [1988]. Characteristics of work actions of shoe manufacturing assembly line workers and a cross-sectional factor-control study on occupational cervicobrachial disorders. Jpn J Ind Health *30*:3–12.

Andersen JH, Gaardboe O [1993a]. Musculoskeletal disorders of the neck and upper limb among sewing machine operators: a clinical investigation. Am J Ind Med *24*(6): 689–700.

Andersen JH, Gaardboe O [1993b]. Prevalence of persistent neck and upper limb pain in a historical cohort of sewing machine operators. Am J Ind Med *24*:677–687.

Andersson GBJ [1981]. Epidemiologic aspects of low back pain in industry. Spine *6*:53–60.

Andersson GBJ [1996]. The epidemiology of spinal disorders. In: Frymoyer JW, ed. The adult spine: principles and practice. 2nd ed. New York, NY: Raven Press Ltd.

Andersson GBJ, Pope MH, Frymoyer JW, Snook S [1991]. Epidemiology and cost. In: Pope M, ed. Occupational low back pain. St. Louis, MO: Mosby Year Book.

Andersson JAD [1984]. Shoulder pain and tension neck and their relation to work. Scand J Work Environ Health *10*(6): 435–442.

Armstrong RB, Warren GL, Warren JA [1991]. Mechanisms of exercise-induced muscle fibre injury. J Sports Med *12*(3): 184–207.

Armstrong TJ, Chaffin DB [1979]. Carpal tunnel syndrome and selected personal attributes. J Occup Med *21*(7):481–486.

Armstrong TJ, Foulke JA, Joseph BS, Goldstein SA [1982]. Investigation of cumulative trauma disorders in a poultry processing plant. Am Ind Hyg Assoc J *43*(2):103–116.

Armstrong TJ, Fine LJ, Goldstein SA, Lifshitz YR, Silverstein BA [1987a]. Ergonomic considerations in hand and wrist tendinitis. J Hand Surg *12A*(5):830–837.

Armstrong TJ, Fine LJ, Radwin RG, Silverstein BS [1987b]. Ergonomics and the effects of vibration in hand-intensive work. Scand J Work Environ Health *13*:286–289.

Armstrong TJ, Punnett L, Ketner P [1989]. Subjective worker assessments of hand tools used in automobile assembly. Am Ind Hyg Assoc J *50*(12):639–645.

Armstrong TJ, Buckle P, Fine LJ, Hagberg M, Jonsson B, Kilbom Å [1993]. A conceptual model for work-related neck and upper-limb musculoskeletal disorders. Scand J Work Environ Health *19*(2):73–84.

Aro S, Leino P [1985]. Overweight and musculoskeletal morbidity: a ten-year follow-up. Int J Obes *9*:267–275.

Asbury FD [1995]. Occupational repetitive strain injuries and gender in Ontario 1986–1991. J Occup Environ Med *37*(4): 479–485.

Åstrand NE [1987]. Medical, psychological, and social factors associated with back abnormalities and self-reported back pain: a cross-sectional study of male employees in a Swedish pulp and paper industry. Br J Ind Med *44*(5):327–336.

Åstrand NE, Isacsson SO [1988]. Back pain, back abnormalities, and competing medical, psychological, and social factors as predictors of sick leave, early retirement, unemployment, labour turnover and mortality: a 22-year follow-up of male employees in a Swedish pulp and paper company. Br J Ind Med *45*(6):387–395.

Atterbury MR, Limke JC, Lemasters GK, Li Y, Forrester C, Stinson R, Applegate H [1996]. Nested case-control study of hand and wrist work-related musculoskeletal disorders in carpenters. Am J Ind Med *30*:695–701.

Barnhart S, Demers PA, Miller M, Longstreth WT Jr., Rosenstock L [1991]. Carpal tunnel syndrome among ski manufacturing workers. Scand J Work Environ Health *17*(1):46–52.

Baron S, Milliron M, Habes D, Fidler A [1991]. Hazard evaluation and technical assistance report: Shoprite Supermarkets, New Jersey—New York. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, NIOSH Report No. HHE 88–344–2092.

Battié MC, Bigos SJ, Fisher LD, Hansson TH, Jones ME, Wortley MD [1989]. Isometric lifting strength as a predictor of industrial back pain. Spine *14*(8):851–856.

Battié MC, Bigos SJ, Fisher LD, Spengler

DM, HanssonTH, Nachemson AL, et al. [1990]. The role of spinal flexibility in back pain complaints within industry: a prospective study. Spine *15*(8):768–793.

Battié MC, Videman T, Gibbons LE, Fisher L, Manninen H, Gill K [1995]. Determinants of lumbar disc degeneration: a study relating lifetime exposures and magnetic resonance imaging findings in identical twins. Spine *20*:2601–2612.

Behrens V, Seligman P, Cameron L, Mathias CGT, Fine L [1994]. The preva-lence of back pain, hand discomfort, and dermatitis in the U.S. working population. Am J Public Health *84*(11):1780–1785.

Bennett GE [1946]. Shoulder and elbow lesions distinctive of baseball players. Ann Surg *126*:107–110.

Berg M, Sanden Å, Torell G, Järvholm B [1988]. Persistence of musculoskeletal symp-toms: a longitudinal study. Ergonomics *31*(9):1281–1285.

Bergenudd H, Nilsson B [1988]. Back pain in middle age. Occupational workload and psychologic factors: an epidemiologic survey. Spine *13*(1):58–60.

Bergenudd H, Lindgärde, Nilsson B, Petersson C [1988]. Shoulder pain in middle age: a study of prevalence and relation to occupational work load and psychosocial factors. Clin Orthop Res *23*:234–238.

Bergqvist U [1984]. Video display terminals and health. Scand J Work Environ Health *10*(2):68–77.

Bergqvist U [1989]. Possible health effects of working with VDUs (editorial). Br J Ind Med *46*:217–221.

Bergqvist U, Wolgast E, Nilsson B, Voss M [1995a]. Musculoskeletal disorders among visual display terminal workers: individual, ergonomic, and work organizational factors. Ergonomics *38*(4):763–776.

Bergqvist U, Wolgast E, Nilsson B, Voss M [1995b]. The influence of VDT work on musculoskeletal disorders. Ergonomics *38*(4):754–762.

Bergqvist-Ullman M, Larsson N [1977]. Acute low back pain in industry. Acta Orthop Scand *170*(Suppl):1–117.

Berkeley M, Bennett J, Woods W [1985]. Elbow problems: injuries to the throwing arm. Zarins B, Andrews J, Carson W, eds. Phildelphia, PA: W.B. Saunders Publishing Company, pp. 235–249.

Bernard B, Sauter S, Fine LJ [1993]. Hazard evaluation and technical assistance report: Los Angeles Times, Los Angeles, CA. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH Report No. HHE 90–013–2277.

Bernard B, Sauter S, Fine LJ, Petersen M, Hales T [1994]. Job task and psychosocial risk factors for work-related musculoskeletal disorders among newspaper employees. Scand J Work Environ Health *20*(6):417– 426.

Biering-Sørensen F [1983]. A prospective study of low-back pain in a general population. I. Occurrence, recurrence, and aetilogy. Scand J Rehabil Med *15*:81–88.

Biering-Sørensen F [1984]. Physical measurements as risk indicators for low back trouble over a one-year period. Spine *9*(2):106–119.

Biering-Sørensen F, Thomsen CE, Hilden J [1989]. Risk indicators for low back trouble. Scand J Rehabil Med *21*:151–157.

Bigos SJ, Spengler DM, Martin NA, Zeh J, Fisher L, Nachemson A, et al. [1986a]. Back injuries in industry: a retrospective study. II. Injury factors. Spine *11*:246–251.

Bigos SJ, Spengler DM, Martin NA, Zeh J, Fisher L, Nachemson A [1986b]. Back injuries in industry: a retrospective study. III. Employee-related factors. Spine *11*:252–256.

Bigos SJ, Battié MC, Fisher LD [1991a]. Methodology for evaluating predictive factors for the report of back injury. Spine *16*(6):669–670.

Bigos SJ, Battié MC, Spengler DM, Fisher LD, Fordyce WE, Hansson TH, et al. [1991b]. A prospective study of work perceptions and psychosocial factors affecting the report of back injury. Spine *16*(1):1–6.

Bigos S, Bowyer O, Braen G, et al. [1994]. Acute low back problems in adults. Clinical practice guideline, quick reference guide No. 14. Rockville, MD: U.S. Department of Health and Human Services, Public Health Service, Agency for Health Care Policy and Research, AHCPR Pub. No. 95–6043.

Bjelle A, Hagberg M, Michaelsson G [1979]. Clinical and ergonomic factors in prolonged shoulder pain among industrial workers. Scand J Work Environ Health *5*(3):205–210.

Bjelle A, Hagberg M, Michaelson G [1981]. Occupational and individual factors in acute shoulder-neck disorders among industrial worker. Br J Ind Med *38*:356–363.

Blåder S, Barck-Holst U, Danielsson S, Ferhm E, Kalpamaa M, Leijon M, et al. [1991]. Neck and shoulder complaints among sewing-machine operators: a study concerning frequency, symptomatology and dysfunction. Appl Ergonomics *22*(4):251– 257.

Bleecker ML, Bohlman M, Moreland R, Tipton A [1985]. Carpal tunnel syndrome: role of carpal canal size. Neurol *35*(11): 1599–1604.

BLS [1995]. Workplace injuries and ill-nesses in 1994. Washington, DC: U.S. Department of Labor, Bureau of Labor Statistics, USDL 95–508.

Bongers PM, Boshuizen HC [1990]. Back disorders and whole-body vibration at work [Dissertation]. Amsterdam, The Nether-lands: University of Amsterdam.

Bongers PM, de Winter CR [1992]. Psychosocial factors and musculoskeletal disease: a report of the literature. The Netherlands: TNO Institute of Preventive Health Care, Report No. 92–082.

Bongers PM, Boshuizen HC, Hulshof CTJ, Koemeester AP [1988]. Back disorders in crane operators exposed to whole-body vibration. Int Arch Occup Environ Health *60*:129–137.

Bongers PM, Hulshof CTJ, Dijkstra L, Boshuizen HC [1990]. Back pain and exposure to whole-body vibration in helicopter pilots. Ergonomics *33*:1007– 1026.

Bongers PM, de Winter CR, Kompier MAJ, Hildebrandt VH [1993]. Psychosocial factors at work and musculoskeletal disease. Scand J Work Environ Health *19*(5):297–312.

Boshuizen HC, Bongers PM, Hulshof CTJ [1990a]. Self-reported back pain in tractor drivers exposed to whole-body vibration. Int Arch Occup Environ Health *62*:109–115.

Boshuizen HC, Hulshof CTJ, Bongers PM [1990b]. Long-term sick leave and disability pensioning due to back disorders of tractor drivers exposed to whole-body vibration. Int Arch Occup Environ Health *62*:117–122.

Boshuizen HC, Bongers PM, Hulshof CTJ [1992]. Self-reported back pain in fork-lift truck and freight-container tractor drivers exposed to whole-body vibration. Spine *17*:59–65.

Boshuizen HC, Verbeek JHAM, Broersen JPJ, Weel ANH [1993]. Do smokers get more back pain? Spine *18*(1):35–40.

Bovenzi M [1990]. Medical aspects of the hand-arm vibration syndrome. Int J Ind Ergonomics *6*(1):61–73.

Bovenzi M, Italian study group on physical hazards in the stone industry [1994]. Hand-arm vibration syndrome and dose-response relation for vibration-induced white finger among quarry drillers and stonecarvers. Occup Environ Med *51*(9):603–611.

Bovenzi M, Zadini A [1992]. Self-reported low back symptoms in urban bus drivers exposed to whole-body vibration. Spine *17*(9):1048–1059.

Bovenzi M, Betta A [1994]. Low-back disorders in agricultural tractor drivers exposed to whole-body vibration and postural stress. Appl Ergonomics *25*:231–241.

Bovenzi M, Franzinelli A, Strambi F [1988]. Prevalence of vibration-induced white finger and assessment of vibration exposure among travertine workers in Italy. Int Arch Occup Environ Health *61*:25–34.

Bovenzi M, Zadini A, Franzinelli A, Borgogni F [1991]. Occupational mus-culoskeletal disorders in the neck and upper limbs of forestry workers exposed to hand-arm vibration. Ergonomics *34*(5): 547–562.

Bovenzi M, Franzinelli A, Mancini R, Cannava MG, Maiorano M, Ceccarelli F [1995]. Dose-response relation for vascular disorders induced by vibration in the fingers of forestry workers. Occup Environ Med *52*:722–730.

Boyce RW, Jones GR, Hiatt AR [1991]. Physical fitness capacity and absenteeism of police officers. J Occup Med *33*(11):1137–1143.

Brammer AJ, Taylor W, eds. [1981]. Vibration effects on the hand and arm in industry. New

York, NY: John Wiley and Sons.

Brattberg G, Thorslund M, Wikman A [1989]. The prevalence of pain in a general population: the results of a postal survey in a county of Sweden. Pain *37*:215–222.
Brinckmann P [1988]. Stress and strain of human lumbar discs. Clin Biomechanics *3*(4):232–235.

Broberg E [1984]. Ergonomic injuries at work: ISA-information system on occupa-tional injuries. Swedish National Board of Occupational Safety and Health, Report No. 1984:3E.

Bross JD [1966]. Spurious effects from an extraneous variable. J Chron Dis *19*:736–747

Brubaker R, Mackenzie C, Bates D [1983]. Vibration white finger disease among tree fellers in British Columbia. J Occup Med *25*(5):403–408.

Brubaker RL, Mackenzie CJG, Hertzman C, Hutton SG, Slakov J [1987]. Longitudinal study of vibration-induced white finger among coastal fallers in British Columbia. Scand J Work Environ Health *13*(4):305– 308.

Buckwalter JA, Woo SL-Y, Goldberg VM, Hadley EC, Booth F, Oegema TR, et al. [1993]. Current concepts review: soft-tissue aging and musculoskeletal function. J Bone Joint Surg [Am] *75A*(10):1533–1548.

Burdorf A [1992]. Exposure assessment of risk factors for disorders of the back in occupational epidemiology. Scand J Work Environ Health *18*(1):1–9.

Burdorf A, Zondervan H [1990]. An epi-demiological study of low-back pain in crane operators. Ergonomics *33*(8):981–987.

Burdorf A, Monster A [1991]. Exposure to vibration and self-reported health complaints of riveters in the aircraft industry. Ann Occup Hyg *35*(3):287–298.

Burdorf A, Govaert G, Elders L [1991]. Postural load and back pain of workers in the manufacturing of prefabricated concrete elements. Ergonomics *34*(7):909–918.

Burdorf A, Naaktgeboren B, deGroot HC [1993]. Occupational risk factors for low back pain among sedentary workers. J Occup Med *35*:1213–1220.

Burry HC, Gravis V [1988]. Compensated back injury in New Zealand. N Z Med J *101*(852):542–544.

Burt S, Hornung R, Fine L [1990]. Hazard evaluation and technical assistance report: Newsday, Inc., Melville, NY. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, NIOSH Report No. HHE 89–250–2046.

Byström S, Hall C, Welander T, Kilbom Å [1995]. Clinical disorders and pressure-pain threshold of the forearm and hand among automobile assembly line workers. J Hand Surg [Br] *20B*(6):782–790.

Cady LD Jr., Bischoff DP, O'Connell ER, Thomas PC, Allan JH [1979]. Strength and fitness and subsequent back injuries in firefighters. J Occup Med *21*(4):269–272.

Cady LD Jr., Thomas PC, Karwasky RJ [1985]. Program for increasing health and physical fitness of firefighters. J Occup Med *27*(2):110–114.

Cannon LJ, Bernacki EJ, Walter SD [1981]. Personal and occupational factors associated with carpal tunnel syndrome. J Occup Med *23*(4):255–258.

CDC (Centers for Disease Control) [1989]. Occupational disease surveillance: carpal tunnel syndrome. MMWR *38*(28):485–489.

Chaffin DB [1973]. Human strength capability and low back pain. Unpublished paper presented at the American Industrial Health Conference, Denver, CO, April 16–19, 1973.

Chaffin DB [1979]. Manual materials handling the cause of overexertion injury and illness in industry. J Environ Pathol Toxicol *2*(5):67–73.

Chaffin DB, Park KS [1973]. A longitudinal study of low-back pain as associated with occupational weight lifting factors. Am Ind Hyg Assoc J *34*:513–525.

Chaffin DB, Andersson GBJ [1984]. Occupational biomechanics. New York, NY: John Wiley and Sons.

Chaffin DB, Herrin GD, Keyserling WM, Foulke JA [1977]. Preemployment strength testing in selecting workers for materials handling jobs. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Health Services and Mental Health Administration, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 77–163.

Chatterjee D [1992]. Workplace upper limb disorders: a prospective study with intervention. J Occup Med *42*(3):129–136.

Chatterjee DS, Barwick DD, Petrie A [1982]. Exploratory electromyography in the study of vibration-induced white finger in rock drillers. Br J Ind Med *39*:89–97.

Chiang H, Chen S, Yu H, Ko Y [1990]. The occurrence of carpal tunnel syndrome in frozen food factory employees. Kao Hsiung J Med Sci *6*:73–80.

Chiang H, Ko Y, Chen S, Yu H, Wu T, Chang P [1993]. Prevalence of shoulder and upper-limb disorders among workers in the fish-processing industry. Scand J Work Environ Health *19*(2):126–131.

Christensen H, Pedersen MB, Sjøgaard G [1995]. A national cross-sectional study in the Danish wood and furniture industry on working postures and manual materials handling. Ergonomics *38*(4):793–805.

Clemmer DI, Mohr DL, Mercer DJ [1991]. Low-back injuries in a heavy industry: I. Worker and workplace factors. Spine *16*(7):824–830.

Cohen S, Pyrrell DAJ, Smith AP [1991]. Psychological stress and susceptibility to the common cold. New Engl J Med *325*(9):606–612.

Cornfield J [1956]. A statistical problem arising from retrospective studies. Pro-ceedings of the third Berkely Symposium, pp. 135–148.

Cornfield J, Haenszel W, Hammond EC, Lilienfeld AM, Shimkin MB, Wynder EL [1959]. Smoking and lung cancer: recent evidence and a discussion of some questions. J Natl Cancer Inst *22*:173–203.

Cust G, Pearson JCG, Mair A [1972]. The prevalence of low back pain in nurses. Int Nurs Rev *19*(2):169–179.

CWCI [1993]. Report on CTDs. San Francisco, CA: California Workers' Compensation Institute.

Cyriax JH [1936]. The pathology and treatment of tennis elbow. J Bone Joint Surg Am *18*(4):921–940.

Damkot DK, Pope MH, Lord J, Frymoyer JW [1984]. The relationship between work history, work environment and low-back pain in men. Spine *9*(4):395–399.

Dammeskiold-Samsøe B, Christiansen E, Lund B, Andersen RB [1982]. Regional muscle tension and pain ("fibrositis"). Scand J Rehabil Med *15*:17–20.

Dehlin O, Berg S [1977]. Back symptoms and psychological perception of work: a study among nursing aides in a geriatric hospital. Scand J Rehabil Med *9*:61–65.

Dehlin O, Hedenrud B, Horal J [1976]. Back symptoms in nursing aides in a geriatric hospital. Scand J Rehabil Med *8*(2):47.

Dehlin O, Berg S, Hedenrud B, Anderson G, Grimby G [1978]. Muscle training, psychological perception of work and low back symptoms in nursing aides. Scand J Rehabil Med *10*(4):201–209.

Dehlin O, Berg S, Andersson GBJ, Grimby G [1981]. Effect of physical training and ergonomic counseling on psychological perception of work and on the subjective assessment of low-back insufficiency. Scand J Rehabil Med *13*:1–9.

deKrom MCT, Kester ADM, Knipschild PG, Spaans F [1990]. Risk factors for carpal tunnel syndrome. Am J Epidemiol *132*(6):1102–1110.

Deyo RA, Bass JE [1989]. Lifestyle and low back pain: the influence of smoking and obesity. Spine *14*(5):501–506.

Dieck GS, Kelsey JL [1985]. An epidemiologic study of the carpal tunnel syndrome in an adult female population. Prev Med *14*(1):63–69.

Dimberg L [1987]. The prevalence and causation of tennis elbow (lateral humeral epicondylitis) in a population of workers in an engineering industry. Ergonomics *30*(3):573–580.

Dimberg L, Oden A [1991]. White finger symptoms: a cross-sectional study. Aviat Space Environ Med *62*:879–883

Dimberg L, Olafsson A, Stefansson E, Aagaard H, Oden A, Andersson GBJ, et al. [1989]. The correlation between work environment and the occurrence of cervicobrachial symptoms. J Occup Med *31*(5): 447–453.

Dixon SJ [1973]. Progress and problems in back pain research. Rheumatol Rehabil *12*:165.

Dupuis H [1994]. Medical and occupational preconditions for vibration-induced spinal disorders: occupational disease No. 2110 in Germany. Int Arch Occup Environ Health *66*:303–308.

Earman WA, Andersson GB, Leavitt F, McNeill TW, Durudogan H, Reagan J [1996]. Factors influencing the cost of chronic low back injuries: an analysis of data from independent medical examinations. J Occup Rehabil *6*(1):5–16.

Ekberg K, Björkqvist B, Malm P, Bjerre-Kiely B, Karlsson M, Axelson O [1994]. Case-control study of risk factors for disease in the neck and shoulder area. Occup Environ Med *51*(4):262–266.

Ekberg K, Karlsson M, Axelson O [1995]. Cross-sectional study of risk factors for symptoms in the neck and shoulder area. Ergonomics *38*(5):971–980.

Eklund J, Odenrick P, Zettergren S, Johansson H [1994]. Head posture measure-ments among work vehicle drivers and implications for work and workplace design. Ergonomics *37*(4):623–639.

English CJ, Maclaren WM, Court-Brown C, Hughes SPF, Porter RW, Wallace WA [1995]. Relations between upper limb soft tissue disorders and repetitive movements at work. Am J Ind Med *27*(1):75–90.

Falck B, Aarnio P [1983]. Left-sided carpal tunnel syndrome in butchers. Scand J Work Environ Health *9*(3):291–297.

Färkkilä M, Aatola S, Starck J, Korhonen O, Pyykkö I [1986]. Hand-grip force in lumberjacks: two-year follow-up. Int Arch Occup Environ Health *58*:203–208.

Färkkilä M, Pykkö I, Jäntti V, Aatola S, Starck J, Korhonen O [1988]. Forestry workers exposed to vibration: a neurological study. Br J Ind Med *45*:188–192.

Feldman RG, Travers PH, Chirico-Post J, Keyserling WM [1987]. Risk assessment in electronic assembly workers: carpal tunnel syndrome. J Hand Surg [Am] *12A*(5): 849–855.

Ferguson D [1976]. Posture, aching and body build in telephonists. J Hum Ergol *5*:183–196.

Feyer A, Williamson A, Mandryk J, de Silva I, Healy S [1992]. Role of psychosocial risk factors in work-related low back pain. Scand J Work Environ Health *18*(6):368–375.

Finkelstein MM [1995]. Back pain and parenthood. Occup Environ Med *52*(1): 51–53.

Fishbein M, Middlestadt S, Ottati V, Straus S, Ellis A [1988]. Medical problems among ICSOM musicians: overview of a national survey. Med Prob Perform Art *1*:136–139.

Flodmark BT, Aase G [1992]. Musculo-skeletal symptoms and type A behaviour in blue collar workers. Br J Ind Med *49*(10): 683–687.

Frank JW, Pulcins IR, Kerr MS, Shannon HS, Stansfield SA [1995]. Occupational back pain—an unhelpful polemic. Scand J Work Environ Health *58*:203–208.

Franklin GM, Haug J, Heyer N, Checkoway H, Peck N [1991]. Occupational carpal tunnel syndrome in Washington State, 1984–1988. Am J Public Health *81*(6): 741–746.

Fransson-Hall C, Byström S, Kilbom Å [1995]. Self-reported physical exposure and musculoskeletal symptoms of the forearm-hand among automobile assembly-line workers. J Occup Environ Med *37*(9): 1136–1144.

Frymoyer JW, Pope MH, Costanza MC, Rosen JC, Goggin JE, Wilder DG [1980]. Epidemiologic studies of low-back pain. Spine *5*(5):419–423.

Frymoyer JW, Pope MH, Clements JH [1983]. Risk factors in low back pain. J Bone Joint Surg [Am] *65A*:213.

Frymoyer JW, Cats-Baril WL [1991]. An overview of the incidence and costs of low back pain. Orthop Clin North Am *22*: 262–271.

Futatsuka M, Uneno T [1985]. Vibration exposure and vibration induced white finger due to chain saw operation. J Occup Med 27:257–264.

Futatsuka M, Uneno T [1986]. A follow-up study of vibration-induced white finger due to chain saw operation. Scand J Work Environ Health 12(4):304–306.

Garg A, Moore SJ [1992]. Epidemiology of low-back pain in industry. Occup Med: State of the Art Rev *7*(4):593–608.

Gelberman RH, Herginroeder PT, Hargens AR, Lundborg GN, Akeson WH [1981]. The carpal tunnel syndrome: a study of carpal canal pressures. J Bone Joint Surg *63A*(3): 380–383.

Gemne G [1982]. Pathophysiology and multifactorial etiology of acquired vaso-spastic disease (Raynaud Syndrome) in vibration exposed workers. Scand J Work Environ Health *8*:243–249.

Gemne G, Lundström R, Hansson J [1993]. Disorders induced by work with hand-held vibrating tools: a review of current knowledge for criteria documentation. Arbete och Hälsa *6*:1–83.

Gerr F, Letz R [1992]. Risk factors for carpal tunnel syndrome in industry: blaming the victim? [Letter to the editor.] J Occup Med *34*(11):1117–1119.

Gerr F, Letz R, Landrigan PJ [1991]. Upper-extremity musculoskeletal disorders of occupational origin. Ann Rev Public Health *12*:543–566.

Graham NM, Douglas RM, Ryan P [1986]. Stress and acute respiratory infection. Am J Epidemiol *124*(3):389–401.

Grandjean E, Hunting W, Nishiyama K [1984]. Preferred VDT workstation settings, body posture and physical impairments. Appl Ergonomics *15*(2):99–104.

Guo HR, Tanaka S, Cameron LL, Seligman PJ, Behrens VJ, Ger J, et al. [1995]. Back pain among workers in the United States: national estimates and workers at high risk. Am J Ind Med *28*(5):591–602.

Hadler NM [1993]. Occupational musculo-skeletal disorders. New York, NY: Raven Press.

Hadler N [1997]. Repetitive upper-extremity motions in the workplace are not hazardous. J Hand Surg [Am] *22A*(1):19–29.

Hagberg M [1981]. Work load and fatigue in repetitive arm elevations. Ergonomics *24*:543–555.

Hagberg M [1984]. Occupational musculo-skeletal stress and disorders of the neck and shoulder: a review of possible pathophysio-logy. Int Arch Occup Environ Health *53*:269–278.

Hagberg M, Kvarnström S [1984]. Muscular endurance and electromyographic fatigue in myofascial shoulder pain. Arch Phys Med Rehabil *65*:522–525.

Hagberg M, Wegman DH [1987]. Preva-lence rates and odds ratios of shoulder-neck diseases in different occupational groups. Br J Ind Med *44*(9):602–610.

Hagberg M, Morgenstern H, Kelsh M [1992]. Impact of occupations and job tasks on the prevalence of carpal tunnel syndrome. Scand J Work Environ Health *18*(6):337– 345.

Hagberg M, Silverstein B, Wells R, Smith M, Hendrick H, Carayon P [1995]. Work-related musculoskeletal disorders (WMSDs): a reference book for prevention. London, England: Taylor and Francis.

Hägg G, Suurküla J, Kilbom Å [1990]. Predictors for work-related shoulder/neck disorders: a longitudinal study of female assembly workers. Arbete och Hälsa *10*:1–78.

Hägg GM, Öster J, Byström S [1996]. Forearm muscular load and wrist angle among automobile assembly line workers in relation to symptoms. Appl Ergonomics *28*(1):41–47.

Hales TR, Fine L [1989]. Hazard evaluation and technical assistance report: Cargill Poultry Division, Buena Vista, CA. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, NIOSH Report No. HHE 89–251–1997.

Hales TR, Sauter S [1992]. Hazard evalua-tion and technical assistance report: U.S. West Communications, Phoenix, AZ; Minneapolis, MN; Denver, CO. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH Report No. HHE 89–299–2230.

Hales TR, Habes D, Fine L, Hornung R, Boiano J [1989]. Hazard evaluation and tech-nical assistance report: John Morrell and Co., Sioux Falls, SD. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, NIOSH Report No. HHE 88–180–1958.

Hales TR, Sauter SL, Peterson MR, Fine LJ, Putz-Anderson V, Schleifer LR, et al. [1994]. Musculoskeletal disorders among visual display terminal users in a telecom-munications company. Ergonomics *37*(10): 1603–1621.

Harms-Ringdahl K, Ekholm J [1986]. Intensity and character of pain and muscular activity levels elicited by maintained extreme flexion position of the lower-cervical-upper thoracic spine. Scand J Rehabil Med *18*:117–126.

Hart DA, Frank CB, Bray RC [1995]. Inflammatory processes in repetitive motion and overuse syndromes: potential role of neurogenic mechanisms in tendons and ligaments. In: Gordon SL, Blair SJ, Fine, LJ, eds. Repetitive motions disorders of the upper extremity. Rosemont, IL: American Academy of Orthopaedic Surgeons, pp. 247–262.

Hartz CR, Linscheid RL, Gramse RR, Daube JR [1981]. The pronator teres syndrome: compressive neuropathy of the median nerve. J Bone Joint Surg *63*(6): 885–890.

Heliövaara M [1987]. Occupation and risk of herniated lumbar intervertebral disc or sciatica leading to hospitalization. J Chronic Dis *40*(3):259–264.

Heliövaara M, Knekt P, Aromaa A [1987]. Incidence and risk factors of herniated lumbar intervertebral disc or sciatica leading to hospitalization. J Chronic Dis *40*:251– 258.

Heliövaara M, Mäkelä M, Knekt P, Impivaara O, Aromaa A [1991]. Determi-nants of sciatica and low back pain. Spine *16*(6):608–614.

Helliwell PS, Mumford DB, Smeathers JE, Wright V [1992]. Work-related upper limb disorders: the relationship between pain, cumulative load, disability, and psychological factors. Ann Rheum Dis *51*(12): 1325–1329.

Herberts P, Kadefors R [1976]. A study of painful shoulders in welders. Acta Orthop Scand *47*:381–387.

Herberts P, Kadefors R, Andersson G, Petersen I [1981]. Shoulder pain in industry: an epidemiological study on welders. Acta Orthop Scand *52*:299–306.

Herberts P, Kadefors R, Högfors C, Sigholm G [1984]. Shoulder pain and heavy manual labor. Clin Orthop *191*:166–178.

Herrin GD, Jaraiedi M, Anderson CK [1986]. Prediction of overexertion injuries using biomechanical and psychophysical models. Am Ind Hyg Assoc J *47*(6):322– 330.

Heyer N, Checkoway H, Daniell, et al. [1990]. Self-reported musculoskeletal symptoms among office video display terminal operators. In: Sakurai H, Okazaki I, Omae I, eds. Occupational epidemiology. Amsterdam, The Netherlands: Elsevier Science Publishers, B.V., pp. 255–258.

Higgs P, Young VL, Seaton M, Edwards D, Feely C [1992]. Upper extremity impairment in workers performing repetitive tasks. Plast Reconstr Surg *90*(4):614–620.

Hildebrandt VH [1987]. A review of epi-demiological research on risk factors of low back pain. In: Buckle P, ed. Musculoskeletal disorders at work. Proceedings of a con-ference held at the University of Surrey, Guilford, April, 1987. London, England: Taylor and Francis, pp. 9–16.

Hildebrandt VH [1995]. Back pain in the working population: prevalence rates in Dutch trades and professions. Ergonomics *38*(6):1283–1298.

Hildebrandt VH, Bongers PM, Dul J, van Dijk FJH, Kemper HCG [1996]. Identifica-tion of high-risk groups among maintenance workers in a steel company with respect to musculoskeletal symptoms and workload. Ergonomics *39*(2):232–242.

Hill AB [1965]. The environment and disease: association or causation. Proc Royal Soc Med *58*:295–300.

Hill AB [1966]. Principles of medical statistics. 8th ed. London, England: Lancet.

Hill AB [1971]. Principles of medical statistics. 9th ed. New York, NY: Oxford University Press.

Hoekstra EJ, Hurrell JJ, Swanson NG [1994]. Hazard evaluation and technical assistance report: Social Security Admin-istration Teleservice Centers, Boston, MA; Fort Lauderdale, FL. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH Report No. 92–0382–2450.

Holmström E [1992]. Musculoskeletal disorders in construction workers. Lund, Sweden: Lund University, Department of Physical Therapy, pp. 1–175.

Holmström E, Moritz U [1991]. Low back pain correspondence between questionnaire interview and clinical examination. Scand J Rehabil Med *23*:119–125.

Holmström EB, Lindell J, Moritz U [1992]. Low back and neck/shoulder pain in construction workers: occupational work-load and psychosocial risk factors. Spine *17*(6):663–671.

Holmström E, Lindell J, Moritz U [1993]. Healthy lower backs in the construction industry in Sweden. Work and Stress *7*(3):259–271.

Hopkins A [1990]. Stress, the quality of work, and repetition strain injury in Australia. Work and Stress *4*(2):129–138.

Horal J [1969]. The clinical appearance of low back disorders in the city of Gothen-burg, Sweden. Acta Orthop Scand *118*(Suppl):7–37.

Houtman ILD, Bongers PM, Smulders PGW, Kompier MAJ [1994]. Psychosocial stressors at work and musculoskeletal problems. Scand J Work Environ Health *20*(2):139–145.

Hrubec Z, Nashold BS [1975]. Epidemio-logy of lumbar disc lesions in the military in World War II. Am J Epidemiol *102*(5):366– 376.

Huang J, Ono Y, Shibata E, Takeucki Y, Hisanaga N [1988]. Occupational musculo-skeletal disorders in lunch centre workers. Ergonomics *31*(1):65–75.

Hughes RE, Silverstein BA, Evanoff BA [1997]. Risk factors for work-related musculoskeletal disorders in an aluminum smelter. Am J Ind Med *32*:66–75.

Hulshof C, Veldhuijzen van Zanten B [1987]. Whole-body vibration and low-back pain: a review of epidemiologic studies. Int Arch Occup Environ Health *59*:205–220.

Hunting KL, Welch LS, Cuccherini BA, Seiger LA [1994]. Musculoskeletal symptoms among electricians. Am J Ind Med *25*(2):149–163.

Hünting W, Läubli TH, Grandjean E [1981]. Postural and visual loads at VDT workplaces. I. Constrained postures. Ergonomics *24*(12):917–931.

Hurrell JJ, Murphy LR [1992]. Psycho-logical job stress. In: Rom WN, ed. Environmental and occupational medicine. 2nd ed. New York, NY: Little, Brown and Company, pp. 675–684.

Hurrell JJ Jr., Murphy LR, Sauter SL, Cooper CL [1988]. Occupational stress: issues and developments. New York, NY: Taylor and Francis.

Ignatius Y, Yee T, Yan L [1993]. Selfreported musculoskeletal problems amongst typists and possible risk factors. J Hum Ergol *22*:83–93.

ILO [1986]. Psychosocial factors at work: recognition and control. Geneva, Switzer-land: International Labour Office.

Iwata H, Makimo S [1987]. Prevalence of Raynaud's phenomenon in individuals not using vibrating tools. Sangyo Igaku *29*: 500–503.

Jensen RC [1987]. Disabling back injuries among nursing personnel: research needs and justification. Res Nurs Health *10*(1): 29–38.

Jensen RC [1988]. Epidemiology of work-related back pain. Top Acute Care Trauma Rehabil *2*(3):1–15.

Jensen RC [1990]. Back injuries among nursing personnel related to exposure. Appl Occup Environ Hyg *5*:38–45.

Johanning E [1991]. Back disorders and health problems among subway train operators exposed to whole-body vibration. Scand J Work Environ Health *17*(6):414– 419.

Johanning E, Wilder DG, Landrigan PJ, Pope MH [1991]. Whole-body vibration exposure in subway cars and review of adverse health effects. J Occup Med *33*(5):605–612.

Johansson JA [1994]. Work-related and non-work-related musculoskeletal symptoms. Appl Ergonomics *25*(4):248–251.

Johansson JA, Rubenowitz S [1994]. Risk indicators in the psychosocial and physical work environment for work-related neck, shoulder and low back symptoms: a study among blue and white collar workers in eight companies. Scand J Rehabil Med *26*:131–142.

Johnson JV, Stewart W, Hall EM, Fredlund P, Theorell T [1996]. Long-term psychosocial work environment and cardiovascular mortality among Swedish men. Am J Public Health *86*(3):324–331.

Jonsson B [1988]. The static load component in muscle work. Eur J Appl Physiol *57*:305–310.

Jonsson BG, Persson J, Kilbom Å [1988]. Disorders of the cervicobrachial region among female workers in the electronics industry: a two-year follow-up. Int J Ind Ergo *3*(1):1–12.

Kaji H, Honma H, Usui M, Yasuno Y, Saito K [1993]. Hypothenar hammer syndrome in workers occupationally exposed to vibrating tools. J Hand Surg [Br] *18B*(6):761–766.

Kamwendo K, Linton, SJ, Moritz U [1991]. Neck and shoulder disorders in medical secretaries. Part I. Pain prevalence and risk factors. Scand J Rehabil Med *23*(3):127–33.

Karasek RA, Baker D, Marxer F, Ahlbom A, Theorell T [1981]. Job decision latitude, job demands, and cardiovascular disease: a prospective study of Swedish men. Am J Public Health *71*(7):694–705.

Karasek RA, Gardell B, Lindell J [1987]. Work and non-work correlates of illness and behaviour in male and female Swedish white collar workers. J Occup Behav *8*(3):187– 207.

Karasek RA, Theorell T, Schwartz JF, Schnall PL, Pieper CF, Michela JL [1988]. Job characteristics in relation to the preva-lence of myocardial infarction in the U.S. Health Examination Survey (HES) and the Health and Nutrition Examination Survey (HANES). Am J Public Health *78*(8):910– 918.

Katz JN, Punnett L, Simmons BP, Fossel AH, Mooney N, Keller RB [1996]. Workers compensation recipients with carpal tunnel syndrome: the validity of self-reported health measures. Am J Public Health *86*(1):52–56.

Kelley JD, Lombardo SJ, Pink M, Perry G, Giangarra CE [1994]. Electromyographic and cinematographic analysis of elbow function in tennis players with lateral epicondylitis. Am J Sports Med *22*(3): 359–363.

Kellgren JH, Lawrence JS [1958]. Osteo-arthrosis and disc degeneration in an urban population. Ann Rheum Dis *17*(4):338–397.

Kelsey CA, Mettler FA [1990]. Flexible protective gloves: the Emperor's new clothes? Radiology *174*(1):275–276.

Kelsey JL [1975a]. An epidemiological study of acute herniated lumbar inter-vertebral disc. Rheumatol Rehabil *14*:144.

Kelsey JL [1975b]. An epidemiological study of the relationship between occupations and acute herniated lumbar intervertebral discs. Int J Epidemiol *4*(3):197–205.

Kelsey JL, Hardy RJ [1975]. Driving of motor vehicles as a risk factor for acute herniated lumbar intervertebral disc. Am J Epidemiol *102*(1):63–73.

Kelsey JL, White AA [1980]. Epidemiology and impact on low back pain. Spine *5*(2): 133–142.

Kelsey JL, Golden AL [1988]. Occupational and workplace factors associated with low back pain. Occup Med: State of the Art Rev *3*(1):7–16.

Kelsey JL, Githens PB, White AA, Holford TR, Walter SD, O’Connor T, et al. [1984]. An epidemiologic study of lifting and twisting on the job and risk for acute pro-lapsed lumbar intervertebral disc. J Orthop Res *2*(1):61–66.

Kelsey JL, Golden AL, Mundt DJ [1990].

Low back pain/prolapsed lumbar inter-vertebral disc. Epidemiol Rheum Dis *16*(3):699–716.

Kennedy JC, Hawkins R, Krissoff WB [1978]. Orthopaedic manifestations of swimming. Am J Sports Med *6*:309–322.

Keyserling WM, Herrin GD, Chaffin DB [1980]. Isometric strength testing as a means of controlling medical incidents on stren-uous jobs. J Occup Med *22*(5):332–336.

Kiken S, Stringer W, Fine LJ [1990]. Hazard evaluation and technical assistance report: Perdue Farms, Lewiston, NC; Roberson-ville, NC. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, NIOSH Report No. HHE 89–307–2009.

Kilbom Å [1994]. Repetitive work of the upper extremity. Int J Ind Ergonomics *14*(1/2):51–86.

Kilbom Å, Persson J [1987]. Work technique and its consequences for musculo-skeletal disorders. Ergonomics *30*(2): 273–279.

Kilbom Å, Horst D, Kemfert K, Richter A [1986]. Observation methods for reduction of load and strain on the human body—a review. Abetarskyddsstyrelsen Publikation Service *171*(84):92.

Kim SH, Chung MK [1995]. Effects of posture, weight and frequency on trunk muscular activity and fatigue during repetitive lifting tasks. Ergonomics *38*(5):853–863.

King JW, Brelsford HJ, Tullos HS [1969]. Analysis of the pitching arm of the pro-fessional baseball pitcher. Clin Orthop *67*:116–123.

Kivekäs J, Riihimäki H, Husman K, Hänninen K, Härkönen H, Kuusela T, et al. [1994]. Seven-year follow-up of white-finger symptoms and radiographic wrist findings in lumberjacks and referents. Scand J Work Environ Health *20*(2):101–106.

Kivi P [1984]. Rheumatic disorders of the upper limbs associated with repetitive occupational tasks in Finland, 1975–1979. Scand J Rheumatol *13*:101–107.

Klein BP, Jensen RC, Sanderson LM [1984]. Assessment of workers' compen-sation claims for back strains/sprains. J Occup Med *26*(6):443–448.

Kleinbaum DG, Kupper LL, Morgenstern H [1982]. Epidemiologic research: principles and quantitative methods. London, England: Lifetime Learning Publications.

Knave BG, Wibom RI, Voss M, Hedström LD, Bergqvist UO [1985]. Work with video display terminals among office employees. I. Subjective symptoms and discomfort. Scand J Work Environ Health *11*(6):457–466.

Knibbe JJ, Friele RD [1996]. Prevalence of back pain and characteristics of the physical workload of community nurses. Ergonomics *39*(2):186–198.

Kompier MAJ [1988]. Arbeid en gezondheid van stadsbus-chauffeurs. Delft Eburon (Proefschrift Rijksuniversitiet Groningen).

Kopf T, Von Feder T, Karmaus W [1988]. Risks for musculoskeletal disorders of the low back, the shoulders, the elbows, and the wrists in bricklayers. In: Hogstedt C, Reuterwall C, eds. Progress in occupational epidemiology. Amsterdam: Elsevier Science Publishers B.V., pp. 219–222.

Koskimies K, Färkkilä M, Pyykkö I, Jäntti V, Aatola S, Starck J, et al. [1990]. Carpal tunnel syndrome in vibration disease. Br J Ind Med *47*(6):411–416.

Koskimies K, Pyykkö I, Starck J, Inaba R [1992]. Vibration syndrome among Finnish forest workers between 1972 and 1990. Int Arch Occup Environ Health *64*:251–256.

Kukkonen R, Luopajärvi T, Riihimäki V [1983]. Prevention of fatigue amongst data entry operators. In: Kvalseth TO, ed. Ergonomics of workstation design. London, England: Buttersworth, pp. 28–34.

Kumar S [1994]. The back compressive forces during maximal push-pull activities in the sagittal plane. J Hum Ergol *23*(2):133– 150.

Kuorinka I, Koskinen P [1979]. Occupa-tional rheumatic diseases and upper limb strain in manual jobs in a light mechanical industry. Scand J Work Environ Health *5*(Suppl 3):39–47.

Kuorinka I, Forcier L [1995]. Work-related musculoskeletal disorders (WMSDs): a reference book for prevention. London, England: Taylor & Francis, p. 1.

Kurppa K, Viikari-Juntura E, Kuosma E, Huuskonen M, Kivi P [1991]. Incidence of tenosynovitis or peritendinitis and epicondy-litis in a meat-processing factory. Scand J Work Environ Health *17*(1):32–37.

Kvarnström S [1983a]. Incidence of musculoskeletal disorders in a mechanical engineering plant, with emphasis on occupat-ional shoulder injuries. Abetarskyddssty-relsen Publikation Service *171*(84):79.

Kvarnström S [1983b]. Occurrence of musculoskeletal disorders in a manufac-turing industry with special attention to occupational shoulder disorders. Scand J Rehabil Med (Suppl 8):1–114.

Kvarnström S, Halden M [1983]. Occupa-tional cervicobrachial disorders in an engineering company. Scand J Rehabil Med *8*:1–114.

Lapidus PW, Guidotti FP [1970]. Lateral and medical epicondylitis of the humerus. Ind Med Surg *39*(4):30–32; 171–173.

Larsson SE, Bengtsson A, Bodegard L, Henriksson KG, Larsson J [1988]. Muscle changes in work-related chronic myalgia. Acta Orthop Scand *59*(5):552–556.

Larsson SE, Bodegard L, Henriksson KG, Öberg PA [1990]. Chronic trapezius myalgia: morphology and blood flow studied in 17 patients. Acta Orthop Scand *61*(5):394–398.

Lawrence JS [1955]. Rheumatism in coal miners. Part III: Occupational factors. Br J Ind Med *12*(3):249–261.

Leboeuf-Yde C, Klougart N, Lauritzen T [1996]. How common is low back pain in the Nordic population? Spine *21*(13):1518– 1526.

Leigh JP, Sheetz RM [1989]. Prevalence of back pain among full-time United States workers. Br J Ind Med *46*:651–657.

Leigh JP, Markowitz S, Fahs M, et al. [1996]. Costs of occupational injuries and illnesses in 1992. NIOSH cooperative agreement with ERC, Inc., contract no. U60/CCU902886.

Leino P [1989]. Symptoms of stress predict musculoskeletal disorders. J Epidemiol Community Health *43*(3):293–300.

Leino P, Lyyra A [1990]. The effect of mental stress and social support on the development of musculoskeletal morbidity in the engineering industry. In: Sakurai H, Okazaki L, Omae I, eds. Occupational epidemiology. Amsterdam, The Nether-lands: Elsevier Science Publishers B.V., pp. 267–272.

Leino P, Aro S, Hasan J [1987]. Trunk muscle function and low back disorders: a ten-year follow-up study. J Chronic Dis *40*(4):289–296.

Leino P, Hasan J, Karppi SL [1988]. Occupational class, physical workload, and musculoskeletal morbidity in the engineer-ing industry. Br J Ind Med *45*(10):672–681.

Letz R, Cherniack MG, Gerr F, Hershman D, Pace P [1992]. A cross-sectional epidemiological survey of shipyard workers exposed to hand-arm vibration. Br J Ind Med *49*(1):53–62.

Levitz CL, Iannotti JP [1995]. Overuse injuries of the shoulder. In: Gordon SL, Blair SJ, Fine LJ, eds. Repetitive motions disorders of the upper extremity. Rosemont, IL: American Academy of Orthopaedic Surgeon.

Liira JP, Shannon HS, Chambers LW, Haines TA [1996]. Long-term back problems and physical work exposures in the 1990 Ontario Health Survey. Am J Public Health *86*(3):382–387.

Liles DH, Deivanayagam S, Ayoub MM, Mahajan P [1984]. A job severity index for the evaluation and control of lifting injury. Hum Factors *26*(6):683–693.

Lindman R, Hagberg M, Ängqvist KA, Söderlund K, Hultman E, Thornell L [1991]. Changes in muscle morphology in chronic trapezius myalgia. Scand J Work Environ Health *17*(5):347–355.

Linton SJ [1990]. Risk factors for neck and back pain in a working population in Sweden. Work and Stress *4*(1):41–49.

Linton SJ, Kamwendo K [1989]. Risk factors in the psychosocial work environ-ment for neck and shoulder pain in secre-taries. J Occup Med *31*(7):609–613.

Liss GM, Jesin E, Kusiak RA, White P [1995]. Musculoskeletal problems among Ontario dental hygienists. Am J Ind Med *28*(4):521–540.

Loslever P, Ranaivosoa A [1993]. Biomechanical and epidemiological investigation of carpal tunnel syndrome at workplaces with high risk factors. Ergonomics *36*(5): 537–555.

Louis, Harris & Associates [1996]. Pain and absenteeism in the workplace. New York, NY: Louis, Harris & Associates.

Lukaš E [1970]. Lesion of the peripheral nervous system due to vibration. Work Environ Health *7*(1):67–79.

Lundberg U, Granqvist M, Hansson T, Magnusson M, Wallin L [1989]. Psychological and physiological stress responses during repetitive work at an assembly line. Work and Stress *3*(2):143–153.

Lundborg G, Dahlin LB, Danielsen N, Hansson HA, Necking LE, Pyykkö I [1987]. Intraneural edema following exposure to vibration. Scand J Work Environ Health *13*(4):326–329.

Lundborg G, Dahlin LB, Hansson HA, Kanje M, Necking LR [1990]. Vibration exposure and peripheral nerve fiber damage. J Hand Surg [Am] *15A*(2):346–351.

Luopajärvi T, Kuorinka I, Virolainen M, Holmberg M [1979]. Prevalence of tenosynovitis and other injuries of the upper extremities in repetitive work. Scand J Work Environ Health *5*(Suppl 3):48–55.

Maeda K, Hirayama H, Takamatsu M [1977]. Occupational cervicobrachial disorders in workwomen in assembly lines of a cigarette factory. Jpn J Ind Health *19*:8–21.

Maeda K, Horiguchi S, Hosokawa M [1982]. History of the studies on occupa-tional cervicobrachial disorders in Japan and remaining problems. J Human Ergol *11*:17–29.

Magnusson M, Hanson T [1994]. The effect of seat back inclination on spine height changes. Appl Ergonomics *25*(5):294–298.

Magnusson ML, Pope MH, Wilder DG, Areskoug B [1996]. Are occupational drivers at an increased risk for developing musculoskeletal disorders? Spine *6*:710–717.

Magora A [1970]. Investigation of the relation between low back pain and occupation. Ind Med *39*:31–37.

Magora A [1972]. Investigation of the relation between low back pain and occupation. III. Physical requirements: sitting, standing, and weight lifting. Ind Med *41*(12):5–9.

Magora A [1973]. Investigation of the relation between low back pain and occupation. IV. Physical requirements: bending, rotation, reaching, and sudden maximal effort. Scand J Rehabil Med *5*:191–196.

Magora A, Schwartz A [1978]. Relation between the low back pain syndrome and x-ray findings. I. Degenerative osteoarthritis. Scand J Rehabil Med *10*:135–145.

Maizlish N, Rudolph L, Dervin K, Sankaranarayan M [1995]. Surveillance and prevention of work-related carpal tunnel syndrome: an application of the Sentinel Events Notification System for Occupational Risks. Am J Ind Med *27*(5):715–729.

Mäkelä M, Heliövaara M, Sievers K, Impivaara O, Knekt P, Aromaa A [1991]. Prevalence, determinants, and consequences of chronic neck pain in Finland. Am J Epidemiol *134*(11):1356–1367.

MaKinnon SE, Novak CB [1997]. Repeti-tive strain in the workplace. J Hand Surg [Am] *22A*(1):2–18.

Marcus M, Gerr F [1996]. Upper extremity musculoskeletal symptoms among female office workers: associations with video display terminal use and occupational psychosocial stressors. Am J Ind Med *29*(2):161–170.

Marley RJ, Fernandez JE [1995]. Psychophysical frequency and sustained exertion at varying wrist postures for a drilling task. Ergonomics *38*(2):303–325.

Marras WS, Schoenmarklin RW [1991]. Quantification of wrist motion in highly repetitive, hand-intensive industrial jobs. Washington, DC: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health.

Marras W, Schoenmarklin RW [1993]. Wrist motions in industry. Ergonomics *36*(4):341–351.

Marras WS, Lavender SA, Leurgans SE, Rajulu SL, Allread WG, Fathallah FA, et al. [1993]. The role of dynamic three-dimen-sional trunk motion in occupationally-related low back disorders: the effects of workplace factors, trunk position, and trunk motion characteristics on risk of injury. Spine *18*(5):617–628.

Marras WS, Lavender SA, Leurgans SE, Fathallah FA, Ferguson SA, Allread WG, et al. [1995]. Biomechanical risk factors for occupationally-related low back disorders. Ergonomics *38*(2):377–410.

Martin DK, Dain SJ [1988]. Postural modifications of VDU operators wearing bifocal spectacles. Appl Ergonomics *19*(4):293–300.

Masset D, Malchaire J [1994]. Low back pain: epidemiologic aspects and work-related factors in the steel industry. Spine *19*(2):143–146.

Matheson LN, Brophy RG, Vaughan KD, Nunez C, Saccoman KA [1995]. Workers' compensation managed care: preliminary findings. J Occup Rehabil *5*(1):27–36.

Mathiowetz V, Kashman N, Volland G, Weber K, Dowe M, Rogers S [1985]. Grip and pinch strength: normative data for adults. Arch Phys Med Rehabil *66*(2):69–72.

Matthews KA, Cottington EM, Talbott E, Kuller LH, Siegel JM [1987]. Stressful work conditions and diastolic blood pressure among blue collar factory workers. Am J Epidemiol *126*(2):280–290.

Mayer TG, Gatchel RJ, Kishino N, Keeley J, Capra P, Mayer H, et al. [1985]. Objective assessment of spinal function following industrial injury: a prospective study with comparison group and one-year follow-up. Spine *10*(6):482–493.

McCormack RR Jr., Inman RD, Wells A, Berntsen C, Imbus HR [1990]. Prevalence of tendinitis and related disorders of the upper extremity in a manufacturing workforce. J Rheumatol *17*:958–964.

McKenna K, McGrann S, Blann A, Allen J [1993]. An investigation into the acute vascular effects of riveting. Br J Ind Med *50*:160–166.

McNeil T, Warwick D, Andersson G, Schultz A [1980]. Trunk strengths in attempted flexion, extension, and lateral bending in healthy subjects and patients with low back disorders. Spine *5*(6):529–538.

Merriam WP, Burwell RG, Mulholland RC, Pearson JCG, Webb JK [1980]. A study revealing a tall pelvis in subjects with low back pain. J Bone Joint Surg [Br] *65B*:153–156.

Milerad E, Ekenvall L [1990]. Symptoms of the neck and upper extremities in dentists. Scand J Work Environ Health *16*(1): 129–134.

Mintz G, Fraga A [1973]. Severe osteo-arthritis of the elbow in foundry workers. Arch Environ Health *27*:78–80.

Mirbod SM, Inaba R, Iwata H [1992a]. A study on the vibration-dose limit for Japanese workers exposed to hand-arm vibration. Ind Health *30*:1–22.

Mirbod SM, Yoshida H, Nagata C, Inaba R, Komura Y, Iwata H [1992b]. Hand-arm vibration syndrome and its prevalence in the present status of private forestry enterprises in Japan. Int Arch Occup Environ Health *64*:93–99.

Mirbod SM, Yoshida H, Komura Y, Fujita S, Nagata C, Miyashita K, et al. [1994]. Prevalence of Raynaud's phenome-non in different groups of workers operating hand-held vibrating tools. Int Arch Occup Environ Health *66*:13–22.

Miyashita K, Morioka I, Iwata H, Takeda S [1992]. Symptoms of construction workers exposed to whole-body vibration and local vibration. Int Arch Occup Environ Health *64*:347–351.

Moon SD, Sauter SL [1996]. Beyond biomechanics: psychosocial aspects of musculoskeletal disorders in office work. London, England: Taylor and Francis.

Moore JS [1992]. Carpal tunnel syndrome. Occup Med: State of the Art Rev *7*(4):741–763.

Moore JS, Garg A [1991]. Determination of the operational characteristics of ergonomic exposure assessments for prediction of disorders of the upper extremities and back. In: Proceedings of the 11th Congress of the International Ergonomics Association. London, England: Taylor & Francis, pp. 144–146.

Moore JS, Garg A [1994]. A comparison of different approaches for ergonomic job evaluation for predicting risk of upper extremity disorders. IEA 94. Occup Health Saf *2*.

Morgenstern H, Kelsh M, Kraus J, Margolis W [1991]. A cross-sectional study of hand/wrist symptoms in female grocery check-ers. Am J Ind Med *20*(2):209–218.

Morris HH, Peters BH [1976]. Pronator syndrome: clinical and electrophysiological features in seven cases. J Neurol Neurosurg Psychiatry *39*:461–464.

Mostardi RA, Noe DA, Kovacik MW, Porterfield JA [1992]. Isokinetic lifting strength and occupational injury: a prospective study. Spine *17*(2):189–193.

Musson Y, Burdorf A, van Drimmelen D [1989]. Exposure to shock and vibration and symptoms in workers using impact power tools. Ann Occup Hyg *33*(1):85–96.

Nachemson A, Lindh M [1969]. Measurement of abdominal and back muscle strength with and without low back pain. Scand J Rehabil Med *1*:60–65.

Nachemson A, Elfstrom G [1970]. Intravital dynamic pressure measurements in lumbar discs. Scand J Rehabil Med *1*(Suppl):1–40.

Nagata C, Yoshida H, Mirbod S, Komura Y, Fujita S, Inaba R, et al. [1993]. Cutaneous signs (Raynaud's phenomenon, sclerodacty-lia, and edema of the hands) and hand-arm vibration exposure. Int Arch Occup Environ Health *64*:587–591.

Nathan PA, Meadows KD, Doyle LS [1988]. Occupation as a risk factor for impaired sensory conduction of the median nerve at the carpal tunnel. J Hand Surg [Br] *13B*(2): 167–170.

Nathan PA, Keniston RC, Myers LD, Meadows KD [1992a]. Longitudinal study of median nerve sensory conduction in industry: relationship to age, gender, hand dominance, occupational hand use, and clinical diagnosis. J Hand Surg [Am] *17A*(5):850–857.

Nathan PA, Keniston RC, Myers LD, Meadows KD [1992b]. Obesity as a risk factor for slowing of sensory conduction of the median nerve in industry: a cross-sectional and longitudinal study involving 429 workers. J Occup Med *34*(4):379–383.

Nathan PA, Keniston RC, Meadows KD, Lockwood RS [1993]. Validation of occupational hand use categories. J Occup Med *35*(10):1034–1042.

Nathan PA, Keniston RC, Meadows KD, Lockwood RS [1994a]. The relationship between body mass index and the diagnosis of carpal tunnel syndrome [letter to the editor]. Muscle Nerve, December 1994, pp. 1491–1492.

Nathan PA, Takigawa K, Keniston RC, Meadows KD, Lockwood RS [1994b]. Slowing of sensory conduction of the median nerve and carpal tunnel syndrome in Japanese and American industrial workers. J Hand Surg [Am] *19B*(1):30–34.

Necking LE, Dahlin LB, Fridin J, Lundborg G, Lundström R, Thornell LE [1992]. Vibration-induced muscle injury: an experimental model and preliminary findings. J Hand Surg [Br] *17B*:270–274.

Nicholas JA [1990]. Clinical observations on sports-induced soft-tissue injuries in sports-induced inflammation. In: Leadbetter WB, Buckwalter JA, Gordon SL, eds. Rosemont, IL: American Academy of Orthopedic Surgeons, p. 143.

Nilsson T, Burström L, Hagberg M [1989]. Risk assessment of vibration exposure and white fingers among platers. Int Arch Occup Environ Health *61*(7):473–481.

Nilsson T, Hagberg M, Burström L [1990]. Prevalence and odds ratio of numbness and carpal tunnel syndrome in different exposure categories of platers. In: Okada A, Dupuis WTH, eds. Hand-arm vibration. Kanazawa, Japan: Kyoei Press Co., pp. 235–239.

Nilsson T, Hagberg M, Burström L, Kihlberg S [1994]. Impaired nerve conduction in the carpal tunnel of platers and truck assemblers exposed to hand-arm vibration. Scand J Work Environ Health *20*:189–199.

Nilsson T, Hagberg M, Burström L, Lundström R [1995]. A five-year follow-up study of nerve conduction across the carpal tunnel among workers at a heavy engineer-ing production plant. In: International Conference on the Prevention of Musculo-skeletal Disorders (PREMUS). Montreal, Canada: International Committee on Occupational Safety and Health, pp.81–83.

NIOSH [1989]. NIOSH criteria for a recommended standard: occupational exposure to hand-arm vibration. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 89–106.

NIOSH [1991]. Epidemiological basis for manual lifting guidelines. In: Scientific support documentation for the revised 1991 NIOSH lifting equation: technical contract reports. Springfield, VA: National Technical Information Service (NTIS), NTIS No. PB–91–226274.

NIOSH [1996]. National occupational research agenda. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 96–115.

Nirschl RP [1973]. Tennis elbow. Orthop Clin North Am *4*(3):787–800.

Nirschl RP [1975]. The etiology and treatment of tennis elbow. J Sports Med *2*(6):308–319.

Nirschl R [1993]. Muscle and tendon trauma: tennis elbow. In: Morrey B, ed. The elbow and its disorders. 2nd ed. Philadel-phia, PA: W.B. Saunders Company, pp. 552–573.

Nordgren B, Schek R, Linrotn K [1980]. Evaluation and prediction of back pain during military field service. Scand J Rehabil Med *12*(1):1–8.

Ohara H, Nakagiri S, Itani T, Wake K, Aoyama H [1976]. Occupational health hazards resulting from elevated work rate situations. J Hum Ergol *5*(2):173–182.

Ohlsson K, Attewell R, Skerfving S [1989]. Self-reported symptoms in the neck and upper limbs of female assembly workers. Scand J Work Environ Health *15*(1):75–80.

Ohlsson K, Hansson GA, Balogh I, Strömberg U, Pålsson B, Nordander C, et al. [1994]. Disorders of the neck and upper limbs in women in the fish processing industry. Occup Environ Med *51*:826–832.

Ohlsson K, Attewell R, Paisson B, Karlsson B, Balogh I, Johnsson B, et al. [1995]. Repetitive industrial work and neck and upper limb disorders in females. Am J Ind Med *27*(5):731–747.

Olafsdottir H, Rafnsson V [1995]. New tech-niques increases the prevalences of musculoskeletal symptoms from upper limbs among women in fish fillet plants. In: Second International Scientific Conference on Prevention of Work-Related Musculoskeletal

Disorders. Montreal, Canada, pp. 248–249.

Ollivierre CO, Nirschl RP, Pettrone FA [1995]. Resection and repair for medical tennis elbow: a prospective analysis. Am J Sports Med *23*(2):214–221.

Onishi N, Namura H, Sakai K, Yamamoto T, Hirayama K, Itani T [1976]. Shoulder muscle tenderness and physical features of female industrial workers. J Hum Ergol *5*(2):87–102.

Osorio AM, Ames RG, Jones J, Castorina J, Rempel D, Estrin W, et al. [1994]. Carpal tunnel syndrome among grocery store workers. Am J Ind Med *25*(2):229–245.

Owen B, Damron C [1984]. Personal characteristics and back injury among hospital nursing personnel. Res Nurs Health *7*:305–313.

Parker KG, Imbus HR [1992]. Cumulative trauma disorders. Current issues and ergonomic solutions: a system approach. Chelsea, MI: Lewis Publishers.

Partridge REH, Duthie JJR [1968]. Rheumatism in dockers and civil servants: a comparison of heavy manual and sedentary workers. Ann Rheum Dis *27*:559–568.

Payne R [1988]. Individual differences in the study of occupational stress. In: Cooper CL, Payne R, eds. Causes, coping, and consequences of stress at work. Chichester, England: John Wiley & Sons, pp. 209–232.

Pecina M, Krmpotic-Nemanic J, Markiewitz A [1991]. Tunnel syndromes. Boston, MA: CRC Press.

Pietri-Taleb F, Riihimaki H, Viikari-Juntura E, Lindström K, Moneta GB [1995]. The role of psychological distress and personal-ity in the incidence of sciatic pain among working men. Am J Public Health *85:*541– 545.

Pope MH, Rosen JC, Wilder DG, Frymoyer JW [1980]. The relation between biomechanical and psychological factors in patients with low back pain. Spine *5*(2): 173–178.

Pope MH, Frymoyer JW, Andersson GBJ, et al. [1984]. Occupational low back pain. New York, NY: Praeger.

Pope MH, Andersson GBJ, Frymoyer JW, et al. [1991]. Occupational low back pain: assessment, treatment, and prevention. St. Louis, MO: Mosby-Year Book, pp. 105–108.

Porter RW [1987]. Does hard work prevent disc protrusion? Clin Biomechanics *2*(4): 196–198.

Pot F, Padmos P, Brouwers A [1987]. Determinants of the VDU operator's well-being. In: Knave B, Wideback PG, eds. Work with display units 86. Selected papers from the International Scientific Conference on Work with Display Units, Stockholm, Sweden, May 12–15, 1986. Amsterdam: Elsevier Science Publishers B.V., pp. 16–25.

Priest JD, Braden V, Gerberich SG [1980]. The elbow and tennis, part 1: an analysis of players with and without pain. Physician Sports Med *8*:81–91.

Priest JD, Hones HH, Tichenor CJ, Nagel DA [1977]. Arm and elbow changes in expert tennis players. Minn Med *60*:399– 404.

Punnett L, Robins JM, Wegman DH, Keyserling WM [1985]. Soft-tissue disorders in the upper limbs of female assembly workers: impact of length of employment, work pace, and selection. Scand J Work Environ Health *11*(6): 417–425.

Punnett L, Fine LJ, Keyserling WM, Herrin GD, Chaffin DB [1991]. Back disorders and nonneutral trunk postures of automobile assembly workers. Scand J Work Environ Health *17*(5):337–346.

Pyykkö I, Starak J [1986]. Pathophysiologic and hygienic aspects of hand-arm vibration. Scand J Work Environ Health *12*(4):237– 241.

Queinnec Y, Daniellou F, eds. [1991]. Shoulder symptoms and headache in light sedentary work. In: Designing for everyone. Proceedings of the 11th Congress of the International Ergonomics Association, Paris, France, July 15–20, 1991. London, England: Taylor and Francis, pp. 129–131.

Radecki P [1995]. Variability in the median and ulnar nerve latencies: implications for diagnosing entrapment. J Occup Med 37: 1293–1299.

Radwin RG, VanBergeijk E, Armstrong TJ [1989]. Muscle response to pneumatic hand tool torque reaction forces. Ergonomics *32*(6):655–673.

Ranney D, Wells R, Moore A [1995]. Upper limb musculoskeletal disorders in highly repetitive industries: precise anatomical physical findings. Ergonomics *38*(7):1408– 1423.

Rathburn JB Macnab I [1970]. The microvascular pattern of the rotator cuff. J Bone Joint Surg [Br] *52B*(3):540–553.

Rempel D [1995]. Musculoskeletal loading and carpal tunnel pressure. In: Gordon SL, Blair SJ, Fine LJ, eds. Repetitive motions disorders of the upper extremity. Rosemont IL: American Academy of Orthopaedic Surgeons, pp. 123–133.

Rempel D, Harrison R, Barnhart S [1992]. Work-related cumulative trauma disorders of the upper extremity. JAMA *267*(6): 838–841.

Rempel D, Dennerlein J, Mote CD, Armstrong T [1994a]. A method of mea-suring fingertip loading during keyboard use. J Biomechanics *27*(8):1101–1104.

Rempel D, Manojlovic R, Levinsohn DG, Bloom T, Gordon L [1994b]. The effect of wearing a flexible wrist splint on carpal tunnel pressure during repetitive hand activity. J Hand Surg [Am] *19A*(1):106–110.

Riihimäki H [1991]. Low-back pain, its origin and risk indicators. Scand J Work Environ Health *17*(2):81–90.

Riihimäki H [1995]. Hands up or back to work—future challenges in epidemiologic research on musculoskeletal diseases. Scand J Work Environ Health *21*(6):401–403.

Riihimäki H, Tola S, Videman T, Hänninen K [1989a]. Low-back pain and occupation: a cross-sectional questionnaire study of men in machine operating, dynamic physical work, and sedentary work. Spine *14*: 204–209.

Riihimäki H, Wickström G, Hänninen K, Luopajärvi T [1989b]. Predictors of sciatic pain among concrete reinforcement workers and house painters: a five-year follow-up. Scand J Work Environ Health *15*(6):415– 423.

Riihimäki H, Wickström G, Hänninen K, Mattson T, Waris P, Zitting AG [1989c]. Radiographically detectable lumbar degenerative changes as risk indicators of back pain. Scand J Work Environ Health *15*:280–285.

Riihimäki H, Viikari-Juntura E, Moneta G, Kuha J, Videman T, Tola S [1994]. Incidence of sciatic pain among men in machine operating, dynamic physical work and sedentary work. Spine *19*(2):138–142.

Ringel SP, Treihaft M, Carry M, Fisher R, Jacobs P [1990]. Suprascapular neuropathy in pitchers. Am J Sports Med *18*(1):80–86.

Ritz BR [1995]. Humeral epicondylitis among gas- and waterworks employees. Scand J Work Environ Health *21*:478–486.

Rodgers SH, The Ergonomics Group, Health and Environment Laboratories, Eastman Kodak Co. [1986]. Ergonomic design for people at work. Vol. II: The design of jobs, including work patterns, hours of work, manual materials handling tasks, methods to evaluate job demands, and the physiological basis of work. New York, NY: Van Nostrand Reinhold Co., Inc.

Rose L, Ericson M, Glimskar B, Nordgren B, Ortengren R [1992]. Ergo-index: a model to determine pause needs after fatigue and pain reactions during work. In: Kumar S, ed. Advances in industrial ergonomics and safety, IV, Proceedings of the Annual International Industrial Ergonomics and Safety Conference, Denver, CO, June 10–14, 1992. London, England: Taylor and Francis, pp. 303–310.

Rossignol AM, Morse EP, Summers VM, Pagnotto LD [1987]. Video display terminal use and reported health symptoms among Massachusetts clerical workers. J Occup Med *29*(2):112–118.

Rothfleisch SD, Sherman S [1978]. Carpal tunnel syndrome: biomechanical aspects of occupational occurrence and implications regarding surgical management. Orthop Rev *7*(6):107–109.

Rothman KJ, ed. [1986]. Modern epidemiology. Boston, MA: Little, Brown, and Company.

Roto P, Kivi P [1984]. Prevalence of epicondylitis and tenosynovitis among meatcutters. Scand J Work Environ Health *10*(3):203– 205.

Rowe ML [1965]. Disc surgery and chronic low back pain. J Occup Med *7*(5):196–202.

Rowe ML [1985]. Backache at work. Fairport, NY: Perington Press.

Ruberman W [1992]. Psychosocial influences on mortality of patients with coronary heart disease. JAMA *267*(4): 559–560.

Ruberman W, Weinblatt E, Goldberg JD, Chaudhary BS [1984]. Psychosocial influences on mortality after myocardial infarction. N Engl J Med *311*(9):552–559.

Ryan GA, Bampton M [1988]. Comparison of data process operators with and without upper limb symptoms. Community Health Stud *12*(1):63–68.

Ryan GA, Hage B, Bampton M [1987]. Postural factors, work organization and musculoskeletal disorders. In: Buckle P, ed. Musculoskeletal disorders at work. Proceedings of a conference held at the University of Surrey, Guilford, April, 1987. London, England: Taylor and Francis, pp. 251–253.

Ryden LA, Molgaard CA, Bobbitt S, Conway J [1989]. Occupational low-back injury in a hospital employee population: an epidemiologic analysis of multiple risk factors of a high-risk occupational group. Spine *14*:315–320.

Sairanen E, Brüshaber L, Kaskinen M [1981]. Felling work, low back pain and osteoarthritis. Scand J Work Environ Health *7*(1):18–30.

Saito K [1987]. Prevention of the hand-arm vibration syndrome. Scand J Work Environ Health *13*:301–304.

Sakakibara H, Masaru M, Kondo T, Yamada S [1987]. Relation between overhead work and complaints of pear and apple orchard workers. Ergonomics *30*(5):805–815.

Sakakibara H, Miyao M, Kondo T, Yamada S [1995]. Overhead work and shoulder-neck pain in orchard farmers harvesting pears and apples. Ergonomics *38*(4):700–706.

Sauter SL [1984]. Predictors of strain in VDT users and traditional office workers. In: Grandjean E, ed. Ergonomics and health in modern offices. London, England: Taylor and Francis, pp. 129–135.

Sauter SL, Swanson NG [1996]. Psychological aspects of musculoskeletal disorders in office work. In: Moon S, Sauter S, eds. Psychosocial factors and musculoskeletal disorders. London, England: Taylor and Francis.

Sauter SL, Gottlieb MS, Jones KC, Dodson VN, Rohrer KM [1983]. Job and health implications of VDT use: initial results of the Wisconsin-NIOSH study. Commun of the ACM *26*(4):284–294.

Schibye B, Skov T, Ekner D, Christiansen J, Sjøgaard G [1995]. Musculoskeletal symptoms among sewing machine operators. Scand J Work Environ Health *21*:427–434.

Schierhout GH, Meyers JE, Bridger RS [1995]. Work-related musculoskeletal disorders and ergonomic stressors in the South African workforce. Occup Environ Med *52*(1):46–50.

Schlesselman J [1978]. Assessing the effects of confounding variables. Am J Epidemiol *108*:3–8.

Schlesselman J [1982]. Monographs in epidemiology and biostatistics. Case-control studies: design, conduct, analysis. New York, NY: Oxford University Press.

Schnall PL, Pieper C, Schwartz JE, Karasek RA, Schlussel Y, Devereux RB, et al. [1990]. The relationship between job strain, workplace diastolic blood pressure, and left ventricular mass: results of a case-control study. JAMA *263*(14):1929–1935.

Schnall PL, Schwartz JE, Landsbergis PA, Warren K, Pickering TG [1992]. The relationship between job strain, alcohol, and ambulatory blood pressure. Hypertension *19*:488–494.

Schnall PL, Landsbergis PA, Baker D [1994]. Job strain and cardiovascular disease. Ann Rev Public Health *15*:381–411.

Schottland JR, Kirschberg GJ, Fillingim R, Davis VP, Hogg F [1991]. Median nerve latencies in poultry processing workers: an approach to resolving the role of industrial "cumulative trauma" in the development of carpal tunnel syndrome. J Occup Med *33*(5):627–631.

Scott V, Gijsbers K [1981]. Pain perception in competitive swimmers. Br Med J *283*: 91–93.

Seidel H, Heide R [1986]. Long-term effects of whole-body vibration: a critical survey of the literature. Int Arch Occup Environ Health *58*:1–26.

Shinev V, Komleva L, Zhuravlev A, Druzhinin V [1992]. Study of the physical characteristics of percussive vibration of hand-held machines and its effect on the body. Noise and Vibration Bulletin, pp. 138–140.

Silverstein BA [1985]. The prevalence of upper extremity cumulative trauma disorders in industry [Dissertation]. Ann Arbor, MI: The University of Michigan.

Silverstein BA, Fine LJ, Armstrong TJ [1986]. Hand wrist cumulative trauma disorders in industry. Br J Ind Med *43*(11):779–784.

Silverstein BA, Fine LJ, Armstrong TJ [1987]. Occupational factors and the carpal tunnel syndrome. Am J Ind Med *11*(3):343– 358.

Silverstein B, Grossman E, Kalat J, Nelson N [in press]. Upper limb and low back musculoskeletal disorders: State and national estimates based on workers' compensation accepted claims. Proceedings for managing ergonomics in the 90's. Alexandria, VA: Center for Office Technology and the American Automobile Manufacturer's Association.

Sinclair A [1964]. Tennis elbow in industry. Br J Ind Med *22*:144–148.

Sjøgaard G [1988]. Intramuscular changes during long-term contraction. In: Corlett N, Wilson J, Manenica I, eds. The ergonomics of working postures: models, methods and cases. Proceedings of the First International Occupational Ergonomics Symposium, Zadar, Yugoslavia, April 18–20, 1985, London, England: Taylor and Francis, pp. 136–143.

Sjøgaard G, Savard G, Juel C [1988]. Muscle blood flow during isometric activity and its relation to muscle fatigue. Eur J Appl Physiol *57*:327–335.

Skie M, Zeiss J, Ebraheim NA, Jackson WT [1990]. Carpal tunnel changes and median nerve compression during wrist flexion and extension seen by magnetic resonance imaging. J Hand Surg [Am] *15A*(6):939.

Skov T, Borg V, Orhede E [1996]. Psycho-social and physical risk factors for musculoskeletal disorders of the neck, shoulders, and lower back in salespeople. Occup Environ Med *53*:351–356.

Skovron ML, Mulvihill MN, Sterling RC, Nordin M, Tougas G, Gallagher M, et al. [1987]. Work organization and low back pain in nursing personnel. Ergonomics *30*(2):359–366.

Skovron ML, Szpalski M, Nordin M, Melot C, Cukier D [1994]. Sociocultural factors and back pain: a population-based study in Belgian adults. Spine *19*(2):129– 137.

Slocum D [1960]. Overuse syndromes of the lower leg and foot in athletes. AAOS Instructional Course Lectures, pp. 359–367.

Smith MJ, Stammerjohn LW, Cohen BGF, Lalich NR [1977]. Job stress in video display operations. In: Grandjean E, Vigliani E, eds. Ergonomic aspects of video display terminals. London, England: Taylor and Francis, pp. 201–210.

Snook SH [1978]. The design of manual handling tasks. Ergonomics *21*(12):963– 985.

Snook SH [1982]. Low back pain in industry. In: White AA, Gordon SL, eds. American Academy of Orthopaedic Surgeons Symposium on Idiopathic Low Back Pain. St. Louis, MO: C.O. Mosby Company, pp. 23–38.

Snook SH [1987]. Approaches to preplacement testing and selection of workers. Ergonomics *30*(2):241–247.

Snook SH, Webster BS [1987]. The cost of disability. Clin Orthop *221*:77–84.

Snook SH, Ciriello VM [1991]. The design of manual handling tasks: revised tables of maximum acceptable weights and forces. Ergonomics *34*(9):1197–1213.

Snook SH, Campanelli RA, Hart JW [1978]. A study of three preventive approaches to low back injury. J Occup Med *20*(7):478– 487.

Sokal RR, Rohlf FJ [1981]. Biometry: the principles and practice of statistics in biological research. 2nd ed. San Francisco, CA: WH Freeman and Co.

Sommerich CM, McGlothin JD, Marras WS [1993]. Occupational risk factors associated with soft tissue disorders of the shoulder: a review of recent investigations in the literature. Ergonomics *36*(6):697–717.

Spengler DM, Bigos S, Martin NA, Zeh J, Fisher L, Nachemson A [1986]. Back injuries in industry: a retrospective study. I. Overview and cost analysis. Spine *11*: 241–245.

Starck J, Jussi P, Ilmari P [1990]. Physical characteristics of vibration in relation to vibration-induced white finger. Am Ind Hyg Assoc J *51*(4):179–184.

Stenlund B [1993]. Shoulder tendinitis and osteoarthritis of the acromioclavicular joint and their relation to sports. Br J Sports Med *27*:125–128.

Stenlund B, Goldie I Hagberg M, Hogstedt C, Marions O [1992]. Radiographic osteoarthrosis in the acromioclavicular joint resulting from manual work or exposure to vibration. Br

J Ind Med *49*:588–593.

Stenlund B, Goldie I, Hagberg M, Hogstedt C [1993]. Shoulder tendinitis and its relation to heavy manual work and exposure to vibration. Scand J Work Environ Health *19*: 43–49.

Stetson DS, Keyserling WM, Silverstein BA, Leonard JA [1991]. Observational analysis of the hand and wrist: a pilot study. Appl Occup Environ Hyg *6*(11):927–937.

Stetson DS, Silverstein BA, Keyserling WM, Wolfe RA, Albers JW [1993]. Median sensory distal amplitude and latency: comparisons between nonexposed managerial/professional employees, and industrial workers. Am J Ind Med *24*:175–189.

Stevens JC, Sun MD, Beard CM, O'Fallon WM, Kurland LT [1988]. Carpal tunnel syndrome in Rochester, Minnesota, 1961 to 1980. Neurology *38*:134–138.

Stevens PH, Chase DO, Brownlie AW [1966]. Industrial design of a narrow aisle sit-down lift truck. Hum Factors *8*:317–325.

Stock SR [1991]. Workplace ergonomic factors and the development of musculo-skeletal disorders of the neck and upper limbs: a meta-analysis. Am J Ind Med *19*(1):87–107.

Stubbs DA [1986]. Back pain and its relationship to manual handling. In: Morrison D, Hartley L, Kemp D, eds. Trends in the ergonomics of work. Proceed-ings of the 23rd Annual Conference of the Ergonomics Society of Australia, pp. 118–128.

Susser M [1991]. What is a cause and how do we know one?: a grammar for pragmatic epidemiology. Am J Epidemiol *133*(7):635–648.

Svensson H [1982]. Low back pain in 40- to 47-year-old men: II. Socioeconomic factors and previous sickness absence. Scand J Rehabil Med *14*:55–60.

Svensson H, Andersson GBJ [1983]. Low-back pain in 40- to 47-year old men: work history and work environment factors. Spine *8*:272–276.

Svensson H, Andersson GBJ [1989]. The relationship of low-back pain, work history and work environment, and stress: a retrospective cross-sectional study of 38- to 64-year old women. Spine *14*(5):517–522.

Sweeney MH, Petersen M, O'Neill V [1994]. Hazard evaluation and technical assistance report: Registry of Interpreters for the Deaf, Ohio Chapter. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH Report No. HHE 92–0268–2477.

Szabo RM, Chidgey LK [1989]. Stress carpal tunnel pressures in patients with carpal tunnel syndrome and normal patients. J Hand Surgery [Am] *14A*(4):624–627.

Takala E, Viikari-Juntura E [1991]. Muscle force endurance and neck-shoulder symp-toms of sedentary workers: an experimental study on bank cashiers with and without symptoms. Amsterdam, The Netherlands: Elsevier Science Publishers. B.V., pp. 123–132.

Takala EP, Viikari-Juntara E, Moneta G,

Saarenmaa K, Kaivanto K [1991]. Predic-tors for the natural course of neck–shoulder symptoms and headache in light sedentary work. In: Queinnec Y, Daniellou F, eds. Designing for everyone. Proceedings of the 11th Congress of the International Ergono-mics Association, Paris, France, July 15–20, 1991. London, England: Taylor and Francis, pp. 129–131.

Takeuchi T, Futatsuka M, Imanishi H, Yamada S [1986]. Pathological changes observed in the finger biopsy of patients with vibration-induced white finger. Scand J Work Environ Health *12*:280–283.

Tanaka S, Wild DK, Seligman PJ, Halperin WE, Behrens VJ, Putz-Anderson V [1995]. Prevalence of work-related carpal tunnel syndrome among U.S. workers: analysis of the occupational health supplement data of 1988 National Health Interview Survey. Am J Ind Med *27*(4):451–470.

Tanaka S, Wild DK, Cameron L, Freund E [in press]. Association of occupational and non-occupational risk factors with the prevalence of self-reported carpal tunnel syndrome in a national survey of the working population. Am J Ind Med.

Tanii K, Kogi K, Sadoyama T [1972]. Spontaneous alteration of the working arm in static overhead work. J Hum Ergol *1*:143–155.

Tauber J [1970]. An unorthodox look at backaches. J Occup Med *12*(4):128–130.

Taylor W [1982]. Vibration white finger in the workplace. J Soc Occup Med *32*:159–166.

Theorell T, Harms-Ringdahl K, Ahlberg-Hultén G, Westin B [1991]. Psychosocial job factors and symptoms from the locomotor system: a multicausal analysis. Scand J Rehabil Med *23*(3):165–173.

Theorell T, Ahlberg-Hulten G, Jodko M, Sigala F, de la Torre B [1993]. Influence of job strain and emotion on blood pressure levels in female hospital personnel during work hours. Scand J Work Environ Health *19*(5):313–318.

Tola S, Riihimäki H, Videman T, Viikari-Juntura E, Hänninen K [1988]. Neck and shoulder symptoms among men in machine operating, dynamic physical work and sedentary work. Scand J Work Environ Health *14*(5):299–305.

Toomingas A, Hagberg M, Jorulf L, Nilsson T, Burström L, Kihlberg S [1991]. Outcome of the abduction external rotation test among manual and office workers. Am J Ind Med *19*(2):215–227.

Toomingas A, Theorell T, Michélsen H, et al. [1992]. Associations between preceived psychosocial job factors and prevalence of musculoskeletal disorders in the neck and shoulder regions. In: Hagberg M, Kilbom Å, eds. International Scientific Conference on Prevention of Work-Related Musculo-skeletal Disorders PREMUS, Sweden, May 12–14, 1992. Arbete och Hälsa 17:289.

Toroptsova NV, Benevolenskaya LI, Karyakin AN, Sergeev IL, Erdesz S [1995]. Cross-sectional study of low back pain among workers at an industrial enterprise in Russia. Spine *20*(3):328–332.

Torrell G, Sanden A, Järvholm B [1988]. Musculoskeletal disorders in shipyard workers.

J Soc Occup Med *38*(4):109–112.

Troup JDG [1978]. Driver's back pain and its prevention—a review of the postural, vibratory, and muscular factors, together with the problem of transmitted road shock. Appl Ergonomics *9*(4):207–214.

Troup JDG, Martin JW, Lloyd DC [1981]. Back pain in industry: a prospective survey. Spine *6*(1):61–69.

Troup JDG, Foreman TK, Baxter CE, Brown D [1987]. Musculoskeletal disorders at work, tests of manual working capacity and the prediction of low back pain. In: Buckle P, ed. Musculoskeletal disorders at work. London, England: Taylor and Francis, pp. 165–170.

Uhl JE, Wilkinson WE, Wilkinson CS [1987]. Aching backs? A glimpse into the hazards of nursing. AAOHN J *35*(1):13–17.

Ulin SS, Armstrong TJ, Snook SH, Keyserling WM [1993]. Perceived exertion and discomfort associated with driving screws at various work locations and at different work frequencies. Ergonomics *36*(7):833–846.

Undeutsch K, Gärtner KH, Luopajärvi T, Küpper R, Karvonen MJ, Löwenthal I, et al. [1982]. Back complaints and findings in transport workers performing physically heavy work. Scand J Work Environ Health *8*(Suppl 1):92–96.

Ursin H, Endresen IM, Ursin G [1988]. Psychological factors and self-reports of muscle pain. Eur J Appl Physiol *57*(3):282–290.

Veiersted KG, Westgaard RH [1992]. Work-related risk factors for trapezius myalgia. In: Hagberg M, Kolbom Å, eds. International Scientific Conference on Prevention of Work-Related Musculoskeletal Disorders PREMUS, Sweden, May 12–14, 1992. Arbete och Hälsa 17:307–309.

Veiersted KG, Westgaard RH [1994]. Subjectively assessed occupational and individual parameters as risk factors for trapezius myalgia. Int J Ind Ergo *13*(3):235–245.

Veiersted KB, Westgaard RH, Andersen P [1993]. Electromyographic evaluation of muscular work pattern as a predictor of trapezius myalgia. Scand J Work Environ Health *19*:284–290.

Vessey MP, Villard-Mackintosh L, Yeates D [1990]. Epidemiology of carpal tunnel syndrome in women of childbearing age. Findings in a large cohort study. Int J Epidemiol *19*(3):655–659.

Videman T, Nurminen T, Tola S, Kuorinka I, Vanharanta H, Troup JDG [1984]. Low-back pain in nurses and some loading factors of work. Spine *9*(4):400–404.

Videman T, Rauhala H, Asp S, Lindstrom K, Cedercreutz G, Kamppi M, et al. [1989]. Patient-handling skill, back injuries, and back pain: an intervention study in nursing. Spine *14*(2):148–156.

Videman T, Nurminen M, Troup JDG [1990]. Lumbar spine pathology in cadaveric material in relation to history of back pain, occupation, and physical loading. Spine *15*(8):728–740.

Vihma T, Nurminen M, Mutanen P [1982]. Sewing machine operators' work and musculoskeletal complaints. Ergonomics *25*(4):295–298.

Viikari-Juntura E [1995]. The role of physical stressors in the development of hand/wrist, and elbow disorders. In: Gordon SL, Blair SJ, Armstrong, et al., eds. Pathophysiology and clinical factors in upper extremity repetitive motion syndromes. Bethesda, MD: American Academy of Orthopedic Surgeons.

Viikari-Juntura EJ, Vuori J, Silverstein B, Kalimo R, Kuosma E, Videman T [1991a]. A life-long prospective study on the role of psychosocial factors in neck-shoulder and low back pain. Spine *16*:1056–1061.

Viikari-Juntura E, Kurppa K, Kuosma E, Huuskonen M, Kuorinka I, Ketola R, et al. [1991b]. Prevalence of epicondylitis and elbow pain in the meat-processing industry. Scand J Work Environ Health *17*(1):38–45.

Viikari-Juntura E, Riihimäki H, Tola S, Videman T, Mutanen P [1994]. Neck trouble in machine operating, dynamic physical work and sedentary work: a prospective study on occupational and individual risk factors. J Clin Epidemiol *47*(12):1411– 1422.

Virokannas H [1995]. Dose-response relation between exposure to two types of hand-arm vibration and sensorineural per-ception of vibration. Occup Environ Med *52*:332–336.

Virokannas H, Tolonen U [1995]. Responses of workers exposed to vibration in autono-mic nervous function tests. Int Arch Occup Environ Health *67*(3):201–205.

Waersted M, Bjorklund R, Westgaard RH [1986]. Generation of muscle tension related to a demand of continuing attention. In: Knave B, Wideback PG, eds. Work with display units. Amsterdam, The Netherlands: Elsevier Science Publishers, B.V. North-Holland, pp. 288–293.

Walsh K, Varnes N, Osmond C, Styles R, Coggin D [1989]. Occupational causes of low back pain. Scand J Work Environ Health *15*(1):54–59.

Waris P, Kuorinka I, Kurppa K, Luopajärvi T, Virolainen M, Pesonen K, et al. [1979]. Epidemiologic screening of occupational neck and upper limb disorders: methods and criteria. Scand J Work Environ Health *5*(Suppl 3):25–38.

Washington State Department of Labor and Industries [1996]. Work-related musculo-skeletal disorders. Washington State summary 1992–1994. Olympia, WA: Washington State Department of Labor and Industries, Consultation and Compliance Services Division.

Waters TR, Putz-Anderson V, Garg A, Fine LJ [1993]. Revised NIOSH equation for the design and evaluation of manual lifting tasks. Ergonomics *36*:749–776.

Webster BS, Snook SH [1994a]. The cost of compensable upper extremity cumulative trauma disorders. J Occup Med *36*(7):713–727.

Webster BS, Snook SH [1994b]. The cost of 1989 workers' compensation low back pain claims. Spine *19*(10):1111–1116.

Weiss ND, Gordon L, Bloom T, So Y, Rempel DM [1995]. Position of the wrist associated with the lowest carpal-tunnel pressure: implications for splint design.

J Bone Joint Surg *77A* (11):1695–1699.

Welch LS, Hunting KL, Kellogg J [1995]. Work-related musculoskeletal symptoms among sheet metal workers. Am J Ind Med *27*(6):783–791.

Wells JA, Zipp JF, Schuette PT, McEleney J [1983]. Musculoskeletal disorders among letter carriers. J Occup Med *25*(11):814–820.

Werner RA, Franzblau A, Albers JW, Buchele H, Armstrong TJ [1997]. Use of screening nerve conduction studies for predicting future carpal tunnel syndrome. Occup Environ Med *54*:96–100.

Werner RA, Franzblau A, Johnston E [1994a]. Quantitative vibrometry and electrophysiological assessment in screening for carpal tunnel syndrome among industrial workers: a comparison. Arch Phys Med Rehabil *75*:1228–1232.

Werner S, Albers JW, Franzblau A, Armstrong TJ [1994b]. The relationship between body mass index and the diagnosis of carpal tunnel syndrome. Muscle Nerve *December*:1492.

Westerling D, Jonsson BG [1980]. Pain from the neck-shoulder region and sick leave. Scand J Soc Med *8*(3):131–136.

Westgaard R, Aaras A [1985]. The effect of improved workplace design on the development of work-related musculoskeletal disorders. Appl Ergonomics *16*(2):91–97.

Westgaard R, Bjorklund R [1987]. Generation of muscle tension additional to postural muscle load. Ergonomics *30*(7):911–923.

White AA, Gordon SL [1982]. Synopsis: workshop on idiopathic low back pain. Spine *7*(2):141–149.

WHO [1985]. Identification and control of work-related diseases. Geneva, Switzerland: World Health Organization. WHO Technical Report Series 714.

WHO [1989]. Work with visual display terminals: psychosocial aspects and health. J Occup Med *31*(12):957–968.

Wickström BO, Kjellberg A, Landström U [1994]. Health effects of long-term occupational exposure to whole-body vibration: a review. Int J Ind Ergonomics *14*:273–292.

Wieslander G, Norbäck D, Göthe CJ, Juhlin L [1989]. Carpal tunnel syndrome (CTS) and exposure to vibration, repetitive wrist movements, and heavy manual work: a case-referent study. Br J Ind Med *46*(1): 43–47.

Wiktorin C, Karlqvist L, Winkel J [1993]. Validity of self-reported exposures to work postures and manual materials handling. Scand J Work Environ Health *19*:208–214.

Wilder DG, Pope MH [1996]. Epidemiological and aetiological aspects of low back pain in vibration environments—an update. Clin Biomechanics *11*:61–73.

Wilson RN, Wilson S [1957]. Tenosynovi-tis in industry. Practitioner *178*:612–615.

Winkel J, Westgaard R [1992]. Occupational and individual risk factors for shoulder-neck complaints. Part II: the scientific basis (literature review) for the guide. Int J Ind Ergonomics *10*:85–104.

Winkel J, Westgaard R [1992]. Occupational and individual risk factors for shoulder-neck complaints. Part II. The scientific basis (literature review) for the guide. Int J Ind Ergonomics *10*:85–104.

Winn FJ, Habes DJ [1990]. Carpal tunnel area as risk factor for carpal tunnel syndrome. Muscle Nerve *13*:254–258.

Wisseman C, Badger D [1976]. Hazard evaluation and technical assistance report: Eastman Kodak, Windsor, Colorado. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Report No. TA 76–0131.

Yu ITS, Wong TW [1996]. Musculoskeletal problems among VDU workers in a Hong Kong bank. Occup Med *46*(4):275–280.

Zwerling C, Ryan J, Schootman M [1993]. A case-control study of risk factors for industrial low back injury: the utility of preplacement screening in defining high-risk groups. Spine *18*(9):242–247.

APPENDIX A
Epidemiologic Review

Various investigators have used different occupational epidemiologic methods to identify the patterns of work-related MSD occurrence in different working groups, as well as the factors that influence these disease patterns. The following section briefly summarizes these study designs and then addresses the most common biases (such as misclassification or selection) that can affect the results of these studies.

TYPES OF EPIDEMIOLOGIC STUDY DESIGNS REVIEWED

The NIOSH reviewers have first addressed studies that use a prospective approach. **Prospective cohort studies**, identify groups of subjects (exposed and nonexposed) and observe them over a period of time to compare the number of new work-related MSD cases in the two groups. All subjects are initially disease-free. The rate (or risk) of new cases (the incidence) is calculated for both groups, and the ratio of these two incidences (the relative risk or rate ratio, RR) can be used to assess the association of the exposure with the occurrence of the MSD. A RR greater than 1.0 implies that the incidence of cases was higher in the exposed group than in the nonexposed group and that an association has been observed between the exposure and the disease. A confidence interval (CI) is derived, which is an estimated range of values within which the true RR is likely to fall. The CI reflects the precision of the effect observed in the study. Ordinarily, if the CI includes 1.0, the association between the exposure and the MSD could be due to chance alone and the elevated odds ratio (OR) is not considered statistically significant.

The cohort study ensures that the exposure to work-related factors occurs before the observation of the MSD, thereby allowing a causal interpretation of the observed association. Cohort studies are often done prospectively; they follow a group of current workers forward in time. The length of time required for a prospective study depends on the problem studied. With adverse health conditions that occur as a result of long-term exposure to some factor in the workplace, many years may be needed. Extended time periods make prospective studies costly. Arguing causation is more difficult with extended time periods because other events may affect outcome. Prospective studies that require long periods of time are especially vulnerable to problems associated with worker follow-up, particularly worker attrition (workers discontinue participation in the study) and worker migration (diseased workers move to other employment before investigators ascertain their disease).

The second type of epidemiologic study evaluated for this document is the **case-control study**, which is retrospective and examines differences in exposures among workers with (cases) and without (controls) MSDs. In such studies, cases should be all incident (new) cases in a given population over a defined period or a representative sample of the cases. Controls should be a representative sample of non-cases from the same population. The ratio of the odds of exposed cases to the odds of exposed controls is called the OR. An OR above 1.0 indicates an association between the exposure and the work-related MSD, and a 95% CI indicates the probable range of the true OR. Case control studies are useful for evaluating rarely occurring conditions or small numbers of cases. One limitation of case control studies is the difficulty of obtaining accurate information about past exposures. In occupational studies of MSDs, a further limitation of case-control studies is the difficulty of identifying cases who are representative of all cases that occurred in a defined period (many of these workers will have left the workforce). Another problem with case-control studies is the selection of an inappropriate control group.

Third, the reviewers considered **cross-sectional studies**. Cross-sectional studies provide a "snapshot in time" of a disease process; that is, they measure both health outcomes and exposures at a single point in time. These studies usually identify occupations with differing levels of exposure and compare the prevalences of MSDs in each group. Cross-sectional studies are most useful for identifying risk factors of a relatively frequent disease with a long duration that is often undiagnosed or unreported [Kleinbaum et al. 1982]. Typically, cross-sectional studies do not provide the evidence of the correct temporal relationship between exposure and disease inherent in prospective studies, but they nevertheless can be valuable. Some cross-sectional studies discussed here had inclusion criteria such as working at a specific job for a defined period of time before onset of symptoms. This condition adds a dimension of temporality to the studies. A common problem with cross-sectional studies that use surveys is obtaining sufficiently large response rates; many people who are asked to participate decline because they are busy, not interested, etc. The conclusions are therefore based on a subset of workers who agree to participate, and these workers may not be representative of or similar to the entire population of workers. Furthermore, cross-sectional studies are often confined to current workers who may not be representative of true prevalence rates if workers with disease have left the workforce. (The problem of representativeness is not confined to cross-sectional studies and may occur in the other study designs mentioned whenever subjects are selected, decline, or drop out.) Either ORs or prevalence ratios (PRs) (proportion of diseased in exposed divided by the proportion of diseased in unexposed) may be used to report results in cross-sectional studies.

The last type of observational study used is the **case-series study**, in which certain characteristics of a group (or series) of cases (or patients) are described. The simplest design is a set of case reports for which the author describes some interesting or intriguing observations that occurred in a small number of patients. Cases included in case series have usually been drawn from a single patient population, whose makeup may have influenced the observations noted because of selection bias. Case-series studies frequently lead to a generation of hypotheses that are subsequently investigated in a cross-sectional, case-control, or prospective study. Because case-series do not involve comparison groups (who do not have the condition or exposure to the risk factors being studied), some investigators would not consider them epidemiologic studies because they are generally not planned studies and do not involve any research hypotheses.

BIASES AND OTHER ISSUES IN EPIDEMIOLOGIC STUDIES

In interpreting the validity of epidemiologic studies to provide evidence for work-relatedness of MSDs, several assumptions and sources of bias must be considered when analyzing the findings from such studies.

1. Selection bias (internal validity). In occupational health studies, at least two types of selection bias may occur: (a) a selection of "healthy workers" in the work population studied, and (b) an exclusion of "sick" workers who leave the active workforce. Both of these biases tend to cause an underestimate of the true relationship between a workplace risk factor and an observed health effect because the workers who are in better health tend to be those in the workforce and available for study.

   A basic assumption underlying the analysis of these studies is that the selected cases of work-related MSDs in the specific studies are representative of all workers at that worksite with work-related MSDs. In a single study, representativeness generally increases with increasing population size and participation rate. A parallel assumption is that the nondiseased groups are representative of the entire nondiseased population. The fact that some cases leave the workforce causes the disease prevalence among currently employed workers to be underestimated. However, if cases are missing from the current workforce in equal proportion for both nonexposed and exposed workers, the underestimate of prevalence will not affect the internal validity of the study.

2. Generalizability (external validity). Some studies are based on a single population, occupation, or restricted data base (individual insurance companies, specific industrial settings) and, therefore, the sample may not be representative of the general population. Another assumption is that MSD cases in one study are comparable to cases in another study. This assumption needs particular scrutiny in work-related MSD studies because no standardized case definitions may exist for the particular illnesses.

3. Misclassification bias. Misclassification bias may be introduced during selection of cases and determination of their exposure. Erroneous diagnoses may result in work-related MSD cases misclassified as noncases, and similarly, noncases may be misclassified as cases. The calculated RR or OR would usually underestimate the true association because of a dilutional effect if both exposed and nonexposed cases are equally misclassified. Similarly, misclassification can occur when determining the exposure factor of interest. Again, such misclassification will create a bias towards finding no association if equal misclassification is assumed for cases and noncases.

4. Confounding and effect modification. Other factors may explain the supposed relationship between work and disease. Confounding is a situation in which the relationship (in this case with MSDs) appears stronger or weaker than it truly is as a result of something (the confounder) being associated with both the outcome and the apparent causal factor. In other words, the risk estimate is distorted because symptoms of exposed and nonexposed workers differ because of some other factors that cause disease. For example, diabetes might result in abnormal nerve conduction testing, a sign of CTS. If a higher proportion of exposed workers than nonexposed workers were diabetic, diabetes would act as a positive confounder, causing an apparent exposure-disease association.

   An effect modifier is a factor that alters the effect of exposure on disease. For example, it is possible that repetitive motion causes tendinitis only in older workers; in this case, age would be an effect modifier. Although effect modification is not a bias per se, if an investigator has failed to analyze old and young workers separately, the investigator might have missed a true work/disease association.

5. Sample size, precision, and CIs. The CI around an estimated measure of effect (such as a RR) is an estimated range of values in which the true effect is likely to fall. It reflects the precision of the effect observed in the study. Large studies generally have smaller CIs and can estimate effects more precisely. In studies that are “statistically significant” the CI excludes the null value for no effect (for example, a RR of 1.0). Small studies are generally less precise, lead to wider CIs, and less likely to be “statistically significant” even if the exposed have a greater prevalence of disease than the nonexposed.

APPENDIX B
Individual Factors Associated with Work-Related Musculoskeletal Disorders (MSDs)

Although the purpose of this document is to examine the weight of evidence for the contribution of work factors to MSDs, the multifactorial nature of MSDs requires a discussion of individual factors that have been studied to determine their association with the incidence and prevalence of work-related MSDs. These factors include age [Guo et al. 1995; Biering-Sorensen 1983; English et al. 1995; Ohlsson et al. 1994]; gender [Hales et al. 1994; Johansson 1994; Chiang et al. 1993; Armstrong et al. 1987a]; anthropometry [Werner et al. 1994b; Nathan et al. 1993, Heliövaara 1987]; and cigarette smoking [Finkelstein 1995; Owen and Damron 1984; Svensson and Andersson 1983; Kelsey et al. 1990; Hildebrandt 1987], among others. Nonoccupational physical activities, such as nonoccupational VDT use, hobbies, second jobs, and household activities that might increase risk for MSDs are described in the detailed tables for those studies in which they were analyzed as risk factors.

A worker's ability to respond to external work factors may be modified by his/her own capacity, such as tissue resistance to deformation when exposed to high force demands. The level, duration, and frequency of the loads imposed on tissues, as well as adequacy of recovery time, are critical components in whether increased tolerance (a training or conditioning effect) occurs, or whether reduced capacity occurs which can lead to MSDs. The capacity to perform work varies with gender and age, among workers, and for any worker over time. The relationship of these factors and the resulting risk of injury to the worker is complex and not fully understood.

Certain epidemiologic studies have used statistical methods to take into account the effects of these individual factors (e.g., gender, age, body mass index), that is, to control for their confounding or modifying effects when looking at the strength of work-related factors. Studies that fail to control for the influence of individual factors may either mask or amplify the effects of work-related factors. The comments column of the detailed tables notes whether studies have adjusted for potential confounders.

A number of factors can influence a person's response to risk factors for MSDs in the workplace and elsewhere. Among these are the following:

AGE

The prevalence of MSDs increases as people enter their working years. By the age of 35, most people have had their first episode of back pain [Guo et al. 1995; Chaffin 1979]. Once in their working years (ages 25 to 65), however, the prevalence is relatively consistent [Guo et al. 1995; Biering-Sorensen 1983]. Musculoskeletal impairments are among the most prevalent and symptomatic health problems of middle and old age [Buckwalter et al. 1993]. Nonetheless, age groups with the highest rates of compensable back pain and strains are the 20–24 age group for men, and 30–34 age group for women. In addition to decreases in musculoskeletal function due to the development of age-related degenerative disorders, loss of tissue strength with age may increase the probability or severity of soft tissue damage from a given insult.

Another problem is that advancing age and increasing number of years on the job are usually highly correlated. Age is a true confounder with years of employment, so that these factors must be adjusted for when determining relationship to work. Many of the epidemiologic studies that looked at populations with a wide age variance have controlled for age by statistical methods. Several studies found age to be an important factor associated with MSDs [Guo et al. 1995; Biering-Sorensen 1983; English et al. 1995; Ohlsson et al. 1994; Riihimäki et al. 1989a; Toomingas et al. 1991] others have not [Herberts et al. 1981; Punnett et al. 1985]. Although older workers have been found to have less strength than younger workers, Mathiowetz et al. [1985] demonstrated that hand strength did not decline with aging; average hand pinch and grip scores remained relatively stable in their population with a range of 29 to 59 years. Torell et al. [1988] found no correlation between age and the prevalence of MSDs in a population of shipyard workers. They found a strong relationship between workload (categorized as low, medium, or heavy) and symptoms or diagnosis of MSDs.

Other studies have also reported a lack of increased risk associated with aging. For example, Wilson and Wilson [1957] reported that the age and gender distribution of 88 patients with tenosynovitis from an ironworks closely corresponded to that of the general population of that plant. Similarly, Wisseman and Badger [1976] reported that the median age of workers with chronic hand and wrist injuries in their study was 23 years, while the median age of the unaffected workers was 24 years. Riihimäki et al. [1989a] found a significant relationship between sciatica and age in machine operators, carpenters, and sedentary workers. Age was also a strong risk factor for neck and shoulder symptoms in carpenters, machine operators and sedentary workers [Riihimäki et al. 1989a]. Some authors may have incorrectly attributed age as the sole cause of their findings in their analysis, when data presented suggested a relationship with work [Schottland et al. 1991].

An explanation for the lack of an observed relationship between an increased risk for MSDs and aging may be “survivor bias” (this is different from the “healthy worker effect”). If workers who have health problems leave their jobs, or change jobs to one with less exposure, the remaining population includes only those workers whose health has not been adversely affected by their jobs. As an example, in a study of female plastics assembly workers, Ohlsson et al. [1989] reported that the degree of increase in the odds of neck and shoulder pain with the duration of employment depended on the age of the worker. For the younger subjects, the odds increased significantly as the duration of employment increased (*p*=0.01), but for the older ones no statistical change was found with length of employment. The older women who had been employed for shorter periods of time had more reported symptoms than the younger ones, while older workers with longer employment times reported fewer symptoms than younger workers. Ohlsson et al. [1989] interviewed 76 former assembly workers and found that 26% reported pain as the cause of leaving work. This finding supports the likely role of a survivor bias in this study, the effect of which is to underestimate the true risk of developing MSDS, in this case in the older workers.

GENDER

Some studies have found a higher prevalence of some MSDs in women [Bernard et al. 1994; Hales et al. 1994; Johansson 1994; Chiang et al. 1993]. A male to female ratio of 1:3 was described for carpal tunnel syndrome (CTS) in a population study in which occupation was not evaluated [Stevens et al. 1988]. However, in the Silverstein [1985] study of CTS among industrial workers, no gender difference could be seen after controlling for work exposure. Franklin et al. [1991] found no gender difference in workers compensation claims for CTS. Burt et al. [1990] found no gender difference in reporting of neck or upper extremity MSD symptoms among newspaper employees using video display terminals (VDTs). Nathan et al. [1988, 1992a] found no gender differences for CTS. In contrast, Hagberg and Wegman [1987] reported that neck and shoulder muscular pain is more common among females than males, both in the general population and among industrial workers. Whether the gender difference seen with some MSDs in some studies is due to physiological differences or differences in exposure is unclear. One laboratory study, Lindman et al. [1991], found that women have more type I muscle fibers in the trapezius muscle than men, and have hypothesized that myofascial pain originates in these Type I muscle fibers. Ulin et al. [1993] noted that significant gender differences in work posture were related to stature and concluded that the lack of workplace accommodation to the range of workers' height and reach may, in part, account for the apparent gender differences. The reporting bias may exist because women may be more likely to report pain and seek medical treatment than men [Armstrong et al. 1993; Hales et al. 1994]. The fact that more women are employed in hand-intensive jobs and industries may account for the greater number of reported work-related MSDs among women. Byström et al. [1995] reported that men were more likely to have deQuervain’s disease than women; they attributed this to more frequent use of hand tools. Some studies have reported that workplace risk factors account for increased prevalence of MSDs among women more than personal factors (e.g., Armstrong et al. [1987a], McCormack et al. [1990]). In a recent evaluation of Ontario workers compensation claims for “RSI,” Asbury [1995] reported a RR for female to male claims ranging from 1.3 to 1.6 across industries. Within 5 different broad occupational categories, females were approximately 2–5 times as likely to have a lost-time RSI claim. No information on gender differences in hand intensive jobs was reported. May researchers have noted that men and women tend to be employed in different jobs.

In order to separate the effect of work risk factors from potential effects that might be attributable to biological differences, researchers must study jobs that men and women perform relatively equally.

SMOKING

Several papers have presented evidence that a positive smoking history is associated with low back pain, sciatica, or intervertebral herniated disc [Finkelstein 1995; Owen and Damron 1984; Frymoyer et al. 1983; Svensson and Anderson 1983; Kelsey et al. 1984]; whereas in others, the relationship was negative [Kelsey et al. 1990; Riihimäki et al. 1989b; Frymoyer 1993; Hildebrandt 1987]. Boshuizen et al. [1993] found a relationship between smoking and back pain only in those occupations that required physical exertion. In their study, smoking was more clearly related to pain in the extremities than to pain in the neck or the back. Deyo and Bass [1989] observed that the prevalence of back pain increased with the number of pack-years of cigarette smoking and with the heaviest smoking level. Heliövaara et al. [1991] only observed a relationship in men and women older than 50 years. Two studies did not find a relationship between sciatica and smoking among concrete reinforcement workers and house painters [Heliövaara et al. 1991; Riihimäki et al. 1989b].

In the Viikari-Juntura et al. [1994] prospective study of machine operators, carpenters, and office workers, current smoking (OR 1.9 1.0–3.5), was among the predictors for change from "no neck trouble" to "severe neck trouble." In a study of Finnish adults ages 30–64, [Mäkelä et al. 1991], neck pain was found to be significantly associated with current smoking (OR 1.3, 95% CI 1–1.61) when the logistic model was adjusted for age and gender. However, when the model included mental and physical stress at work, obesity, and parity, then smoking (OR 1.25, 95% CI 0.99–1.57) was no longer statistically significant [Mäkelä et al. 1991]. With univariate analysis, Holmström [1992] found a PRR of 1.2 (95% CI 1.1–1.3) for neck-shoulder trouble in "current" smokers versus "never" smokers. But using multiple logistic regression, when age, individual and employment factors were in the model, only "never smoked" contributed significantly to neck-shoulder trouble. Toomingas et al. [1991] found no associations between multiple health outcomes (including tension neck, rotator cuff tendinitis, CTS or problems in the neck/scapula or shoulder/upper arm) and nicotine habits among platers, assemblers and white collar workers. In a case/referent study, Wieslander et al. [1989] found that smoking or using snuff was not related to CTS among men operated on for CTS .

Several explanations for the relationship have been postulated. One hypothesis is that back pain is caused by coughing from smoking. Coughing increases the abdominal pressure and intradiscal pressure and puts strain on the spine. A few studies have observed this relationship [Deyo and Bass 1989; Frymoyer et al. 1980; Troup et al. 1987]. The other mechanisms proposed include nicotine-induced diminished blood flow to vulnerable tissues [Frymoyer et al. 1983], and smoking-induced diminished mineral content of bone causing microfractures
[Svensson and Andersson 1983]. Similar associations with diminished blood flow to vulnerable tissues have been found between smoking and Raynaud's disease.

PHYSICAL ACTIVITY

The relationship of physical activity and MSDs is more complicated than just "cause and effect." Physical activity may cause injury. However, the lack of physical activity may increase susceptibility to injury, and after injury, the threshold for further injury is reduced. In construction workers, more frequent leisure time was related to healthy lower backs [Holmström et al. 1993] and severe low back pain was related to less leisure time activity [Holmström et al. 1992]. On the other hand, some standard treatment regimes have found that musculoskeletal symptoms are often relieved by physical activity. Having good physical condition may not protect workers from risk of MSDs. NIOSH [1991] stated that persons with high aerobic capacity may be fit for jobs that require high oxygen uptake, but will not necessarily be fit for jobs that require high static and dynamic strengths and vice versa.

When physical fitness is examined as a risk factor for MSDs, results are mixed. For example, some early case series reported an increased risk of MSDs associated with playing professional sports [Bennet 1946; Nirschl 1993], or with physical fitness and exercise [Kelsey 1975b; Dehlin et al. 1978, 1981] while other studies indicate a protective effect and reduced risk [Cady et al. 1979; Mayer et al. 1985; Åstrand et al. 1987; Biering-Sorensen 1984]. Boyce et al. [1991] reported that only 7% of absenteeism could be explained by age, sex, and physical fitness among 514 police officers 35 years or older. Cady et al. [1979, 1985], on the other hand, found that physical capacity was related to musculoskeletal fitness. Cady defined fitness for most physical activities as combinations of strength, endurance, flexibility, musculoskeletal timing and coordination. Cady et al. [1979] evaluated male fire fighters and concluded that physical fitness and conditioning had significant preventive effects on back injuries (least fit 7.1% injured, moderately fit 3.2% injured and most fit 0.8% injured). However, the most fit group had the most severe back injuries. Low cardiovascular fitness level was a risk factor for disabling back pain in a prospective longitudinal study among aerospace manufacturing workers by Battie et al. [1989]. Good endurance of back muscles was found to be associated with low occurrence of low back pain [Biering-Sorensen 1984].

Few occupational epidemiologic studies have looked at non-work-related physical activity in the upper extremities. Most NIOSH studies [Hales and Fine 1989; Kiken et al. 1990; Burt et al. 1990; Baron et al. 1991; Hales et al. 1994; Bernard et al. 1994] have excluded MSDs due to sports injury or other nonwork-related activity or injury and have not included these factors in analyses. However, many of the risk factors that are important in occupational studies occur in sports activities—forceful, repetitive movements with awkward postures. A combination of high exposure to load lifting and high exposure to sports activities that engage the arm was a risk factor for shoulder tendinitis, as well as osteoarthritis of the acromioclavicular joint [Stenlund et al. 1993]. Kennedy et al. [1978] found that 15% of competitive swimmers with repetitive overhead arm movements had significant shoulder disability primarily due to impingement from executing butterfly and freestyle strokes. Epicondylitis in professional athletes has been well documented, and many of the biomechanical and physiological studies of epicondylitis have been conducted

in professional tennis players and baseball pitchers [King et al. 1969; Nirschl 1993]. One prospective study of healthy baseball players has found slowing of the suprascapular nerve function as the season progresses [Ringel et al. 1990]. Scott and Gijsbers [1981] found an association between athletic performance and pain tolerance, and suggested that physically fit persons may have a higher threshold for injury.

In summary, although physical fitness and activity is generally accepted as a way of reducing work-related MSDs, the present epidemiologic literature does not give such a clear indication. The sports medicine literature, however, does give a better indication that sports involving activities of a forceful, repetitive nature (such as tennis and baseball pitching) are related to MSDs. It is important to note that professional sports activities usually provide players (i.e., workers) with more substantial breaks for recovery and shorter durations for intense tasks as compared with more traditional work settings in which workers are required to perform repetitive, forceful work for 8 hours per day, 5 days per week.

STRENGTH

Some epidemiologic support exists for the relationship between back injury and a mismatch of physical strength and job tasks. Chaffin and Park [1973] found a sharp increase in back injury rates in subjects performing jobs requiring strength that was greater or equal to their isometric strength-test values. The risk was three times greater in the weaker subjects. In a second longitudinal study, Chaffin et al. [1977] evaluated the risk of back injuries and strength and found the risk to be three times greater in the weaker subjects. Keyserling et al. [1980] strength-tested subjects, biomechanically analyzed jobs, and assigned subjects to either stressed or non-stressed jobs. Following medical records for a year, they found that job matching based on strength criteria appeared to be beneficial. In another prospective study, Troup et al. [1981] found that reduced strength of back flexor muscles was a consistent predictor of recurrent or persistent back pain, but this association was not found for first time occurrence of back pain.

Other studies have not found the same relationship with physical strength. Two prospective studies of low back pain reports (or claims) of large populations of blue collar workers [Battie et al. 1989; Leino 1987] failed to demonstrate that stronger (defined by isometric lifting strength) workers are at lower risk for low back pain claims or episodes. One study followed workers for ten years after strength testing and the other followed workers for a few years. Neither of these studies included precise measurement of exposure level for each worker, so the authors could not estimate the degree of mismatch between workers' strength and tasks demands. Battie et al. [1990] compared workers with back pain with other workers on the same job (by isometric strength testing) and did not find that workers with back pain were weaker. In two studies of nurses [Videman et al. 1989; Mostardi et al. 1992] lifting strength was not a reliable predictor of back pain.

When examined together, these studies reveal the following: The studies that found a significant relationship between strength/job task and back pain used more thorough job assessment or analysis and have focused on manual lifting jobs. However, these studies only followed workers for a period of one year, and whether this same relationship would hold over a much longer working period remains unclear. Studies that did not find a relationship, although they followed workers for a longer period of time, did not include precise measurements of exposure level for each worker, so they could not assess the strength capabilities that were important in the individual jobs. Therefore, they could not estimate the degree of mismatch between workers' strength and task demands.

ANTHROPOMETRY

Weight, height, body mass index (BMI) (a ratio of weight to height squared), and obesity have all been identified in studies as potential risk factors for certain MSDs, especially CTS and lumbar disc herniation.

Few studies examining anthropometric risk factors in relationship to CTS have been occupational epidemiologic studies; most have used hospital-based populations who may differ substantially from working populations. Nathan et al. [1989, 1992, 1994] have published several papers on the basis of a single industrial population and have reported an association between CTS and obesity; however, the methods employed in their studies have been questioned in a number of subsequent publications [Gerr and Letz 1992; Stock 1991; Werner et al. 1994b]. Several investigators have reported that their industrial study subjects with CTS were shorter and heavier than the general population [Cannon et al. 1981; Dieck and Kelsey 1985; Falk and Aarnio 1983; Nathan et al. 1992; Werner et al. 1994b; Wieslander et al. 1989]. In the Werner et al. [1994b] study of a clinical population requiring electrodiagnostic evaluation of the right upper extremity, patients classified as obese (BMI>29) were 2.5 times more likely than slender patients (BMI<20) to be diagnosed with CTS. Werner et al. [1994b] developed a multiple linear regression CTS model (with the difference between median and ulnar sensory latencies as the dependent variable) that demonstrated that BMI was the most influential variable, but still only accounted for 5% of the variance in the model. In Nathan's [1994a] logistic model, body mass index accounted for 8.6% of the total risk; however, this analysis used both hands from each study subject as separate observations, although they are not independent of each other. Falck and Aarnio [1983] found no difference in BMI among 17 butchers with (53%) and without (47%) CTS. Vessey et al. [1990] found that the risk for CTS among obese women was double for that of slender women. The relationship of CTS and BMI has been suggested to relate to increased fatty tissue within the carpal canal or to increased hydrostatic pressure throughout the carpal canal in obese persons compared with slender persons [Werner 1994b].

Carpal tunnel canal size and wrist size has been suggested as a risk factor for CTS, however, some studies have linked both small and large canal areas to CTS [Bleecker et al. 1985; Winn and Habes 1990].

For back MSDs, Hrubec and Nashold [1975] found that height and weight were predictive of herniated disc disease among World War II U.S. army recruits compared with age-matched controls. Some studies have reported that people with back pain, are, on the average, taller than those without it [Rowe 1965; Tauber 1970; Merriam et al. 1980; Biering-Sorensen 1983]. Heliövaara et al. [1987], in a Finnish population study, found that height was a significant predictor of herniated lumber disc in both sexes, but a moderately increased BMI was predictive only in men. Severe obesity (exceeding 30 kg/m^2) involved less risk than moderate obesity. Kelsey [1975a] and Kelsey et al. [1984] failed to reveal any such relationships between height or BMI among patients with herniated lumber discs and control subjects. Magora and Schwartz [1978] found an association between obesity and radiological disc degeneration, but Kellgren and Lawrence [1958] did not. A study of Finnish white collar and blue collar workers found no association between overweight (relative weight (>120%) and lumbosacral disorders either cross-sectionally or in a 10-year follow-up [Aro and Leino 1985].

Schierhout et al. [1995] found that short stature was significantly associated with pain in the neck and shoulder among workers in 11 factories, but not in the back, forearm, hand and wrist. Height was not a factor for neck, shoulder or hand and wrist MSDs among newspaper employees [Bernard et al. 1994]. Kvarnström [1983a] found no relationship between neck/shoulder MSDs and body height in a Swedish engineering company with over 11,000 workers.

Anthropometric data are conflicting, but in general indicate that there is no strong correlation between stature, body weight, body build and low back pain. Obesity seems to play a small but significant role in the occurrence of CTS.

APPENDIX C
Summary Tables

Appendix C contains summary tables of articles reviewed in this document. These tables provide a concise overview of the studies reviewed relative to the evaluation criteria, risk factors addressed, and other issues.

Appendix C Table C-1. Summary table for epidemiologic studies evaluating work-related neck musculoskeletal disorders

Components of study	Andersen 1993a	Andersen 1993b	Baron 1991	Bergqvist 1995a	Bergqvist 1995b	Bernard 1994	Ferguson 1976	Hales 1989
Study type	CS	CS	CS	CS	CS	CS	CS	CS
Participation rate $70%	Y	Y	N	Y	Y	Y	Y	Y
Outcome	S	S and PE	S and PE	S and PE	S and PE	S	S	S and PE
Exposure	Job title categorization	Categorization by job duration	Observation, video analysis, measurement of items, (assessment was for hand/wrist, not neck)	Questionnaire, observation	Questionnaire, observation	Observation, questionnaire	Measurements, observation, questionnaire	Observation, video taping, job categorization, (assessment was for hand/wrist, not neck)
Covariates considered	Age, having children, not exercising, smoking, SES, marital status	Age, having children, not exercising, smoking, SES	Age, gender, duration of work environment	Age, gender	Adjustments made for confounders	Age, gender, height, psychosocial factors	Height, weight	Age, duration of employment
Investigators blinded	Y	Y	Y	Y	Y	Y	NR	Y
Repetition	Combined	Combined	Combined	Repeated work movements: 3.6 (0.4-29.6)	Combined	Time spent typing: NS	Õ	Combined
Force	Combined	Combined	Combined	Õ	Õ	Õ	Õ	Combined
Extreme posture	Combined	Õ	Combined	Too highly placed keyboard: 4.4 (1.1-17.0)	Õ	Time spent on telephone: 1.4 (1.0-1.8)	NR, sig.	Õ
Vibration	Õ	Õ	Õ	Õ	Õ	Õ	Õ	Õ

See footnotes at end of table.

(Continued)

Appendix C Table C-1. Summary table for epidemiologic studies evaluating work-related neck musculoskeletal disorders

Components of study	Andersen 1993a	Andersen 1993b	Baron 1991	Bergqvist 1995a	Bergqvist 1995b	Bernard 1994	Ferguson 1976	Hales 1989
Risk factors (combined)	Sewing operators vs. referents: 4.9 (2.0-12.8)	Current high exposure: 1.6 (0.7-3.6) 8 to 15 years: 6.8 (1.6-28.5)	Checkers vs. noncheckers: 2.0 (0.6-6.7)	Õ	VDT work >20 hr and eye glasses at VDT: 6.9 (1.1-42)	Õ		High exposure vs. Low exposure jobs (estimated crude OR): 3.7 (0.4-164) Outcome, neck symptoms: RR=1.64 (0.4-3.9)
Duration of employment	0 to 7 years: 1.9 (1.3-2.9) 8 to 15 years: 3.8 (2.3-6.4) >15 years: 5.0 (2.9-8.7)	0 to 7 years: 2.3 (0.5-11) 8 to 15 years: 6.8 (1.6-28.5) >15 years: 16.7 (4.1-67.5)	NS	Õ	Õ	NS	Õ	Adjusted for in analysis
Physical workload	Õ	Õ	Õ	Õ	Õ	Õ	Õ	Õ
Psychosocial factors	Õ	Õ	Job satisfaction: NS	Limited break opportunity: 7.4 (3.1-17.4)		Deadline hr: 1.7 work variance: 1.7 management issues: 1.9	Õ	Õ
Individual/other factors considered	Age at least 40 years: 1.5 (1.1-2.2); having children: 1.3 (0.8-2.0); SES: 1.29 (0.7-2.3); smoking: 1.39 (0.99-1.9)	Age $ 40 years: 1.9 (0.9-4.1); having children: 0.5 (0.1-1.7); exercise: 1.4 (0.6-2.9); smoking: 1.5 (0.7-3.3)	Age, gender, hobbies controlled for in analysis	Females with children: 6.4; smoking, stress reaction, stomach-related stress, use of spectacles, peer contacts, rest breaks, work task flexibility, overtime, static work position, nonuse of lower arm support, hand in non-neutral posture, high visual angle to VDT, glare on VDT	Smoking, stress reaction, stomach-related stress, use of spectacles, peer contacts, rest breaks, work task flexibility, overtime, static work position, nonuse of lower arm support, hand in non-neutral posture, high visual angle to VDT, glare on VDT	Age, gender, height, psychosocial factors; VDT use outside of work	Õ	Age
Dose/response	Years worked: Sig.	Õ	Õ	Õ	Õ	Õ	Õ	Õ

See footnotes at end of table. (Continued)

Appendix C Table C-1. Summary table for epidemiologic studies evaluating work-related neck musculoskeletal disorders

Components of study	Hales 1994	Hunting 1994	Kamwendo 1991	Kiken 1990	Knave 1985	Kukkonen 1983	Kuorinka 1979	Linton 1990
Study type	CS	CS	CS	CS	CS	Prospective, intervention	CS	CS
Participation rate $70%	Y	Y	Y	Y	Y	NR	Y	Y
Outcome	S and PE	S	S	S and PE	S	S and PE	S and PE	S
Exposure	Observation, questionnaire	Questionnaire	Questionnaire	Observation, (assessment was for hand/wrist, not neck)	Observation, gaze direction instrument, job title or self-report	Observation, interview	Observation, job analysis, video taping (assessment was for hand/wrist, not neck)	Questionnaire
Covariates considered	demographics, work practices, age, gender, hobbies	Years worked, age, current work as electrician, gender	Age, length of employment, psychosocial work environment	Age, gender	Age, gender, smoking, educational status, drinking	Gender, prospective design	Age, duration of employment, BMI, metabolic disease, hobbies, "extra work"	Age, gender, exercise, eating regularly, smoking, alcohol consumption, psychosocial variables
Investigators blinded	Y	NR	NR	Y	NR	Y	NR	NR
Repetition	Õ	Õ	Combined	Combined	Combined	Combined	Scissor makers vs. Referents: 4.1 (2.3-7.5) Short cycle tasks vs. long cycle tasks: 1.64 (0.7-3.8)	Õ
Force	Õ	Õ	Õ	Combined	Õ	Õ	Combined	Õ
Extreme posture	Use of bifocals: 3.8 (1.5-9.4)	Õ	Combined	Combined	Combined	Combined	Combined	Uncomfortable posture and poor psychosocial environment: 3.5 (2.7-4.5)
Vibration	Õ	Õ	Õ	Õ	Õ	Õ	Õ	Univariate analysis showed elevated OR for vibration

See footnotes at end of table. (Continued)

Appendix C Table C-1. Summary table for epidemiologic studies evaluating work-related neck musculoskeletal disorders

Components of study	Hales 1994	Hunting 1994	Kamwendo 1991	Kiken 1990	Knave 1985	Kukkonen 1983	Kuorinka 1979	Linton 1990
Risk factors (combined)	Õ	Õ	Work with office machines >5 hr/day: 1.65 (1.02-2.67)	High exposure vs. low exposure jobs: 1.3 (0.2-11)	Typing hr: Sig.	Intervention group: PRR=3.6 (2.2-5.9) No intervention 1.0	Scissor-makers vs. department store shop assistants: OR=4.1 (2.3-7.5)	Õ
Duration of employment	NS	1 to 3 years: 1 4 to 5 years: 1.3 6 to 10 years: 1.6 >10 years: 1.3	Length of employment: Sig.	Õ	Õ	Õ	Controlled for	Õ
Physical workload	Õ	Õ	Being given too much to do: Sig.	Õ	Õ	Õ	Õ	Õ
Psychosocial factors	Decision making: 4.2; productivity standard: 3.5; fear of replacement by computer: 3.0; higher information processing demands: 3.0; job task variety: 2.9; work pressure: 2.4		Ability to influence work, cooperative spirit between co-workers: sig.	Õ	Interest in work, positive attitude	Õ		Monotonous work SS, work content, work load, social support
Individual/other factors considered	Electronic performance monitoring, keystrokes, hobbies, recreational activities: NS	Age group, current work as electrician: NS	Sitting 5 or more hr/day: 1.6 (0.9-2.8); age: Sig.	Õ	Õ	Õ	Extra work, hobbies, outside activities: NS	Exercise, eating, smoking, alcohol consumption
Dose/response	Õ	Õ	Õ	Õ	Between registered work duration and musculoskeletal complaints	Õ	Õ	Õ

See footnotes at end of table. (Continued)

Appendix C Table C-1. Summary table for epidemiologic studies evaluating work-related neck musculoskeletal disorders

Components of study	Liss 1995	Luopajärvi 1979	Milerad 1990	Ohlsson 1989	Ohlsson 1995	Onishi 1976	Ryan 1988	Sakakibara 1987
Study type	CS	CS	CS	CS	CS	CS	CS	CS
Participation rate $70%	N	Y	Y	NR	Y	NR	Y	Y
Outcome	S	S and PE	S	S	S and PE	S and PE	S and PE	S
Exposure	Questionnaire	Observation, video analysis, interviews	Questionnaire	Questionnaire	Videotaping, observation, analysis of posture, flexion of neck, questionnaire	Observation, then job categorization	Observation measurements at work stations	Observation job analysis and neck angle measurements
Covariates considered	N	Age, gender, social background, hobbies, amount of housework	Gender, age, leisure-time exposure, systemic disease	Age, gender, duration of employment	Age , gender, psychosocial scales	Õ	Age, height, length of training time	Õ
Investigators blinded	N	Y	NR	NR	Blinded to exposure information but "Not possible to completely blind the examiners."	NR	Y	NR
Repetition	Combined	Combined	Combined	Combined	Combined	Combined	Õ	Combined
Force	Combined	Combined	Õ	Õ	Industrial workers exposed to repetitive tasks vs. referents: 3.6 (1.5-8.80)	Combined	Õ	Õ
Extreme posture	Combined	Combined	Combined	Combined	Õ	Combined	Significant difference in mean elbow angle and shoulder flexion of left arm	Combined
Vibration	Õ	Õ	NS for exposure to vibration	Õ	Õ	Õ	Õ	Õ

See footnotes at end of table. (Continued)

Appendix C Table C-1. Summary table for epidemiologic studies evaluating work-related neck musculoskeletal disorders

Components of study	Liss 1995	Luopajärvi 1979	Milerad 1990	Ohlsson 1989	Ohlsson 1995	Onishi 1976	Ryan 1988	Sakakibara 1987
Risk Factors (Combined)	Dental hygienists vs. dental assistants: 1.7 (1.1-2.6)	Assembly workers vs. shop assistants: 1.6 (0.9-2.7)	Dentists compared to pharmacists: 2.1 (1.4-3.1)	Assemblers vs. referents pain in last 12 months: 1.9 (0.9-3.7)	Õ	Film rolling workers: 3.8 Lamp assemblers: 3.8 (2.1-6.6) Teachers and nurses: 1.5 (0.7-3.2)	Õ	Pear work vs. apple work right side: *p*<0.05 Pear work vs. Apple work at left side: *p<0.01*
Duration of employment	NS	Õ	NS	Employees <35 years: Sig.	Õ	Õ	NS	Õ
Physical workload	Õ	Õ	Õ	Õ	Õ	Õ	Õ	Õ
Psychosocial factors	Õ	Õ	Õ	Increased OR for medium and fast paced work compared to slow paced but OR lower for very fast paced work		Õ	Insufficient rest, break time, more boredom, more stress, lower peer cohesion, lower antonomy, lower job clarity, higher staff support, higher work pressure	Õ
Individual/other factors considered	Gender (99% females in study group); had to modify work or unable to work at some point: 2.4 (1.1-5.4)	Õ	Leisure time exposure, smoking systemic disease		Õ	Õ	Age, height, marital and parental status, handedness, length of training time	Õ
Dose/response	Õ	Õ	Õ	Õ	Õ	Õ	Õ	Õ

See footnotes at end of table. (Continued)

Appendix C Table C-1. Summary table for epidemiologic studies evaluating work-related neck musculoskeletal disorders

Components of study	Sakakibara 1995	Schibye 1995	Veiersted 1994	Viikari-Juntuna 1994	Welch 1995	Wells 1983	Yu 1996
Study type	CS	Cohort	Cohort	Cohort	CS	CS	CS
Participation rate $70%	Y	Y	N (55%)	Y	Y (83%)	Y	Y
Outcome	S and PE	S	S and PE/ pain diaries	S	S	S	S
Exposure	Observation, measurements	Questionnaire	EMG, interviews every 10 weeks	Questionnaire, observation	Questionnaire	Questionnaire, interview	Questionnaire
Covariates considered	Õ	Subjects served as their own controls	Metabolic or other diseases, gender	All male, smoking, age, physical exercise, occupation, duration of work, car driving	Smoking, years of employment	Age, gender, number of years on job, previous work experience, education, marital status, quetelet ratio	Age, gender, "other covariates"
Investigators blinded	NR	NR	NR	Y	N	NR	NR
Repetition	Õ	Combined	Õ	Õ	Combined	Õ	Frequent VDT use: 28.9 (2.8-291.8)
Force	Õ	Combined	Strenuous previous work: 6.7 (1.6-28.5)	Combined	Õ	Combined	Õ
Extreme posture	Combined	Combined	Strenuous postures: 7.2 (2.1-25.3)	No neck pain to severe, machine operators vs. office workers: 3.9 (2.3-6.9) Persistently severe: 4.2 (2.0-9.0)	Percent of time hanging duct: 7.5 (0.8-68)	Combined	Inclining neck at work: 784.4 (33.2-18,630)
Vibration	Õ	Õ	Vibration (floor or machine)	Combined (machine operators)	Õ	Õ	Õ

See footnotes at end of table.

(Continued)

Appendix C Table C-1. Summary table for epidemiologic studies evaluating work-related neck musculoskeletal disorders

Components of study	Sakakibara 1995	Schibye 1995	Veiersted 1994	Viikari-Juntuna 1994	Welch 1995	Wells 1983	Yu 1996
Risk factors (combined)	Pear vs. Apple bagging: 1.5 (0.99-2.35)	Other employment group vs. garment workers: 3.3 (1.4-7.7)	Physical environment: 0.9 (0.5-1.7)	Occupation Sig. from no neck trouble to moderate neck trouble; occupation Sig. from no neck to severe neck trouble Carpenters vs. Office workers persistently severe: 3.0 (1.4-6.4)	õ	All letter carriers vs. Clerks and readers: 2.57 (1.13-6.2)	Frequent video display terminal use: 28.9 (2.8-291.8)
Duration of employment	õ	NS	õ	õ	õ	Controlled for in analysis	õ
Physical workload			õ	õ	õ	õ	õ
Psychosocial factors`	õ	õ	Psychosocial factors: 3.3 (0.8-14.2)	Job satisfaction: NS	õ	õ	õ
Individual/other factors considered	õ	Age	Anthropometrics, general health, previous employment variables, draft, noise, personality	Current smoking and age Sig. in model of "no neck trouble to severe neck trouble"	õ	Education, marital status, quetelet ratio	General health
Dose/response	õ	õ	õ	õ	õ	õ	õ

õ Not studied.
BMI Body mass index.
CS Cross-sectional.
EMG Electromyography.
hrs Hours.
MSD Musculoskeletal disorders
MVC Maximum voluntary contraction.
N No.
NR Not reported.
NS Not statistically significant.
OR Odds ratio.
PE Physical examination.
PRR Prevalence rate ratio.
S Symptoms.
SES Socioeconomic status.
Sig. Statistically significant.
VDT Video display terminal.
vs. Versus.
Y Considered (yes).

Appendix C Table C-2. Summary table for evaluating work-related neck/shoulder disorders

Components of study	Åaras 1994	Andersen 1993a	Andersen 1993b	Bergqvist 1995a	Bergqvist 1995b	Bjelle 1981	Blåder 1991	Ekberg 1994
Study type	Prospective	CS	CS	CS	CS	Case Control	CS	Case Control
Participation rate $70%	NR	Y	Y	Y	Y	NR	Y	Y
Outcome	S and Records	S	S and PE	S	S and PE	S and PE	S and PE	S
Exposure	Observation and EMG	Job title categorization	Categorization by job duration	Observation, measurements	Job title and questionnaire	Observation, videotape analysis	Questionnaire	Questionnaire
Covariates considered	ô	Age, having children, education, marital status, smoking, not exercising	Age, having children, education, marital status, smoking, not exercising	Age, gender, smoking, rest breaks, stress	Age, gender, smoking	Age, anthropometric data	Age, nationality, employment time, working hr/week	Age, gender, smoking, having preschool children
Investigators blinded	NR	Y	Y	Y	Y	Y; Videotape analysis blinded to case status	N	NR
Repetition	ô	Combined	Combined	For intensive neck/shoulder discomfort: 3.6 (0.4-29.6)	<20 hr/week VDT use: 1.2 (0.4-3.7) >20 hr/week VDT use: 0.7 (0.3-1.5)	No sig difference in cycle time	Combined	Precise repetitive movements High: 15.6 (2.2-113.0)
Force	Static trapezius load dropped from 4.1 to 1.4% NR, Sig.	Combined	Combined	ô	ô	Cases had significantly higher shoulder loads than controls	ô	ô
Extreme posture	Intervention consisted of equipment and tool adjustment to create relaxed position of shoulders and neck: NR, Sig.	ô	ô	For tension neck syndrome: too highly placed VDT: 4.4 (1.1-17.6)	ô	Cases with longer duration and higher frequency of abduction or forward flexion than referents: NR, Sig.	Combined	Work with lifted arms 4.8 (1.3-18); uncomfortable sitting posture: 3.6 (1.4-9.3)
Vibration	ô	ô	ô	ô	ô	ô	ô	ô

See footnotes at end of table.

(Continued)

Appendix C Table C-2. Summary table for evaluating work-related neck/shoulder disorders

Components of study	Åaras 1994	Andersen 1993a	Andersen 1993b	Bergqvist 1995a	Bergqvist 1995b	Bjelle 1981	Blåder 1991	Ekberg 1994
Risk factors (combined)	ô	Sewing machine operators vs. referents: 4.6 (2.2-10.2)	Current high exposure (yes vs. no): 1.6 (0.7-3.6)	ô	VDT work >20 hr and stressful stomach reactions: 3.9 (1.1-13.8) VDT work $ 20 hr and bifocals or progressive glasses: 6.9 (1.1-42.1)	ô	Working >30 hr per week: *p*<0.05	ô
Duration of employment	ô	Years as sewing machine operators 0 to 7 years: 3.2 (0.6-16.1) 8 to 15 years: 11.2 (2.4-52) >15 years: 36.7 (7.1-189)	Years as sewing machine operators 0 to 7 years: 2.3 (0.5-11) 8 to 15 years: 6.8 (1.6-28.5) >15 years: 16.7 (4.1-67.5)	ô	ô	ô	Working >30 hr/week and tension neck syndrome: *p*<0.05	ô
Physical workload	ô	ô	ô	ô	ô	ô	ô	ô
Psychosocial factors	ô	ô	ô	For cervical diagnoses: Stressful stomach reactions: 5.4 (1.6-17.6)	Combined	ô	Smaller randomized study group interviewed by sociologist and psychologist for psychosocial history	High work pace: 3.5 (1.3-9.4); Low work content: 2.6 (0.7-9.4); Work role ambiguity: 16.5 (6.0-46); Demands on attention: 3.8 (1.4-11)
Individual/ other factors considered	Median sick days decreased from 22.9 to 1.8	Age >40 yrs: 1.96 (0.8-5); exercise: 1.28 (0.5-3.4); smoking: 2.3 (0.9-6.1); children: 0.35 (0.1-1.9)	Age $ 40 years: 1.9 (0.9-4.1); children: 0.5 (0.1-1.7); exercise: 1.4 (0.6-2.96); smoking: 1.5 (0.7-3.3)	Children at home, negative, affectivity, peer contacts, overtime, work task flexibility, visual angle to VDT	Children at home, negative, affectivity, peer contacts, overtime, work task flexibility, visual angle to VDT	Age-isometric testing	Cervical syndrome correlated with age	Female: 11.4 (4.7-28); immigrant status: 4.9 (1.8-14); current smoker: 8.2 (2.3-29)
Dose/response	ô	Duration of employment as sewing machine operator	Duration of employment	ô	ô	ô	ô	Repetitive precision movements, work pace

See footnotes at end of table.

(Continued)

Appendix C Table C-2. Summary table for evaluating work-related neck/shoulder disorders

Components of study	Ekberg 1995	Holmström 1992	Hünting 1981	Jonsson 1988	Kilbom 1986, 1987	Linton 1989	Maeda 1982	Milerad 1990
Study type	CS	CS	CS	Cohort	CS	CS	CS	CS
Participation rate $70%	Y	Y	NR	Y	Y	Y	NR	Y
Outcome	S	S	S and PE	S and PE	S and PE	S	S	S
Exposure	Questionnaire	Questionnaire	Observation, questionnaire	Observation, video taping, job analysis, MVC of forearm	Observation, video taping, job analysis, MVC of forearm	Questionnaire dealing with psychosocial issues	Observation, measurement	Questionnaire
Covariates considered	Age, smoking, exercise habits, family situations with preschool children, immigrant status, gender	Age, physical factors, psychosocial stress scales	Psychosocial factors	Used prospective cohort design with same study sample	Age, spare time physical activities, hobbies, psychosocial stress, muscle strength	ò		Gender, leisure time, smoking, systemic disease
Investigators blinded	NR	Y	NR	Y	Y	NR	NR	NR
Repetition	Repetitive movements demanding precision: 1.2 (1.0-1.3)	ò	Combined	Combined	Combined	ò	ò	Combined
Force	ò	ò	ò	Combined	Combined	ò	ò	ò
Extreme posture		Hand above shoulder: <1 hr/day: 1.1 (0.8-1.5) 1 to 4 hr/day: 1.5 (1.2-1.9) >4 hr/day: 2.0 (1.4-2.7)	Combined/head inclination >56E Sig. for neck/shoulder MSDs	Combined	Combined	ò	Constrained tilted head posture: $p<0.05$	Combined
Vibration	ò	ò	ò	ò	ò	ò	ò	NS

See footnotes at end of table.

(Continued)

Appendix C Table C-2. Summary table for evaluating work-related neck/shoulder disorders

Components of study	Ekberg 1995	Holmström 1992	Hünting 1981	Jonsson 1988	Kilbom 1986, 1987	Linton 1989	Maeda 1982	Milerad 1990
Risk factors (combined)	ō	Roofers: 1.6 Plumbers: 1.5 Floor workers: 1.3	Data entry workers vs. non-keyboard-using office workers: 9.9 (3.7-26.9)	At third year, 38 workers reallocated had improved, 26% with unchanged conditions deteriorated further: NR, Sig.	Average time/work cycle in neck flexion sig, Upper arm abducted 0-30E: NR, Sig.	ō	ō	Dentists vs. pharmacists: 2.1 (1.3-3.0); males: 2.6 (1.2-5.0); females 2.0 (1.3-3.1)
Duration of employment	ō	ō	ō	ō	NS	ō	ō	NS
Physical workload	ō	ō	ō	ō	ō	ō	ō	ō
Psychosocial factors	ō	Qualitative demands: 1.4 (1,2) Quantitative demands: 3.0 (2.1-4) Solitary work: 1.5 (1.2-1.8) Anxiety: 3.2 (2.5-4)	Job satisfaction; relationship with supervisors, colleagues; decision making, use of skills all NS	Job satisfaction, productivity	Productivity, work satisfaction, perceived stress: NS	Poor work content: 2.5 (1.3-4.9) Lack of social support: 1.6 (0.9-2.8) Work demand social support at work	ō	ō
Individual/ other factors considered	Immigrant status: 1.3 (1.1-1.5) Social work climate, work planning, job security, job constraints	Psychosomatic: 5.0 (3.6-6.9) Psychological: 4.7 (3.6-6) Stress: 3.4 (2.6-4.2) Discretion, support, under stimulation, anxiety, job satisfaction, quality of life	Medical findings in neck and shoulder significant for typists with head rotation >20E compared to < 20E	ō	Age, muscle strength, rest pauses: NS	ō	Age	Leisure time, smoking NS
Dose/response	ō	Stress index and neck-shoulder MSDs	ō	ō	ō	ō	ō	ō

See footnotes at end of table. (Continued)

Appendix C Table C-2. Summary table for evaluating work-related neck/shoulder disorders

Components of study	Ohara 1976	Ohlsson 1995	Punnett 1991	Rossignol 1987	Ryan 1988	Tola 1988	Vihma 1982	Viikari-Juntura 1991a
Study type	CS and Cohort	CS	CS	CS	CS	CS	CS	Cohort
Participation rate $70%	CS study: NR; Cohort: Y	Y	Y	N to Y (6 industries)	Y	Y overall: 67% carpenters 67% office workers	NR	Y
Outcome	S and PE	S and PE	S	S	S	S	S	S and PE
Exposure	Observation	Observation, video, analysis, muscle strength testing	Observation, questionnaire	Questionnaire	Observation, workstation measurement, questionnaire	Occupation title	Observation, interview	Questionnaire
Covariates considered	Used prospective cohort design with same study sample	Age, gender, psychosocial scales	Age, gender	Age, cigarette smoking, industry, education, VDT training	Height, weight, gender, age, marital status, parental status	Years in occupation, age, leisure time activities, car driving, general health	Age, duration of employment	Physical hobbies, creative hobbies
Investigators blinded	NR	Y to exposure information, no for physical	NR	NR	Y	NR	NR	NR
Repetition	Combined	Repetitive work: 4.6 (1.9-12)	Combined	Combined	ð	ð	Combined	ð
Force	ð	ð	Combined	ð	ð	ð	ð	ð
Extreme posture	Combined	Significant time spent in neck flexion <60°: NR	Associated with extended duration of and lifting weight in abduction/flexion and extension of the shoulder	Combined	More non-cases trained in adjustment of furniture than cases: NR, Sig.	Use of twisted or bent postures during work: Little (referent): 1.0 Moderate: 1.2 (1.0-1.5) Rather much: 1.6 (1.4-1.9) Very much: 1.8 (1.5-2.2)	Combined Sewing machine operator with significantly greater static work compared to seamstresses	Sitting in a forward posture 1-3 hr/day: 10.7 (0.4-291); >3 hr/day: 1.5 (0.7-29.5)
Vibration	ð	ð	ð	ð	ð	ð	ð	ð

See footnotes at end of table. (continued)

Appendix C Table C-2. Summary table for evaluating work-related neck/shoulder disorders

Components of study	Ohara 1976	Ohlsson 1995	Punnett 1991	Rossignol 1987	Ryan 1988	Tola 1988	Vihma 1982	Viikari-Juntura 1991a
Risk factors (combined)	Operators hired post-intervention had less reports of MSDs	Industrial workers vs. referents: 2.7 (1.2-6.3)	Male: 1.8 (1.0-3.2) Female: 0.9 (0.5-1.9)	½ to 3 hr of VDT use: 1.8 (0.5-6.8) 4 to 6 hr of VDT use: 4.0 (1.1-14.8) 7 $ hr of VDT use: 4.6 (1.7-13.2)	ō	Machine operators vs. office workers: 1.7 (1.5-2.0) Carpenters vs. office workers: 1.4 (1.1-1.6)	Sewing machine operators vs. seamstresses: 1.6 (1.1-2.3)	ō
Duration of employment	ō		ō	ō	ō	ō	ō	ō
Physical workload	ō	ō	ō	ō	ō	ō	Cases had significantly higher shoulder loads	ō
Psychosocial factors	ō	Stress/worry tendency: 1.9 (1.1-3.5)	ō	ō	Adequate rest breaks, boredom, work stress job pressure, autonomy, peer cohesion, role ambiguity, staff support	Job satisfaction, poor vs. very good: 1.2 (1.1-1.4)	ō	Social confidence, much fear vs. none: 1.4 (0.05-42.2); Sense of coherence: 0.95 (0.9-0.99)
Individual/other factors considered	ō	Muscle tension tendency: 2.3 (1.3-4.9)	ō	Smoking, industry, education	ō	Working in a draft: 1.1 (1.0-1.3)	ō	Alexithymia 1.02 (0.97-1.1)
Dose/response	ō	ō	ō	Hours of VDT use	ō	Use of twisted or bent posture	ō	ō

ō Not studied
CI Confidence interval
CS Cross-sectional
EMG Electromyography
hr Hours
Med. Medium
MSDS Musculoskeletal disorders
MVC Maximum voluntary contraction
N No
NR Not reported
NS Not statistically significant
OR Odds ratio
PE Physical examination
S Symptoms
Sig. Statistically significant
VDT Video display terminal
vs. Versus
Y Considered (yes)

Appendix C Table C-3. Summary table for evaluating work-related shoulder musculoskeletal disorders

Components of study	Andersen 1993a	Andersen 1993b	Baron 1991	Bergenudd 1988	Bernard 1994	Bjelle 1979	Bjelle 1981	Burdorf 1991
Study type	CS	CS	CS	CS	CS	Case control	Case control	CS
Participation rate $70%	Y	Y	N	N	Y	NR	NR	Y for riveters; N for referents
Outcome	S	S and PE	S and PE	S and PE	S	S and PE	PE	S
Exposure	Job title, categorization by job duration	Job title, categorization by job duration	Observation and videotape analysis, weight of scanned items, job category	Questionnaire, job classification (light, moderate, heavy physical demands)	Questionnaire and observation	Observation, measurement, EMG on 15 cases, open muscle biopsies on 11 cases	Measurement, videotape analysis, observation, EMG on 3 subjects and 2 healthy volunteers	Observation, measurement of vibration
Covariates considered	Age, having children, not exercising, duration of employment, socioeconomic status, smoking status, current neck/shoulder exposure	None for the shoulder analysis	Age, gender, hobbies, duration of work, second job, metabolic disease, duration of employment	Gender	Age, race, gender, height, medical conditions, psychosocial factors, typing hr away from work	Age, gender, and workshop	Age, gender, and place of work	Height, weight, smoking status
Investigators blinded	Y	Y	Y	NR	N	N	Y	NR
Repetition for shoulder	Combined	Combined	Combined	ð	R no surrogate for hand used: number of hr typing	Combined	Combined	ð
Force	Combined	Combined	Combined	ð	ð	Combined	Cases had Sig. higher shoulder loads than controls	ð
Extreme posture	Combined	Combined	Combined	ð	ð	Combined	Combined	ð

See footnotes at end of table. (Continued)

Appendix C Table C-3. Summary table for evaluating work-related shoulder musculoskeletal disorders

Components of study	Andersen 1993a	Andersen 1993b	Baron 1991	Bergenudd 1988	Bernard 1994	Bjelle 1979	Bjelle 1981	Burdorf 1991
Vibration	õ	õ	õ	õ	õ	õ	õ	1.5 (no confidence limits)
Risk factors (combined)	Increasing years of experience: 1.38-10.25 (Sig.)	Chi sq test for trend using exposure time in years for rotator cuff syndrome: 9.51; p<0.01	Checkers vs. others 3.9 (1.4-11.0) Checkers using scanners vs. others 8.6 (1.0-72.2)	õ	õ	Work at or above shoulders, cases (65%) vs. referents (15%): 10.6 (2.3-54.9)	Cases had Sig. longer duration and higher frequency of abduction or forward flexion than controls, p<0.001	õ
Duration of employment	See under "Physical workload"	See under "Risk factors combined"	Number of hr per week as a checker Sig.	õ	Years at newspaper: 1.4 (1.2-1.8)	õ	õ	Years of riveting: 0.05# p<0.10
Physical workload	0 to 7 years: 1.56 (0.76-3.75) 8 to 15 years: 4.28 (2.14-10.0) >15 years: 7.27 (3.82-16.3)	õ	õ	Prevalence of occupational workload in subjects with shoulder pain: Heavy, 11%; Moderate, 49%; Light, 40%	õ	õ	õ	õ
Psychosocial factors	õ	õ	õ	Females showed Sig. association with shoulder pain and dissatisfaction	Lack of decision making participation: 1.6 (1.2-2.1) job pressure: 1.5 (1.0-2.2)	õ	õ	õ
Individual/other factors considered	Age-matched controls	Age-matched controls	Age, gender, metabolic disease	Gender	Gender, race, height	Age, gender	Age, gender; median number of sick-leave days Sig. different between cases and controls, p=0.01	Age
Dose/response	Y with years of employment	Y with years of exposure	õ	õ		õ	õ	õ

See footnotes at end of table.

(Continued)

Appendix C Table C-3. Summary table for evaluating work-related shoulder musculoskeletal disorders

Components of study	Burt 1990	Chiang 1993	English 1995	Flodmark 1992	Hales 1989	Hales 1994	Herberts 1981	Herberts 1984
Study type	CS	CS	Case control	CS	CS	CS	CS	CS
Participation rate $70%	Y	Y	Y	Y	Y	Y	NR	NR
Outcome	S	S and PE	S and PE	S	S and PE	S and PE	S and PE	S and PE
Exposure	Observation, questionnaire, job sampling	Observation and recording of representative jobs, hand F estimation	Self-reports	ð	Observation walk-through, job categorization High vs. low exposure (hand/wrist exposure)	Observation and questionnaire	Analyses by job title	Analyses by job title
Covariates considered	Age, gender, psychosocial factors, metabolic disease duration of employment	Age, gender, metabolic diseases	Age, height, gender, weight, injury, study center, hobbies, sporting activities, average hr of driving, compensation claim made	Age, headache, tiredness, medical problems, sleeping problems or lack of concentration, sleep	Age and duration of employment	Age, race, gender, work practices, work organization factors, individual factors, electronic performance monitoring, recreational activities, hobbies	Age, job duration	Controls matched for age and gender
Investigators blinded	ð	Y	Y	ð	Y	Y	NR	NR
Repetition for shoulder	Typing speed fast compared to slow: 4.1 (1.8-9.4)	Repetitive movement of upper limb: 1.6 (1.1-2.5)	Combined	ð	Combined	No	Combined	Combined
Force	ð	Sustained forceful movement of upper limb: 1.8 (1.2-2.5)	ð	ð	Combined	ð	Welders vs. office workers: 15-18	Welders vs. office workers: 15-18
Extreme posture	ð	ð	Combined	ð	Combined	Number of times arising from chair: 1.9 (1.2-15.5)	Combined	Combined

See footnotes at end of table.

(Continued)

Appendix C Table C-3. Summary table for evaluating work-related shoulder musculoskeletal disorders

Components of study	Burt 1990	Chiang 1993	English 1995	Flodmark 1992	Hales 1989	Hales 1994	Herberts 1981	Herberts 1984
Vibration	ð	ð	ð	ð	ð	ð	ð	ð
Risk factors (combined)	ð	Repetition multiplied by force: 1.4 (1.0-2.0)	Repeated shoulder rotation with elevated arm: 2.3, *p*<0.05	ð	Any symptom of shoulder: 49% vs. 43%; 1.2 (0.7-2.0) Period prevalence: 19% vs. 4%; 3.8 (0.6-22.8) Point prevalence: 7% vs. 4%;0.9 (0.1-7.3)	ð	Welders vs. office workers: shoulder symptoms: 15.2 (2.1-108) Shoulder Tendinitis: 8.3 (NS)	ST results of 23 welders called back for clinical follow-up exams: 16 had ST; 18.3 (13.7-22.1) (90% CI) ST results of 30 plate-workers called back for clinical follow-up exams: 15 plate-workers had ST: 16.2 (10.9-21.5) (90% CI)
Duration of employment	NS	ð	ð	ð	ð	ð	ð	ð
Physical workload	ð	ð	ð	ð	ð	ð	NS	ð
Psychosocial factors	Job dissatisfaction: 2.3 (1.2-4.3)	ð	ð	Type A Behavior: *p*<0.001	ð	Fear of replacement by computers: 1.5 (1.1-2.0)	ð	ð
Individual/other factors considered	Pre-existing arthritis: 2.3 (1.2-4.4)	Plant effect age: 1.0 (0.9-1.1) Gender: 1.1 (0.7-1.7)	Per 5 years of age: 1.4 (1.2-1.5)	ð	ð	Typing outside of work	ð	ð
Dose/response	ð	Dose response found for shoulder diagnosis as exposure status increased from Group 1 to Group 3	ð	ð	ð	ð	ð	ð

See footnotes at end of table.

(Continued)

Appendix C Table C-3. Summary table for evaluating work-related shoulder musculoskeletal disorders

Component of study	Hoekstra 1994	Hughes 1997	Ignatius 1993	Jonsson 1988	Kiken 1990	Kilbom 1986, 1987	Kvarnström 1983	McCormack 1990
Study type	CS	CS	CS	Prospective	CS	CS	CS and Case control	CS
Participation rate $70%	Y	N	N	Y	Y	Y	NR	Y
Outcome	S	S and PE	S	S and PE	S and PE	S and PE	S and PE	S and PE
Exposure	Analyses based on questionnaire, self-reports	Observation and job analysis	Observation, questionnaire, weight of mail bags	Observation, measurement of exertion, videotaping	Observation (exposure based on repetitive and forceful hand motions, not shoulder)	Observation, measurement, videotaping, observation	Observation, interview, questionnaire	Observation
Covariates considered	Age, seniority, gender	Controlled for age, smoking status, sports, hobbies	Age, duration of employment, bag weight, walking time	Age, hobbies, spare time, physical action, psychosocial factors, breaks, rest pauses	Age and gender	Age, years of employment, productivity, muscle strength	ô	Age, gender, race, job category, duration of employment, general health history
Investigators blinded	Y	NR	NR	Y	Y	Y	N	N
Repetition for shoulder	ô	ô	Combined	Combined	Combined	Fewer total number of upper arm flexions/hr. (*p*<0.05)	Combined	Combined
Force	ô	ô	Combined	ô	Combined	ô	Combined	ô
Extreme posture	Non-optimally adjusted desk height work: 5.1 (1.7-15.5)	Years of forearm twist: 46.0 (3.8-550)	Combined	Relative time spent with shoulder elevated negatively related to 'remaining healthy ' after both 1 and 2 years: Sig.	Combined	Greater percentage of work cycle time with upper arm abducted 0-30° (*p*<0.05)	Combined	Combined
Vibration	ô	ô	ô	ô	ô	ô	ô	ô

See footnotes at end of table. (Continued)

Appendix C Table C-3. Summary table for evaluating work-related shoulder musculoskeletal disorders

Component of study	Hoekstra 1994	Hughes 1997	Ignatius 1993	Jonsson 1988	Kiken 1990	Kilbom 1986, 1987	Kvarnström 1983	McCormack 1990
Risk factors (combined)	Center B compared to Center A: 4.0 (1.2-13.1)	ð	Letter delivery postal workers compared to other postal workers Recurrent: 1.8 (1.5-2.2) Severe joint pain: 2.2 (1.5-3.1)	38 subjects who were reallocated to more varied tasks improved	Plant #1 Any symptom for shoulder: 46% vs. 28%; 1.6 (0.9-2.9) Period prevalence: 13% vs. 3%; 4.0 (0.6-29) Plant #2 Any symptom for shoulder: 50% vs. 30%; 1.7 (0.8-3.3) Period prevalence: 14%vs. 5%; 2.8 (0.4-19.6)	ð	Die casting machine operators: 5.4; plastic workers: 2.2; spray painters: 3.7; surface treatment operators: 4.7; assembly line workers: 5.2	Boarding workers vs. knitting workers: 2.1 (0.6-7.3)
Duration of employment	ð	ð	ð	ð	ð	Years of employment in electronics: $p<0.05$	ð	NS
Physical workload	ð	ð	ð	Low muscle strength no a predictor for shoulder MSD	ð	ð	ð	ð
Psychosocial factors	Job dissatisfaction, exhaustion (not for shoulder)	Low decision latitude: 4.0 (0.8-19)	ð	Strong negative relationship between remaining health and satisfaction with colleagues	ð	ð	9 cases and 1 control reported poor relationship with supervisor. Sig. differences in group piece rate, shift work, heavy work, monotonous work, stressful work,	ð
Individual/other factors considered	Location	Age: 0.93 (0.8-1.0); good health: 0.35 (0.1-0.87)	Age, work experience, bag weight, walking time	Predictors of deterioration, previously physically heavy job, high productivity, and sick leave	ð	Shorter stature: $p<0.05$, productivity: NS, muscle strength: NS	Sig. differences in heavy lifting and unsuitable working conditions	ð
Dose/response	ð	ð	ð	ð	ð	ð	ð	ð

See footnotes at end of table.

(Continued)

Appendix C Table C-3. Summary table for evaluating work-related shoulder musculoskeletal disorders

Components of study	Milerad 1990	Ohara 1976	Ohlsson 1989	Ohlsson 1994	Ohlsson 1995	Onishi 1976	Punnett 1985	Rossignol 1987
Study type	CS	CS and Prospective	CS	CS	CS	CS	CS	CS
Participation rate $70%	Y	NR (CS), Y (Prospective)	NR	Y	Y	NR	Y	Y: clerical workers N: industry groups
Outcome	S	S and PE	S	S and PE	S and PE	S, PE, and measurement	S and PE	S
Exposure	Questionnaire	Observation	Job categorization	Observation, questionnaire, video analysis	Observation, video analysis, measurement	Observation	Observation and questionnaire	Observation and questionnaire
Covariates considered	Age, gender, leisure time exposure, smoking, systemic disease, duration of employment	õ	Age, gender (females only)	Sports activities, age, gender (females only) psychosocial factors	Age, employment status	Body height, weight, grip strength	Age, number of years employed, native language	Age, cigarette smoking, industry, VDT educational training
Investigators blinded	NR	NR	NR	Y	Yes, to exposure information	NR	NR	õ
Repetition for shoulder	Combined	Combined	Combined	Combined	Combined	Combined	Combined	4-6 hrs. VDT use: 4.0 (1.0-16.9) >7 hrs. VDT use: 4.8 (1.6-17.2)
Force	Combined	Combined	Combined	Combined	Combined	Combined	Combined	õ
Extreme posture	Combined	Combined	Combined	Combined	Combined	Combined	Combined	õ
Vibration	NS	õ	õ	õ	õ	õ	õ	õ

See footnotes at end of table.

(Continued)

Appendix C Table C-3. Summary table for evaluating work-related shoulder musculoskeletal disorders

Components of study	Milerad 1990	Ohara 1976	Ohlsson 1989	Ohlsson 1994	Ohlsson 1995	Onishi 1976	Punnett 1985	Rossignol 1987
Risk factors (combined)	Dentists vs. pharmacists: males: 2.4 (1.0-5.4), females: 2.4 (1.5-3.7)	Shoulder stiffness: cashiers (81% vs. office workers (72%), 1.7 (1.0-2.8) Shoulder dullness and pain: cashiers (49%) vs. other workers (68%), 2.0 (1.4-2.8); vs. office workers (30%), 2.2 (1.4-3.5)	Assemblers vs. referents shoulder pain last 7 days: 3.4 (1.6-7.1)	Supraspinatus, infraspinatus, or bicipital tendinitis working in the fish industry: OR=3.03 (2.5-7.2) Shoulder tendinitis alone: PRR=3.5 (2.0-5.9)	Assembly work compared to referent 5.0 (2.2-11.0)	Shoulder tenderness: assemblers vs. ref.: 1.1 (0.6-1.9); film rollers vs. ref.: 6.0 (3.0-12.2); teachers vs. ref.: 1.6 (0.7-3.3) Shoulder stiffness: reservationists vs. ref: 2.5 (1.1-5.6); assemblers vs. ref.: 3.7 (2.0-7.0); film rollers vs. ref.: 2.7 (1.5-4.9); teachers vs. ref.: 2.1 (0.9-4.6)	Garment workers vs. hospital employees 2.2 (1.0-4.9)	õ
Duration of employment	NS	õ	Sig. with duration of employment (*p*=0.03) for younger workers but not older workers	For age <45 years, duration of employment showed dose-response with shoulder MSDs	<10 years: 9.6 (2.8-33.0) 10-19 years: 4.4 (1.5-13.0) >20 years: 3.8 (1.4-10.0)	õ	NS	õ
Physical workload	õ	õ	õ	õ	õ	õ	õ	õ
Psychosocial factors	õ	õ	Increasing work pace	Stress, worry factors, tendencies towards muscle tension Sig.	Control, stimulation, psychosocial climate, work strain, social support, psychosomatic symptoms	õ	õ	õ
Individual/other factors considered		õ		Sports activities: 4-9	Employment status	Body height and weight: NS		õ
Dose/response	õ	õ	Reported pain increased with increasing work pace except for very high paces	For age <45 years, duration of employment and shoulder MSDs	õ	õ	õ	As VDT use increased, shoulder symptoms increased

See footnotes at end of table. (Continued)

Appendix C Table C-3. Summary table for evaluating work-related shoulder musculoskeletal disorders

Components of study	Sakakibara 1987	Sakakibara 1995	Schibye 1995	Stenlund 1992	Stenlund 1993	Sweeney 1994	Wells 1983
Study type	CS	CS	Cohort	CS	CS	CS	CS
Participation rate $70%	Y	Y	Y (But there was a significant dropout of work as a sewing machine operator in those >35 years	Y	Y	N	Y
Outcome	S	S and PE	S	S and PE	S and PE	S and PE	S
Exposure	Observation and measurement of postures	Observation and measurement of representative workers or job titles	Questionnaire	Questionnaire, self-reports, weight of tools job title, duration of employment	Questionnaire and self-reports	Questionnaire	Questionnaire, job categorization
Covariates considered	Gender, age	ð	Cohort study: followed same workers over time	Age, smoking, dexterity, ethnicity	Age, handedness, smoking, sports activities, duration of employment	ð	Age, number of years on job, quetelet ratio, previous work experience, education
Investigators blinded	ð	NR	NR	Y	Y	Yes	NR
Repetition for shoulder	ð	Combined	Combined	ð	ð	Combined	ð
Force	ð	ð	Combined	Combined	Manual work: right side: 1.1 (0.7-1.8) left side: 1.9 (1.0-3.4)	ð	Combined
Extreme posture	Thinning out, bagging pears had significantly more forward shoulder flexion than bagging apples	Combined	Combined	ð	ð	Combined	Combined
Vibration	ð	ð	ð	Right side: 2.2 (1.0-4.6) Left side: 3.1 (1.4-6.9)	Right side 1.7 (1.1-2.6) left side 1.8 (1.1-3.1)	ð	ð

See footnotes at end of table. (Continued)

Appendix C Table C-3. Summary table for evaluating work-related shoulder musculoskeletal disorders

Components of study	Sakakibara 1987	Sakakibara 1995	Schibye 1995	Stenlund 1992	Stenlund 1993	Sweeney 1994	Wells 1983
Risk factors (combined)	ó	Pear baggers compared to apple baggers: 1.7 (1.1-2.9) Posture: NR, Sig.	Development of shoulder symptoms not related to work exposure but significant dropout of workers >35 years	Rockblasters vs. Foremen: 4.0 (1.8-9.2) Bricklayers compared to foremen: right side: 2.2 (1.0-4.7)	Rock blasters compared to foremen: right side: 1.7 (0.7-4.0) left side: 3.3 (1.2-9.3)	>20 hrs./ week signing: 2.5 (0.8-8.2)	Letter carriers with increased shoulder load vs. postal clerks: 5.7 (2.1-17.8)
Physical workload	ó	ó	ó		Right side: 1.0 (0.6-1.8) left side: 1.8 (0.9-3.4)	ó	ó
Psychosocial factors	ó	ó	ó		ó	ó	ó
Individual/other factors considered	ó	ó	ó	Rock blasters compared to foremen: Right side: 2.1 (0.9-4.6) Left side: 4.0 (1.8-9.2)	ó	ó	
Duration of employment	ó	ó	ó	Right side: 2.9 (1.2-7.4) Left side: 2.5 (1.0-5.9)		ó	NS
Dose/response	ó	ó	None for increasing piece work in previous years	As length of employment and exposure to vibration and amount lifted increased, osteoarthritis of shoulder increased	High vibration compared to low vibration	ó	ó

ó Not studied.
EMG Electromyography.
F Force.
MSD Musculoskeletal disorders.
N Considered (no).
NR Not reported.
NS Not statistically significant.
R Repetition.
Ref. Referents.
S Symptoms.
Sig. Significant.
ST Supraspinatus tendinitis.
PE Physical examination.
VDT Video display terminals.
Y Considered (yes).

Appendix C Table C-4. Summary table for evaluating elbow musculoskeletal disorders

Components of study	Andersen 1993a	Baron 1991	Bovenzi 1991	Burt 1990	Byström 1995	Chiang 1993	Dimberg 1987	Dimberg 1989
Study type	CS	CS	CS	CS	CS	CS	CS	CS
Participation rate $70%	Y	N	NR	Y	Y	Y	Y	Y
Outcome	S	S and PE	S and PE	S	S and PE	S and PE	S and PE	S and PE
Exposure	Job categorization by job duration	Observation videotape, questionnaire	Observation, checklist, vibration measured	Questionnaire	Observation, videotape analysis, EMG of forearm muscle load collected, however, job title used for analysis	Observation videotape analysis, EMG	Observation job analysis categorization	Observation, job analysis, categorization
Covariates considered	Age, number of children, smoking, socioeconomic status	Age, gender, hobbies, second jobs, height, systemic disease	Age, ponderal index	Age gender, years on job, psychosocial factors	Gender, age >40 years, psycho-social variables and potential confounders addressed by Fransson-Hall et al. 1995	Age, gender, metabolic disease	Gender, age, employee category, degree of stress, tennis playing	Ponderal index, gender, age, time in present job, height, weight, smoking, house ownership, racquet sports
Investigators blinded	Y	Y	Y	Y	Y to questionnaire responses, No to exposure status	Y	NR	NR
Repetition	Combined	Combined	õ	80% of time reported typing vs. 0-19% of time: 2.8 (1.4-5.7)	Combined	Combined	õ	õ
Force	Combined	Combined	õ	Combined	Combined	Combined	Combined	Combined
Extreme posture	Combined	Combined	õ	Combined	Combined	Combined	Combined	Combined

See footnotes at end of table. (Continued)

Appendix C Table C-4. Summary table for evaluating elbow musculoskeletal disorders

Components of study	Andersen 1993a	Baron 1991	Bovenzi 1991	Burt 1990	Byström 1995	Chiang 1993	Dimberg 1987	Dimberg 1989
Vibration	ò	ò	Vibration-exposed forestry workers vs. referents: 4.9 (1.27-56.0)	ò	ò	ò	ò	*p*<0.01
Risk factors (combined)	Sewing machine operators vs. general population 1.7 (0.9-3.3)	Checkers vs. Noncheckers: 2.3 (0.5-11.0)	ò	Reporters compared to others: 2.5 (1.5-4.0)	Assembly line workers vs. population referen ts: 0.74 (0.04-1.7)	Group III vs. Group I (females): 1.44 (0.3-5.6) High force/high repetition vs. low force/low repetition: (males) 6.75 (1.6-32.7)	Force and posture: NR, Sig.	Force and posture: NR, NS
Physical workload	ò	ò	ò	ò	ò	ò	ò	ò
Psychosocial factors	ò	Job satisfaction: NS	ò	Job control and satisfaction: NS	Addressed by Fransson-Hall et al. 1995	ò	ò	Mental stress at the onset of symptoms: *p*<0.001
Individual/other factors considered	ò	ò	ò	Sick leave more common among strenuous jobs than nonstrenuous jobs	ò	ò	"Work" the cause in 35% of elbow problems, most white collar	Ponderal index associated with elbow symptoms
Duration of employment	ò	NS	ò	ò	ò	ò	ò	ò
Dose/response	ò	ò	ò	Y for time spent typing	ò	Y for males with increasing force/repetition	ò	ò

See footnotes at end of table. (Continued)

Appendix C Table C-4. Summary table for evaluating elbow musculoskeletal disorders

Components of study	Fishbein 1988	Hales 1994	Hoekstra 1994	Hughes 1997	Kopf 1988	Kurppa 1991	Luopajärvi 1979	McCormack 1990
Study type	CS	CS	CS	CS	CS	Cohort	CS	CS
Participation rate $70%	N	Y	Y	N	N	Y	Y	Y
Outcome	S	S and PE	S	S and PE	S	S and PE	S and PE	S and PE
Exposure	Questionnaire	Observation and Questionnaire	Observation and Questionnaire	Observation, checklist, formal job analysis	Questionnaire, job categories	Observation, measurements, categorized by job titles	Observation, interviews, videotape analysis	Observation, job categories based on manual exposure
Confounders considered	Age, gender stratification, smoking status, alcohol, beta blockers, other drugs	Age, gender, metabolic disorder, hobbies, recreation	Age, gender, location, seniority	Age, smoking status, sports, hobbies, metabolic diseases, acute traumatic injuries, smoking	Age, job satisfaction, job security, moistness, vibration, Scheuerman's Disease	Workers used as their own controls; age, gender, duration of employment (with exceptions)	Age, gender, social background, hobbies, amount of housework, length of employment	Gender, age, race, job category, years of employment
Investigators blinded	NR	Y	Y	NR	NR	NR	Y	NR
Repetition	Combined	Number of key-strokes per day: NS	ŏ	ŏ	Combined	Combined	Combined	Combined
Force	ŏ	ŏ	ŏ	Number of years handling >2.5 kg/hand: NS	Combined	Combined	Combined	Combined
Extreme posture	Combined	ŏ	Non optimally adjusted chair: 4.0 (1.2-13.1)	Wrist flexion/ extension: NS; years of ulnar deviation: NS; years of forearm twisting: 37 (3.0-470.0)	Combined	Combined	Combined	ŏ
Vibration	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ

See footnotes at end of table.

(Continued)

Appendix C Table C-4. Summary table for evaluating elbow musculoskeletal disorders

Components of study	Fishbein 1988	Hales 1994	Hoekstra 1994	Hughes 1997	Kopf 1988	Kurppa 1991	Luopajärvi 1979	McCormack 1990
Risk factors (combined)	Female musicians compared to males: 2.04 (1.6-2.6)	õ	õ	õ	Bricklayers compared to manual workers: 2.8; Increasing job demands OR increased from 1.8 to 3.4	Workers in strenuous vs. nonstrenuous jobs: 6.7 (3.3-13.9)	Assembly workers vs. shop assistants: for epicondylitis: 2.7 (0.66-15.9)	Boarding vs. Non-office workers: 0.5 (0.09-2.1) Knitting vs. Non-office workers: 1.2 (0.5-3.4)
Physical workload	õ	õ	õ	Push/pull; lift carry: NS	Sig	õ	õ	õ
Psychosocial factors	õ	Fear of replacement by computers: 2.9 (1.4-6.1); decision making: 2.8 (1.4-5.7); surge in workload: 2.4 (1.2-5.0)	Job dissatisfaction; exhaustion	Low decision latitude: 3.5 (0.6-19.0)	õ	õ	õ	õ
Individual/other factors considered	õ	Race (non-white): 2.4 (1.2-5.0)	õ	Age: 0.96 (0.9, 1.2)	õ	õ	õ	Age, race Sig
Duration of employment	õ	õ	õ	õ	õ	õ	õ	Y, Sig, with <6 months and >13 years
Dose/response	õ	õ	õ	õ	Yes, increasing levels of job demands	õ	õ	No

See footnotes at end of table. (Continued)

Appendix C Table C-4. Summary table for evaluating elbow musculoskeletal disorders

Components of study	Moore 1994	Ohlsson 1989	Punnett 1985	Ritz 1995	Roto 1984	Viikari-Juntura 1991b
Study type	CS	CS	CS	CS	CS	CS
Participation rate ≥70%	Y	NR	Y for cases N for referents	NR	Y	Y
Outcome	PE records	S	S	S and PE	S and PE	S and PE
Exposure	Observation, videotape analysis, job strain index	Questionnaire, job categorization	Questionnaire, job category	Observation and record review and employee interviews	Job categorization	Observation, job analysis; weights of items
Confounders considered	Age, gender, duration of employment	Age, gender, duration of employment	Age, number of years employed, native language	Age, age-squared, and "history of cervical spine symptoms". Having ever played tennis, squash, other racquet sports, rowing, bowling,	Gender, other work tasks	Age, gender, duration of employment, leaving the company, changing the task, being on sick leave
Investigators blinded	Y	NR	NR	Y	Y	NR
Repetition	ô	Combined	Combined	ô	Combined	Combined
Force	5.5 (1.5-62)	ô	Combined	10 years of high exposure to elbow straining work: 1.7 (1.0-2.7)	Combined	Combined
Extreme posture	NR: was not found to be sig. associated with "hazardous" jobs.	Combined	Combined	ô	Combined	ô
Vibration	ô	ô	-	ô	ô	ô
Risk factors (combined)	ô	Non significant pain in last year assembly vs. referents: 1.5 (0.6-3.4) Work inability in last year assembly vs. Referents: 2.8 (0.8-10.7)	Garment workers vs. hospital employees: 2.4 (1.2-4.2)	ô	Meatcutters vs. construction workers: 6.4 (0.99-40.9), *p*=0.05	Strenuous vs. nonstrenuous: NS; difference: 0.88 (0.27-2.8)

See footnotes at end of table. (Continued)

Appendix C Table C-4. Summary table for evaluating elbow musculoskeletal disorders

Components of study	Moore 1994	Ohlsson 1989	Punnett 1985	Ritz 1995	Roto 1984	Viikari-Juntura 1991b
Physical workload	õ	õ	õ	õ	õ	õ
Psychosocial factors	õ	õ	õ	õ	õ	õ
Individual/other factors considered	õ	Not associated with work pace	Age; Non-English speakers sig. less likely to report symptoms	õ	õ	õ
Duration of employment	õ	No association	õ	Increased duration of current exposure increased risk of epicondylitis	All with epicondylitis had >15 years of employment	õ
Dose/response	õ	õ	õ	õ	õ	õ

õ Not studied.
CS Cross-sectional.
EMG Electromyography.
F force.
Hrs Hours.
MSD Musculoskeletal disorders.
N no.
NR Not reported.
NS Not statistically significant.
PE Physical examination.
R Repetition.
Sig. Statistically significant.
S Symptoms.
Y Considered (yes).

Appendix C Table C-5a. Summary table for evaluating work-related carpal tunnel syndrome (CTS)

Components of study	Armstrong 1979	Barnhart 1991	Baron 1991	Bovenzi 1991	Bovenzi 1994	Cannon 1981	Chatterjee 1982	Chiang 1990
Study type	CS	CS	CS	CS	CS	Case control	Case control	CS
Participation rate $70%	NR	N	N	NR	Y	NR	Y	Y
Outcome	S or surgery or PE findings	PE and NCS	S and PE	S and PE	S and PE	Industry medical records	S and PE and NCS	S and PE and NCS
Exposure	Observation, video, EMG	Observation	Observation, videotape analysis, job category	Observation, measurement	Observation, vibration, measurement	Medical records, job category	Observation, Measurement	Observation
Covariates considered	Gender, metabolic or soft tissue disease	Age, gender	Age, gender, hobbies, past employment, years on job	Age, gender, weight	Age, smoking, alcohol, upper limb injuries	Age, gender, race, weight, occupation, years employed, workers compensation status, history of metabolic disease, hormonal status, gynecologic surgery	Age, gender	Age, gender, length of employment, history of metabolic disease
Investigators blinded	N	Y, but clothing may have biased observation	Y	Y	N	NR	Y	Y
Repetition	ô	Repetitive ski manufacturing vs. others NCS: 1.9 (1.0-3.6) PE+NCS: 4.0 (1.0-15.8) S+PE+NCS: 1.6 (0.8-3.2)	Combined	ô	ô	2.1 (0.7-5.3)	ô	1.87 (*p*<0.018)

See footnotes at end of table.

(Continued)

Appendix C Table C-5a. Summary table for evaluating work-related carpal tunnel syndrome (CTS)

Components of study	Armstrong 1979	Barnhart 1991	Baron 1991	Bovenzi 1991	Bovenzi 1994	Cannon 1981	Chatterjee 1982	Chiang 1990
Force	Pinch F: 2.0 (1.6-2.5) Hand F: 1.05 (1.0-1.2)	ð	Combined	ð	ð	ð	ð	ð
Extreme posture	Pinch force exertion: 2.0 (1.6-2.5)	ð	ð	ð	ð	ð	ð	ð
Vibration	ð	ð	ð	23.1 (no confidence limits) *p*=0.002	Quarry drillers and stone carvers vs. polishers and machine operators: 3.4 (1.4-8.3)	7.0 (3.0-170.0)	10.89 (1.02-524.0)	ð
Risk factors (combined)	ð	ð	Grocery checkers vs. other grocery workers: 3.7 (0.7-16.7)	Chain saw operators vs. maintenance workers: 18.8 (2.7-795)	ð	ð	ð	High cold/ high repetition: 11.66 (2.92-46.6)
Duration of employment	ð	ð	Y, Sig.	ð	ð	0.09 (0.8-10)	ð	NS
Physical workload	ð	ð	ð	ð	ð	ð	ð	ð
Psychosocial factors	ð	ð	ð	ð	ð	ð	ð	ð
Individual/other factors considered	ð	ð	ð	ð	ð	ð	ð	ð
Dose/response	ð	ð	Y, Sig.	ð	Y, NS	ð	ð	ð

See footnotes at end of table.

(Continued)

Appendix C Table C-5a. Summary table for evaluating work-related carpal tunnel syndrome (CTS)

Components of study	Chiang 1993	deKrom 1990	English 1995	Färkkilä 1988	Feldman 1987	Franklin 1991	Koskimies 1990	Liss 1995
Study type	CS	CS	Case control	CS	CS for symptoms and cohort for NCS	Retrospective cohort	CS	CS
Participation rate $70%	Y	Y	Y	NR	Y	Y	NR	No
Outcome	S and PE	S and PE and NCS	S and PE	S and PE and NCS	S and in some PE and NCS	Records review of workers' compensation cases	S and PE and NCS	Mailed survey
Exposure	Observation, measurement, EMG	Questionnaire	Questionnaire	Interview	Observation, biomechanical analysis, videotaping	Job title and industry	Records of vibration exposure	Mailed survey
Covariates considered	Age, gender, metabolic disease, hormonal status	Age, gender, weight, slimming courses	Gender, height, weight	Alcohol	Gender, past medical history, cigarette smoking, hobbies (No analyses performed to take these into account)	None	NR	Gender, age
Investigator blinded	Y	NR, participants blinded	Y	NR	NR	Y	NR	N
Repetition	Repetitive fish processing vs. other: 1.1 (0.7-1.8)	õ	CTS patients vs. other patients: 0.4 (0.2-0.7)	õ	Combined	Combined	õ	Combined
Force	Repetitive fish processing vs. other: 1.8 (1.1-2.9)	õ	õ	õ	Combined	Combined	õ	õ
Extreme posture	õ	Reported 20 to 40 hrs./week Flexed wrist: 8.7 (3.1-24.1) Extended 5.4 (1.1-27.4)	CTS patients vs. other patients: 1.8 (1.2-2.8)	õ	õ	Combined	õ	Combined

See footnotes at end of table.

(Continued)

Appendix C Table C-5a. Summary table for evaluating work-related carpal tunnel syndrome (CTS)

Components of study	Chiang 1993	deKrom 1990	English 1995	Färkkilä 1988	Feldman 1987	Franklin 1991	Koskimies 1990	Liss 1995
Vibration	õ	õ	õ	Vibration: $p< 0.05$	õ	õ	Vibration exposure time and NCS Sig. Right hand: r=-0.27; *p*=0.01 Left hand r=-0.12 *p*=NS	õ
Risk factors (combined)	Repetitive and forceful fish processing vs. others: 1.1 (0.7-1.8) Female poultry workers hi R/hi F vs. low R F: 2.6 (1.0-7.3)	õ	õ	õ	Year 2 vs. Year 1, numbness and tingling in fingers: 2.26 (1.14-4.46)	Oyster and crab packers vs. industry-wide rates: 14.8 (11.2-19.5)	õ	CTS symptoms, dental hygienists vs. dental assistants: 3.7 (1.1-11.9) Responder told that they had CTS: 5.2 (0.9-32.0)
Duration of employment	Y,<12 months; No for 12 to 60 months and >60 months	õ	õ	õ	õ	õ	Exposure time Sig.	õ
Physical workload	Y	õ	õ	õ	õ	õ	õ	õ
Psychosocial factors	õ	õ	õ	õ	õ	õ	õ	õ
Individual/other factors considered	õ	õ	õ	õ	õ	õ	õ	õ
Dose/response	Y, Sig.	Y, Sig.	õ	õ	õ	õ	õ	õ

See footnotes at end of table.

(Continued)

Appendix C Table C-5a. Summary table for evaluating work-related carpal tunnel syndrome (CTS)

Components of study	Loslever 1993	Marras 1991	McCormack 1990	Morgenstern 1991	Moore 1994	Nathan 1988	Nathan 1992a	Nathan 1992b
Study type	CS	CS	CS	CS	Retrospective cohort	CS	Cohort	Longitudinal
Participation rate $70%	Jobs selected due to CTS occurrence	NR	Y	Y	Y	NR	N	Y=Japanese N=Overall
Outcome	S	Records and medical records	S and PE	S	PE and NCS from records	NCS	S and NCS	S and NCS
Exposure	Observation; measurements, videotaping	Observation; measurements	Observation, job title	Survey	Observation, videotape, measurement	Observation	Observation	Questionnaire
Covariates considered	Gender, age, years on the job, hand orientation	Age, gender, handedness, job satisfaction	Age, gender, race, job category, years of employment	Age, gender, pregnancy status, work history job tasks, use of selected drugs, history of wrist injury	None	Age, gender	Age, gender, hand dominance, duration of employment and industry	Gender, hand dominance, occupational hand use, duration of employment, industry, leisure exercise, heavy lifting, keyboard use, coffee, tea, alcohol
Investigator blinded	N	NR	NR	N	Y	NR	NR	NR
Repetition	õ	Number of wrist movements: NS	Combined	1.88 (0.9-3.8)	Combined	Group II vs. Group 1:1.0 (0.05-2.0)	Combined	Found to be "protective"
Force	Combined	Grip forces three times as great in high-risk jobs	Combined	õ	Combined	Combined	Combined	
Extreme posture	Combined	Radial/ulnar ROM: 1.52 (1.1-2.1); Flexion/extension ROM: 1.3 (1.0-1.7); Pronation/supination ROM: 1.2 (0.9-1.6)	õ	õ	Combined	õ	õ	õ

See footnotes at end of table.

(Continued)

Appendix C Table C-5a. Summary table for evaluating work-related carpal tunnel syndrome (CTS)

Components of study	Loslever 1993	Marras 1991	McCormack 1990	Morgenstern 1991	Moore 1994	Nathan 1988	Nathan 1992a	Nathan 1992b
Vibration	ô	ô	ô	ô	ô	ô	ô	ô
Risk factors (combined)	High force with high flexion: r=0.62; high force and high extension: r=0.29	Flexion/extension velocity: 3.8 (1.5-9.6) Flexion/extension acceleration: 6.1 (1.7-22)	Boarding vs. non-office: 0.5 (0.05-2.9) Packing vs. Non-office 0.4 (0.04-2.4) Sewing vs. Non-office 0.9 (0.3-2.9)	ô	Meat processors in hazardous vs. safe jobs: 2.8 (0.2-36.7)	Group I vs. Group III: 1.7 (1.3-2.3) Group I vs. Group V: 2.2 (1.3-3.3)	Group V vs. Group I: 1.0 (0.5-2.2) Group IV vs. Group I: 1.4 (0.9-2.1) Group III vs. Group I: 1.5 (1.0-2.2)	Americans with significantly greater prevalence of CTS compared to Japanese
Duration of employment	ô	Sig.	Prevalence higher in workers with <3 years employment	>34 hrs./week: 1.9 (1.1-3.1) >9 years: 1.7 (1.0-3.2)	ô	ô	ô	Duration of employment found to be protective
Physical workload	ô	ô	ô	ô	ô	ô	ô	ô
Psychosocial factors	ô	Job satisfaction: NS	ô	ô	ô	ô	ô	ô
Individual/other factors considered	ô	trunk depth: Sig.	ô	ô	ô	ô	Age, hand dominance sig.	Mean age, body mass index and leisure exercise Sig., cigarettes Sig .
Dose/response	ô	ô	ô	ô	ô	Y, Sig.	ô	ô

See footnotes at end of table.

(Continued)

Appendix C Table C-5a. Summary table for evaluating work-related carpal tunnel syndrome (CTS)

Components of study	Osorio 1994	Punnett 1985	Schottland 1991	Silverstein 1987	Stetson 1993	Tanaka (*In Press*)	Weislander 1989
Study type	CS	CS	CS	CS	CS	CS	Case control
Participation rate $70%	Y	Y for cases; N for comparison group	NR	Y	Y	Y	Y
Outcome	S and PE, NCS	S and PE	NCS	S and PE	S and PE and NCS	S	S and PE and NCS
Exposure	Job title, observation	Observation, questionnaire	Job title	Observation, videotape analysis, EMG	Observation, questionnaire, job analysis	Questionnaire	Telephone interview
Covariates considered	Age, gender, alcohol, medical history	Age, gender, hormonal status, native language, history of metabolic disease	Age, gender	Age, gender, plant, years on job	Age, height, skin temperature, dominant index finger circumference	Age, gender, race, cigarettes, income, education, BMI	Age, gender, year of operation
Investigator blinded	Y	NR	NR	Y	NR	No	No
Repetition	Combined	Combined	Combined	Repetition: 5.5 *p*<0.05	NS	ò	2.7 (1.3-5.4)
Force	Combined	Combined	Combined	Combined	Y, Sig. combined	ò	ò
Extreme posture	ò	ò	Combined	Ulnar deviation and pinching, elevated but NS	Combined (pinch grip)	Bending/twisting of the wrist: 5.9 (3.4-10.2)	ò
Vibration	ò	ò	ò	5.3 (no confidence limits)	ò	Vibration: 1.85 (1.2-2.8)	Vibrating tool use 3.3 (1.6-6.8)
Risk factors (combined)	NCS: 6.7 (0.8-52.9) Super-market workers, high vs. low exposure symptoms: 8.3 (2.6-26.4)	Force, repetition, posture: 2.7 (1.2-7.6)	Workers vs. applicants: females, right hand: 2.86 (1.1-7.9); males, right hand: 1.87 (0.6-9.8)	High force/high repetition vs. low force/low repetition: 15.5 (1.7-142.0)	Y, Sig. median sensory amplitudes Sig. smaller (*p* < 0.01) and latencies longer (*p*<0.05) with exposure to high pinch grip forces	ò	ò

See footnotes at end of table. (Continued)

Appendix C Table C-5a. Summary table for evaluating work-related carpal tunnel syndrome (CTS)

Components of study	Osorio 1994	Punnett 1985	Schottland 1991	Silverstein 1987	Stetson 1993	Tanaka (*In Press*)	Weislander 1989
Duration of employment	Y	NS	ŏ	0.9 $p>0.09$	ŏ	ŏ	ŏ
Physical workload	Y	ŏ	ŏ	ŏ	ŏ	ŏ	Loads on wrist 1.8 (1.0-3.5)
Psychosocial factors	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
Individual/other factors considered	ŏ	ŏ	ŏ	ŏ	ŏ	Female gender: 2.4 (1.6-3.8); BMI $25: 2.1 (1.4-3.1); white race: 4.2 (1.9-15.6) Cigarettes: 1.6 (1-2.5); annual income $$20,000: 1.5 (1-2.4)	ŏ
Dose/response	Y, Sig.	ŏ	ŏ	Y, Sig.	ŏ	ŏ	ŏ

ŏ Not studied
BMI Body Mass Index
CS Cross-sectional
CTS Carpal tunnel syndrome
EMG Electromyography
F Force
hrs Hours
NCS Nerve conduction studies
NR Not reported
NS Not statistically significant
PE Physical examination
R Repetition
Sig. Statistically significant
S Symptoms
Y Considered (yes)

See footnotes at end of table. (Continued)

Appendix C Table C-5b. Summary table for evaluating work-related hand/wrist tendinitis

Components of study	Amano 1988	Armstrong 1987a	Byström 1995	Kuorinka 1979	Kurppa 1991	Luopajärvi 1979	McCormack 1990	Roto 1984
Study type	CS	CS	CS	CS	Cohort	CS	CS	CS
Participation rate $70%	NR	Y	Y	Y	Y	Y	Y	Y
Outcome	S and PE	S and PE	S and PE	S and PE	S and PE	S and PE	S and PE	S and PE
Exposure	Job titles or self-reports	Observation, measurements, video analysis, EMG	Questionnaire, observation, measurements, videotape analysis, EMG	Records, observation, measurements, videotape analysis	Observation, measurements, video analysis. Reader referred to methods found in previous publications	Observation, measurements, video analysis	Observation, job category	Job title
Covariates considered	Age, gender	Age, gender, years on job, and industrial plant	Age, gender, psychosocial factors (addressed by Fransson-Hall et al. 1995)	Age, gender, body mass index, "muscle-tendon" syndrome	Age, gender	Gender (only females in study groups), age, hobbies, housework, medical conditions	Race, age, gender	Rheumatoid arthritis
Investigators blinded	NR	Y	No	NR	NR No=occupation of subjects	Y	NR	Y=occupation meat processing No=construction foremen (referent)
Repetition	Combined	Combined	Combined	Combined	Combined	Combined	Combined	Combined
Force	Combined	Combined	Combined	Combined	Combined	Combined	Combined	Combined
Extreme posture	Combined	Significant differences between males and females	Combined	Combined	Combined	Combined	Combined	Õ
Vibration	Õ	Õ	Õ	Õ	Õ	Õ	Õ	Õ

See footnotes at end of table (Continued)

Appendix C Table C-5b. Summary table for evaluating work-related hand/wrist tendinitis

Components of study	Amano 1988	Armstrong 1987a	Byström 1995	Kuorinka 1979	Kurppa 1991	Luopajärvi 1979	McCormack 1990	Roto 1984
Risk factors (combined)	Right index finger flexor: 3.67 (1.85-7.27) Left index finger flexor: 6.17 (2.72-13.97)	Comparison between low R/low F and high R/high F: 4.8 (0.6-39.7) 5.5 (0.7-46.3) 17.0 (2.3-126.2)	De Quervain's tendinitis among among auto assembly workers vs. general population: 2.5 (1.00-6.23)	Scissor makers vs. shop assistants: 1.38 (0.76-2.51)	Meat cutter compared to office workers: risk ratio: 14.0 (5.7-34.4); Meat packers compared to office workers: risk ratio: 38.5 (11.7-56.1); sausage makers compared to office workers: risk ratio: 25.6 (19.2-77.5)	Assembly line workers vs. shop assistants: 4.13 (2.63-6.49)	Textile workers compared to non-office workers: 3.0 (1.4-6.4) Overall group exposed: 1.75 (0.9-3.39)	Meat cutters vs. construction workers: 3.09 (1.43-6.67)
Physical workload	Õ	Õ	Õ	Õ	Õ	Õ	Õ	Õ
Psychosocial factors	Õ		Analyzed by Fransson-Hall et al. 1995		Õ	Õ	Õ	Õ
Individual/ other factors considered	Õ	Õ	Õ	Pieces handled over the years: a nonsignificant trend with increasing number of pieces handled	Õ	NS for age, hobbies, or housework	Female gender significant for tendinitis at *p*=0.01; job category significant at *p*=0.001	Rheumatoid arthritis found not to be a confounder
Duration of employment	Õ	Õ	Õ	Õ	Õ	No association	Õ	Õ
Dose/response	Õ	With increasing combination of R and F	Õ	Õ	Õ	Õ	Õ	Õ

Õ Not studied.
CS Cross-sectional
EMG Electromyography.
F Force.
HAVS Hand-arm vibration syndrome
NR Not reported.
NS Not statistically significant.
PE Physical examination.
R Repetition.
S Symptoms.
Y Considered (yes).

Appendix C Table 5c. Summary table for evaluating hand-arm vibration syndrome

Components of study	Bovenzi 1988	Bovenzi 1994	Bovenzi 1995	Brubaker 1983	Brubaker 1987	Dimberg 1991	Kivekäs 1994	Koskimies 1992	Letz 1992	McKenna 1993
Study type	CS	CS	CS	CS	Cohort	CS	Cohort	Cohort	CS	CS
Participation rate $70%	NR	Y	Y	Y	N	Y	Y	Y	Y	NR
Outcome	S and PE; cold provocatio n	S and PE	S and PE; cold provocation	S and PE; cold provocatio n	S and PE; cold provocatio n	S	S and PE	S and PE	S	S and PE; cold provocati on
Exposure	Observatio n; measurem ents of the tool	Observatio n, interview, measurem ents of the tool	Questionnair e, observation, measureme nts of the tool	Question-naire data	Observati on; measure ments of the tool	Questionn aire	Questionna ire	Measureme nt of the tools	Questionnai re, measureme nts of the tool used from previous studies	Question naire
Covariates considered	ô	Age, smoking, alcohol consumpti on, upper limb injuries; leisure activities, systemic diseases	Age, smoking, drinking habits, cardiovascul ar, neurologic, previous musculoskel etal injuries, use of medicines	Smoking, age, height, weight	Age, gender, psychoso cial scales	ô	Age	ô	Age, race, smoking, alcohol, medical conditions	Age, smoking, only males studied, those with injury to the neck, upper limbs excluded.
Investigators blinded	NR	N	Y	NR	NR	NR	Y	NR	No	N
Repetition	ô	ô	ô	ô	ô	ô	ô	ô	ô	ô
Force	ô	ô	ô	ô	ô	ô	ô	ô	ô	ô
Extreme posture	ô	ô	ô	ô	ô		ô	ô	ô	ô

See footnotes at end of table (Continued)

Appendix C Table 5c. Summary table for evaluating hand-arm vibration syndrome

Components of study	Bovenzi 1988	Bovenzi 1994	Bovenzi 1995	Brubaker 1983	Brubaker 1987	Dimberg 1991	Kivekäs 1994	Koskimies 1992	Letz 1992	McKenna 1993
Vibration	Stone drillers and cutters vs. quarry and mill workers: 6.06 (2.0-19.6)	Stone workers vs. polishers and machine operators: 9.33 (4.9-17.8)	Forestry workers and 2.6% in ship-yard referents: OR = 11.8 (4.5-31.1) For workers only using antivibration saws: OR = 6.2 (2.3-17.1) For those using non-antivibration saws: OR = 32.3 (11.2-93)	NR	15% of fellers reported new symptoms of VWF from 1979 to 1985; 28% increase in prevalence of VWF in workers using antivibration chain-saws	Vibrating tool use sig. Correlated with HAVS symptom prevalance	Lumberjackes vs. referents: for 1978: 3.4, (1.7-6.9) Cumulative incidence HAVs (7-years) 14.7% vs. 2.3%: 6.5 (2.4-17.5)	Decrease in prevalence in forest workers from 1972 to 1990, attributed to reduction in weight of saws, increase in vibration frequency, reduction in acceleration	Full-time vibration workers vs. referents: 5.0 (2.1-12.1) Full-time vibration workers vs. Controls: 40.6 (11-177)	Riveters vs. referents: 24 (3.1-510)
Risk factors (combined)	õ	õ	õ	õ	õ	õ	õ	õ	õ	õ
Physical workload	õ	õ	õ	õ	õ	õ	õ	õ	õ	õ
Psychosocial factors	õ	õ	õ	õ	õ	õ	õ	õ	õ	õ
Individual/ other factors considered	õ	See "Covariates considered" above	See "Covariates considered" above	Age significantly different between cases and controls, height and weight were not.	õ	Vibrating tool use significantly correlated with HAVS symptoms prevalence	õ	õ	Smoking Sig.	õ
Duration of employment	õ	õ	õ	õ	õ	õ	No differece in lumberjacks with <15 years of exposure, but then increased with duration of exposure	õ	õ	õ
Dose/response	õ	õ	Y, between increasing vibration exposure and "vibration white finger"	õ	õ		Increased HAVS with duration of exposure	õ	Sig. for reported exposure to vibratory tools in workers with <17,000 hours of exposure	õ

See footnotes at end of table. (Continued)

Appendix C Table 5c. Summary table for evaluating hand-arm vibration syndrome

Components of study	Mirbod 1992a, 1994	Mirbod 1992b	Miyashita 1992	Musson 1989	Nagata 1993	Nilsson 1989	Saito 1987	Shinev 1992	Starck 1990	Virokannas 1995
Study type	CS	CS	CS	CS	CS	CS	Cohort	CS	CS	CS
Participation rate $70%	NR	NR	NR	N	NR	Y for platers; NR for office workers	N	NR	NR	NR
Outcome	S	S and PE	S	S	S and PE	S and PE	S and PE	S and PE	S	S and PE
Exposure	Questionnaire; interviews, measurements of the workers and the tools	Questionnaire; measurements of the workers and the tools	Job Title	Postal questionnaire, measurement of representative tools	Based on years of exposure since employment	Questionnaire, measurement of tool, exposure time	Questionnaire	Measurement of tool	Measurement of tools	Interview
Covariates considered	Age	ô	ô	Age, height, weight, smoking, time pressure, working posture	Age	Age	Follow-up of cohort	Age, cigarette smoking, industry, education VDT training	N	Age, duration of employment
Investigators blinded	NR	N	N	NR	N	NR	NR	NR	N	NR
Repetition	ô	ô	ô	ô	ô	ô	ô	ô	ô	ô
Force	ô	ô	ô	ô	ô	ô	ô	ô	ô	ô
Extreme posture	ô	ô	ô	ô	ô	ô	ô	ô	ô	ô
Vibration	Male chain saw operators vs. referents: 3.77 (2.1-6.8)	Symptom severity positively correlated with exposure duration	Male Construction workers compared to male office workers: 0.5 (0.1-11.8)	Exposure duration not related to HAVS symptoms	For >20 years vibration exposure: 7.1 (2.5-19.9)	Office workers with no vibration exposure to former exposure: 14 (5-38) Office workers with no exposure: 85 (15-486)	NR	Percussive vibration had a greater effect on muscle and bone pathology than constant high-frequency vibration	High prevalence of HAVS among workers using vibrating tools	NR

See footnotes at end of table (Continued)

Appendix C Table 5c. Summary table for evaluating hand-arm vibration syndrome

Components of study	Mirbod 1992a, 1994	Mirbod 1992b	Miyashita 1992	Musson 1989	Nagata 1993	Nilsson 1989	Saito 1987	Shinev 1992	Starck 1990	Virokannas 1995
Risk factors (combined)	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
Physical workload	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
Psychosocial factors	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
Individual/ other factors considered	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	Age Sig. Correlated to recovery rates from 1978 to 1983	ŏ	Poor correlation between vibration exposure and HAVS when tools were highly impulsive	ŏ
Duration of employment	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
Dose/response	ŏ	HAVS symptom severity positively correlated with exposure duration	ŏ	ŏ	ŏ	OR increased by 11% for each year of exposure	ŏ	ŏ	ŏ	ŏ

ŏ Not studied.
CS Cross-sectional.
CTS Carpal tunnel syndrome.
EMG Electromyography.
F Force.
Hrs Hours.
NCS Nerve conduction studies.
NR Not reported.
NS Not statistically significant.
OR Odds ratio.
PE Physical examination.
R Repetition.
S Symptoms.
Sig Statistically significant.
VPT Vibration perception threshold.
Y considered (yes).

Appendix C Table C-6. Summary table for evaluating back musculoskeletal disorders

Components of study	Åstrand 1987, 1988	Bergenudd 1988	Bigos 1991b	Bongers 1988	Bongers 1990	Boshuizen 1990a, 1990b
Study type	1987: CS; 1988: Cohort	Cohort	Cohort	Retrospective cohort	CS	CS Cohort
Participation rate $ 70%	Y	N	N	Y	Y	Y
Outcome	S and PE	S	S	Physical exam from disability records	S	CS: S Cohort: records
Exposure	Questionnaire	Questionnaire	Questionnaire; For jobs with >19 workers: job analysis	Job title and records; vibration measurements obtained but not used	Questionnaire; vibration measurements	Questionnaire; vibration measurements
Covariates considered	Education level, psychosocial factors (including neuroticism)	Years of education, psychosocial factors	Medical history, previous episodes of back pain, "individual" factors, psychosocial factors (from MMPI)	Nationality, shift-work, age, and calendar time	Age, height, weight, climate, bending forward, twisted postures and feeling tense at work	Duration of exposure, age, height, smoking, awkward postures, and mental workload
Investigators blinded	N	NR	NR	NR	NR	NR
Heavy physical work	Combined	Workers in moderate and heavy physical demand work groups vs. light physical demand group: 1.8 (1.2-2.7)	No association	õ	õ	õ
Lifting and forceful movements	Combined	õ	õ	õ	õ	õ

See footnotes at end of table. (Continued)

Appendix C Table C-6. Summary table for evaluating back musculoskeletal disorders

Components of study	Åstrand 1987, 1988	Bergenudd 1988	Bigos 1991b	Bongers 1988	Bongers 1990	Boshuizen 1990a, 1990b
Awkward postures	ō	ō	ō	ō	ō	ō
Whole body vibration	ō	ō	ō	All back disorders: 1.32 (0.84-2.1); Intervertebral disc disorders: 2.00 (1.1-3.7); Disc degeneration by years of exposure: 5.7 (for highest exposure category)	LBP in exposed vs. referents: 9.0 (4.9-16.4), Sciatica: 3.3 (1.3-8.5); LBP by total vibration dose: ORs=12.0, 5.6, 6.6, 39.5 LBP by hours of flight time per day: 5.6, 10.3, 14.4;	LBP by vibration dose category: ORs=19.1, 29.4, 28.0, 38.1; By vibration dose: ORs=1.80, 1.78, 2.8; years of exposure: 3.6 (1.2-11)
Static work postures	ō	ō	ō	ō	ō	ō
Risk factors (combined)	Mill workers vs. clerical workers: 2.3 *p*=0.002	ō	ō	ō	ō	ō
Psychosocial factors	Neuroticism and back pain: 2.8 (1.4-5.4)	Those with back pain less satisfied with working conditions; no difference in social support	MMPI: tend towards somatic complaint or denial of emotional distress and reporting injury: 1.37 (1.1-1.7)	ō	ō	ō
Individual/other factors considered	ō	ō	Does not enjoy job tasks and reporting injury: 1.7 (1.3-2.2)	ō	ō	ō
Duration of employment	Duration of employment and back pain: 1.2 (1.0-1.5)	ō	Prior back pain and reporting injury: 1.7 (1.2-2.5)	ō	ō	ō
Dose/response	ō	ō	ō	ō	ō	ō

See footnotes at end of table.

(Continued)

Appendix C Table C-6. Summary table for evaluating back musculoskeletal disorders

Components of study	Boshuizen 1992	Bovenzi 1992	Bovenzi 1994	Burdorf 1990	Burdorf 1991	Burdorf 1993
Study type	CS	CS mail survey	CS	CS	CS	CS
Participation rate $70%	Y	Y	Y	N	Y	Y
Outcome	S	S	S	S	S	S
Exposure	Questionnaire; vibration measurements	Questionnaire, measurement of WBV	Questionnaire, measurement of vibration levels	Questionnaire, job title, and expert knowledge	Questionnaire, task analysis and OWAS	Questionnaire, measurements of WBV, Postures assessed with OWAS
Covariates considered	Mental stress, years lifting >10 kg and twisting spine, height, smoking, looking backwards, hours sitting	Age, awkward posture, duration of exposure, BMI, mental load, education, smoking, sport activities and previous jobs at risk for back pain	Age, BMI, education, sport activity, car driving, marital status, mental stress, climatic conditions, back trauma, and postural load (or total vibration dose)	Age, height, and weight	Age, height, and weight	Age, history of heavy work, exposure to WBV, work requiring prolonged sitting, cold, drafts, working under severe pressure, job satisfaction, height, weight, duration of total employment
Investigators blinded	NR	NR	NR	NR	N	NR
Heavy physical work	ô	ô	ô	Heavy work: 4.02 (0.76-21.2)	Heavy physical work sig in univariate but not multivariate model	ô
Lifting and forceful movements	ô	ô	ô	Frequent lifting: 5.21 (1.10-25.5)	No association	ô
Awkward postures	ô	ô	ô	ô	Postural Index and LBP: 1.23 *p*=0.04	ô
Whole body vibration	Total vibration dose and back pain: 0.99 (0.85-1.2); In younger workers: vibration in past 5 years and lumbago, 3.1 (1.2-7.9)	Low back: Previous 12 months prevalence of LBP, bus drivers vs. controls: 2.57 (1.5-4.4) Multivariate: LBP symptoms in previous. 12 months: and total vibration dose: OR's= 1.67, 3.46, 2.63	LBP in the past year: OR=2.39 (1.6-3.7) Postural load category: OR=4.56 (2.6-8.0) (for the highest exposure category)	WBV: 0.66 (0.14-3.1)	WBV and LBP, 3.1 *p*=0.001	Combined

See footnotes at end of table.

(Continued)

Appendix C Table C-6. Summary table for evaluating back musculoskeletal disorders

Components of study	Boshuizen 1992	Bovenzi 1992	Bovenzi 1994	Burdorf 1990	Burdorf 1991	Burdorf 1993
Static work postures	ŏ	ŏ	ŏ	For univariate analysis: sedentary postures in crance operators: 0.49 (0.11-2.2)	Posture index based on time spent in a working posture with the back in a bent and/or twisted position: 1.23 *p*=0.04	ŏ
Risk factors (combined)	ŏ	ŏ	ŏ	Job title: 3.6 (1.2-10.6)	ŏ	Crane operators vs. office workers: 3.29 (1.52-7.12) Straddle-carrier drivers vs. office workers: 2.5 (1.2-5.4)
Psychosocial factors	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
Individual/other factors considered	ŏ	ŏ	ŏ	ŏ	Postural load, bending, and twisting are causal factors. Standing and sitting are not found to be risk factors.	ŏ
Duration of employment	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
Dose/response	ŏ	Univariate analysis, total vibration dose: lifetime LBP symptoms: 4.05 (1.8-9.3); 12 months LBP symptoms: 3.25 (1.5-7.0).	Dose/response of combined effects to total vibration dose and postural load, highest combination of categories: 4.58.	ŏ	ŏ	ŏ

See footnotes at end of table. (Continued)

Appendix C Table C-6. Summary table for evaluating back musculoskeletal disorders

Components of study	Chaffin 1973	Clemmer 1991	Deyo 1989	Heliövaara 1991	Hildebrandt 1995	Hildebrandt 1996
Study type	Cohort	CS	CS	CS	CS	CS
Participation rate $70%	NR	Y	NHANES-II data	Y	Y	Y, but varied from 60% to 80% by department
Outcome	S	Injury report	Data base (LBP)	S and PE	S	S
Exposure	Observation and measurement	Job title	Data base (smoking, obesity, personal characteristics)	Questionnaire	Questionnaire	Questionnaire
Covariates considered	Age, weight, stature, number of prior back episodes, isometric lifting strengths	Age, job, length of employment	Age, gender, smoking, obesity, exercise level, employment status	Age and gender	Age and gender	Age
Investigators blinded	NR	NR	N	N	N	N
Heavy physical work	ô	Roustabouts vs. control room operator: 4.3 (no confidence limits)	ô	Combined ORs=1.9, 2.5	Heavy physical work vs. sedentary work: 1.2, $p<0.05$	Nonsedentary steel workers vs. referents: No association
Lifting and forceful movements	Approx. 5	ô	ô	ô	ô	ô
Awkward postures	ô	ô	ô	ô	ô	ô
Whole body vibration	ô	ô	ô	ô	ô	ô
Static work postures	ô	ô	ô	ô	ô	ô

See footnotes at end of table. (Continued)

Appendix C Table C-6. Summary table for evaluating back musculoskeletal disorders

Components of study	Chaffin 1973	Clemmer 1991	Deyo 1989	Heliövaara 1991	Hildebrandt 1995	Hildebrandt 1996
Risk factors (combined)	Lifting of loads in positions which create a Lifting Strength Rating $ was considered potentially hazardous to some people	Job was best predictor of lost time.	ð	LBP and physical stress: 2.5 (1.4-4.7)	ð	NS, Reference group had high exposure to adverse working conditions
Psychosocial factors	ð	ð	Ever smoked vs. LBP: 1.13, Sig. 50 pack years vs. LBP: 1.47, Sig. Body mass index vs. LBP: 1.70, Sig.	Stress load index: 2.4 (1.7-3.5)	ð	ð
Individual/ other factors considered	Age, weight, and stature did not correlate with increased incidence of LBP	75% of back strains precipitated by pushing, pulling, or lifting.	ð	Body mass index, alcohol , work-related driving, parity, height not associated with LBP. Smoking sig in both older and younger males, but only older females. Prior traumatic injury increased risk of LBP: 2.5 (1.9-3.3); and sciatica: 2.6 (2.1-3.1)	Rates of LBP: construction: 35%; truckers: 31%; plumbers: 31%	ð
Duration of employment	ð	ð	Smoking risk increases steadily with cumulative exposure and with degree of maximal daily exposure. There is a steady increase in LBP with increasing obesity.	ð	ð	ð
Dose-response	ð	ð	ð	ð	ð	ð

See footnotes at end of table.

(Continued)

Appendix C Table C-6. Summary table for evaluating back musculoskeletal disorders

Components of study	Holmström 1992	Huang 1988	Johanning 1991	Johansson 1994	Kelsey 1975b	Kelsey 1984	Knibbe 1996
Study type	CS	CS	CS mail survey	CS	Case control	Case control	CS
Participation rate $70%	Y	Y	N	Y	Y	Y	Y
Outcome	S; (A sample had PE for purposes of validation)	S	S	S	Medical records: S and PE required	S and PE	S
Exposure	Postal questionnaire	Ergonomic assessment including NLE	Job title, measured WBV in exposed group but results not presented	Questionnaire	Questionnaire	Interview and questionnaire	Questionnaire
Covariates considered	Daily traveling time, leisure activity, height and weight	Age, height, length of employment, olecranon height, weight	Age, gender, job title, employment duration	Age and gender. Non work-related S could have an effect masking result, if not identified.	Age, gender	Age, gender, medical service	Age
Investigators blinded	Y	NR	NR	NR	NR	NR	N
Heavy physical work	ō	ō	ō	Blue collar workers vs. white collar workers: no association	ō	ō	ō
Lifting and forceful movements	One year prevalence of BP and manual materials handling: 1.3 (1.2-1.4); Lifting frequency: >1 per 5 min vs.<1 per 5 min: 1.12, *p*<0.001	The workers in the center with higher rates had greater lifting compared to the referent center: no risk estimate	ō	No association	Lifting vs. herniation: 0.94, *p*=0.10	Lifting >25 lb or more, without twisting the body: 3.8 (0.7-20.1)	Registered nurses vs nursing aides: Unadjusted OR=1.2, *p*=0.04; after adjusting for hr worked, aides had higher rate: 1.3
Awkward postures	Stooping and kneeling with severe LBP compared to no stooping: 2.6; in comparison to no kneeling: 3.5	More awkward postures found in center A than B, *p*=0.05.	ō	Extreme work postures sig associated with outcome in blue collar workers	Combined	Twisting without lifting: 3.0 (0.9-10.2)	ō
Whole body vibration	ō	ō	WBV and sciatica pain: 3.9 (1.7-8.6)	ō	Combined	ō	ō

See footnotes at end of table. (Continued)

Appendix C Table C-6. Summary table for evaluating back musculoskeletal disorders

Components of study	Holmström 1992	Huang 1988	Johanning 1991	Johansson 1994	Kelsey 1975b	Kelsey 1984	Knibbe 1996
Static work postures	No association	ô	ô	ô	Sedentary work and disc herniation for workers 35 years and older: 2.4, *p*=0.01; for those < 35 years, 0.81	ô	ô
Risk factors (combined)	ô	ô	ô	ô	Time sitting, >35 years old: 2.4 *p*=0.01; More than half time driving vs. herniation: 2.75, *p*=0.02; Truck driver vs. herniation: 4.67, Chi-sq.=5.88, *p*=0.02	Lifting >25 lb >5 times per day, and twisting the body half the time: 3.1 (1.3-7.5); Simultaneous lifting and twisting with straight knees: 6.1 (1.3-27.9)	Physically demanding work vs. lifetime LBP, prevalence: 87%; 1-year LBP, prevalence: 67%; 1-week LBP, prevalence: 21%; Prevalence of sick leave due to back pain in previous 3 months: 9.7%
Psychosocial factors	High stress and LBP: 1.6 (1.4-1.8); high anxiety: 1.3 (1.1-1.4).	ô	Blue collar workers were less satisfied with "influence on and control of work, supervisor climate, stimulus from work itself, and relations with fellow workers	In blue-collar workers, 10 of 15 psychosocial job factors sig; in white-collar workers, none of the five psychosocial factors sig	ô	ô	ô
Individual/other factors considered	Severe LBP related to smoking; construction tasks such as brick laying, carpentry, etc. did not affect LBP.	ô	Gastrointestinal problems: subway train operators vs. referents: 1.6 (1.1-2.5)	ô	ô	Carrying >11.3 kg, 5-25 per day: 2.1 (1.0-4.3) Carrying >11.3 kg , >25/day: 2.7 (1.2-5.8)	ô
Duration of employment	ô	ô	ô	ô	ô	ô	ô
Dose/response	ô	ô	ô	ô	ô	ô	ô

See footnotes at end of table. (Continued)

Appendix C Table C-6. Summary table for evaluating back musculoskeletal disorders

Components of study	Leigh 1989	Liles 1984	Magnusson 1996	Magora 1972, 1973	Marras 1993, 1995	Masset 1994	Partridge 1968
Study type	CS	Cohort	CS	CS	CS	CS	CS
Participation rate $70%	Y	NR	NR	NR	NR	Y	Y
Outcome	S	Records	S	S	Records review	S	S and PE
Exposure	Questionnaire (job title)	Observation, use of records	Questionnaire, vibration measurements	Observation, interview, questionnaire	Observation, measurements	Interview, self-reports	Questionnaire, job title
Covariates considered	Gender, race, obesity, height, and repetitious work	ô	ô	ô	ô	Gender (males only), age (all participants younger than 40). General health status, social, demographic, psychologic factors	Age
Investigators blinded	NR	N	NR	NR	NR	NR	N
Heavy physical work	Self reporting: "Job requires a lot of physical effort": 1.5 (1.0-2.2)	ô	ô	ô	ô	No association	Combined
Lifting and forceful movements	ô	Injury rate for highest job severity index category vs lowest : 4.5	Heavy lifting: 1.86 (1.2-2.8) Frequent lifting: 1.55 (1.01-2.39)	1973: Sudden maximal efforts and LBP: 1.65 (1.3-2.1)	Combined	Heavy efforts of the shoulder, 1.62, *p*<0.01	ô
Awkward postures	ô	ô	ô	No association: highest rate of back pain found in the "rarely/never bend" category	ô	Univariate analysis showed trunk torsions associated with LBP in steel workers; no association seen in multivariate	ô
Whole body vibration	ô	ô	Bus and truck drivers compared to referents: 1.8 (1.2-2.8)	Bus drivers compared to bankers: 1.2 (0.8-1.7)	ô	Vehicle driving: 1.2 (*p*<0.001)	ô

See footnotes at end of table.

(Continued)

Appendix C Table C-6. Summary table for evaluating back musculoskeletal disorders

Components of study	Leigh 1989	Liles 1984	Magnusson 1996	Magora 1972, 1973	Marras 1993, 1995	Masset 1994	Partridge 1968
Static work postures	ð	ð	ð	No association	ð	Seated posture: 1.5, *p*<0.09	ð
Risk factors (combined)	High vs. low physical demands: 1.68 (1.05-2.90)	ð	Driving: 1.79 (1.16-2.75) Vibration plus frequent lifting: 2.1 (0.8-5.7) Vibration plus heavy lifting: 2.06 (1.3-3.3)	Sudden maximal physical efforts; prolonged sitting or standing, inability to sit during the working day, and poor lifting technique related to LBP	Max. load moment, max. lateral velocity, ave. twisting velocity, lifting frequency, and max. sagital trunk angle related to high-risk LBP groups: 10.7(4.9-23.6)	ð	Rheumatic S: dockers vs. civil servants: 1.2 (0.98-1.64); LBP: dockers vs. civil servants: NS
Psychosocial factors	ð	ð	ð	ð	ð	Negative perception of the work environment: NS.	ð
Individual/other factors considered	Smoker vs. nonsmoker and LBP: 1.48 (1.0-2.19)	ð	ð	ð	Maximum load moment: 73.65 Nm vs. 23.64 Nm: 5.17, (3.19-8.38); Sagittal mean velocity: 11.74 degrees/sec. vs. 6.55 degrees/ sec: 3.33 (2.17-5.11); Max. weight: 104 N vs. 37 N: 3.17 (2.19-4.58)	Physical work load (no objective measurement) and repetition were NS. Final logistic model included "whole set of variables from general health status, social, demographic, and psychologic characteristics."	ð
Duration of employment	ð	ð	ð	ð	ð	ð	ð
Dose/response	ð	ð	ð	ð	ð	ð	ð

See footnotes at end of table. (Continued)

Appendix C Table C-6. Summary table for evaluating back musculoskeletal disorders

Components of study	Punnett 1991	Riihimäki 1989a	Riihimäki 1989b	Riihimäki 1994; Pietri-Taleb 1995	Ryden 1989	Schibye 1995	Skov 1996
Study type	Case referent (retrospective)	CS mail survey	CS	Prospective	Case control	Cohort	CS
Participation rate $70%	Y	Y	Y	Y	Y	Y	N
Outcome	S and PE	S	X-ray confirmed	S	Records	S	S
Exposure	Observation and measurements, Videotape analysis	Job title and questionnaire	Questionnaire and job title	Postal questionnaire	Work injury reports and self-reports	Questionnaire	Questionnaire, self-reports
Covariates considered	Gender, age, length of employment, recreational activity, medical history, and maximum weight lifted in study job	Age, previous back accidents, awkward postures at work, and annual car driving	Age, self-reported back accidents, body mass index, height, and smoking	Age, gender (only males were studied, previous history of back accidents, mental distress, general state of health, smoking, lifestyle factors, education	Age	Subjects served as their own controls	Age, gender, height, weight, smoking, work-related psychosocial variables, lifting, leisure time sports activities
Investigators blinded	Y	NR	Y	NR	NR	NR	NR
Heavy physical work	ŏ	Combined	ŏ	ŏ	Combined	ŏ	ŏ
Lifting and forceful movements	Lift 44.5 N: 2.16 (1.0-4.7)	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
Awkward postures	Time in non-neutral postures, mild or severe bending: 8.09 (1.4-44)	Sciatica and twisted or bent postures: 1.5 (1.2-1.9)	ŏ	Association found between twisted and bent postures with sciatica in univariate, but not multivariate analysis	ŏ	ŏ	ŏ

See footnotes at end of table. (Continued)

Appendix C Table C-6. Summary table for evaluating back musculoskeletal disorders

Components of study	Punnett 1991	Riihimäki 1989a	Riihimäki 1989b	Riihimäki 1994; Pietri-Taleb 1995	Ryden 1989	Schibye 1995	Skov 1996
Whole body vibration	õ	Longshoremen and earthmovers compared to referents: 1.3 (1.1-1.7)	õ	No association	õ	õ	In Danish salespeople, the annual driving distance for highest category: 2.8 (1.5-5.1)
Static work postures	õ	õ	õ	õ	õ	õ	Sedentary work (% of worktime): 2.45 (1.2-4.9)
Risk factors (combined)	Time in non-neutral posture: 8.09 (1.5-44.0)	Sciatic pain and machine operators: 1.3 (1.1-1.7) Sciatic pain and carpenters: 1.0 (0.8-1.3)	Concrete vs. painting work and disc space narrowing: 1.8 (1.2-2.5); Spondylophytes: 1.6 (1.2-2.3)	Machine operators vs. office workers: 1.4 (0.99-1.87); carpenters vs. office workers: 1.5 (1.1-2.1)	Job title or shifts requiring heaviest physical efforts: 2.2 (1.28-3.89)	No sig differences in back pain in garment workers versus other employment group upon follow-up	Annual driving distance: 2.79 (1.5-5.1)
Psychosocial factors	õ	õ	õ	Monotonous work, problems with co-workers or supervisors, and high paced work were NS.	õ	õ	õ
Individual / other factors considered	Age: 0.96 (0.09-1.0) back injury: 2.37 (1.3-4.3)	õ	Age and disc space narrowing: 6.5 (1.7-26.0) Spondylophytes: 14.9 (2.3-95.0)	Physical exercise >1 time per week vs. 1 time per week: 1.26 (1.0-1.6) Smokers vs. non-smokers: 1.29 (0.98-1.7) Severe back pain and later sciatica: 4.5 (2.7-7.6)	Previous back injury: 2.13 (1.07-4.24); Working day shift: 2.23 (1.28-3.89); Self-reported LBP: 1.25 (1.25-4.12); Self-reported slipped disc: 6.20 (2.64-14.57)	Of 82 workers with another job in 1991, 20% reported MSDs a s the reason for change.	õ
Duration of employment	Analysis controlled for length of employment.	õ	õ	õ	õ	Sig	õ
Dose/respon se	A strong trend found for increasing length of exposure and risk of back disorders to both mild and severe trunk flexion.	Dose/response is observed for twisted or bent postures (see above)	õ	õ	õ	õ	Dose/response is observed for annual driving and sedentary work (see above)

See footnotes at end of table. (Continued)

Appendix C Table C-6. Summary table for evaluating back musculoskeletal disorders

Components of study	Skovron 1994	Svensson 1989	Toroptsova 1995	Undeutsch 1982	Videman 1984	Videman 1990	Walsh 1989
Study type	CS	CS (retrospective)	CS	CS	CS	CS and lab study	CS
Participation rate $70%	Y	Y	Y	NR	Y	NR	Y
Outcome	S	S	S; then S and PE	S and PE (Clinical orthopaedic exam given to 134 of the 366 subjects)	S	X-ray confirmed	S
Exposure	Interview	Questionnaire	Interview	Interview and questionnaire	Postal questionnaire	Questionnaire, Reports from family members	Postal questionnaire
Covariates considered	Age and gender	Age, gender (only females studied), level of education, psychosocial factors, work breaks, demand on concentration	Analysis did not control for confounders	Age, height, weight, nationality, years of experience in transport work	Age, gender (only females studied), menstruation, pregnancy, exercise	Age, gender (only male cadavers used) physical exercise, heaviness of occupation	Age, year of onset of symptoms, gender
Investigators blinded	NR	NR	NR	NR	NR	NR	NR
Heavy physical work	ò	No association	ò	ò	Sig. difference in heavy occupational workload category among ages 20-29 year olds but not other age groups: 1.1	Heavy vs. mixed work: 2.8 (0.3-23.7) Heaviest work category: 12.1 (1.4-107)	ò
Lifting and forceful movements	ò	Lifetime incidence of LBP and Lifting: 1.2, *p*<0.01 found in univariate analysis but not in multivariate analysis	Frequent lifting and LBP: 1.43, *p*<0.05	Combined	No association - no sig difference between qualified nurses and nursing aides	ò	Lifting in jobs just prior to injury: 2.0 (1.1-3.7)
Awkward postures	ò	LBP and bending forward: 1.3, *p*<0.05 in univariate; not sig in multivariate analysis	Trunk flexion and LBP: 1.7 *p*<0.01	ò	ò	ò	ò

See footnotes at end of table. (Continued)

Appendix C Table C-6. Summary table for evaluating back musculoskeletal disorders

Components of study	Skovron 1994	Svensson 1989	Toroptsova 1995	Undeutsch 1982	Videman 1984	Videman 1990	Walsh 1989
Whole body vibration	ð	ð	No association	ð	Combined	ð	Driving on job held prior to symptoms in males: 1.7 (1.0-2.9)
Static work postures	ð	"Standing" associated with LBP: 1.3 in univariate analysis, not sig in multivariate	No association	ð	ð	Sedentary work and disc degeneration: 24.6 (1.5-409)	Sitting and LBP: females: 1.7 (1.1-2.6)
Risk factors (combined)	Occupation: NS	ð	ð	In workers with present S, they occurred most frequently while lifting loads and while in bended postures: no risk estimate	ð	Driving vs. Mixed work: 2.3 (0.8-6.2)	Driving and LBP: males: 1.7 (1.0-2.9)
Psychosocial factors	Work dissatisfaction: 2.4, *p*=0.02	LBP and worry and fatigue at end of work day: *p*<0.0001 Dissatisfaction with work tasks: *p*<0.05	ð	ð	ð	ð	ð
Individual / other factors considered	Female gender: 2.16, *p*=0.001; increasing age: 2.0, *p*=0.001	LBP and standing: *p*<0.01	NS for sitting, standing, walking, or repetitive work	Current back S positively correlated with height and age.	ð	ð	
Duration of employment	ð	ð	ð	Current back S positively correlated with length of experience in transport work.	ð	ð	ð
Dose/response	ð	ð	ð	ð	ð	ð	ð

ð Not studied.
ADL Activities of daily living.
CS Cross-sectional.
F Force.
Hrs Hours.
LBP Low-back disorders.
LBP Low-back pain.
LBS Low-back symptoms.
MMPI Minnesota Multiphasic Personality Inventory.
MS Musculoskeletal.
N No.
NHANES National Health and Nutrition Examination Survey.
NR Not reported.
NS Not statistically significant.
OWAS OVAKO working posture analysis system.
PE Physical examination.
R Repetition.
S Symptoms.
Sig. Statistically significant.
WBV Whole body vibration.
Y Considered (yes).