

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

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E-mail: pubstaf@cdc.gov

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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

Foreword	iii
Note to the Reader	v
Executive Summary	x
Acknowledgments	xvi

Chapter 1. Introduction 1-1

Purpose	1-1
Background	1-1
Scope and Magnitude of the Problem.	1-1
Cost	1-6
Defining Health Outcomes	1-7
Exposure Measurements	1-8
Information Retrieval	1-9
Selection of Studies	1-9
Methods for Analyzing or Synthesizing Studies	1-10
Criteria for Causality	1-11
Categories Used to Classify the Evidence of Work-Relatedness	1-13
Summary	1-14
Description of Tables, Figures, and Appendices	1-14

Chapter 2. Neck Musculoskeletal Disorders: Evidence for Work-Relatedness 2-1

Summary	2-1
Introduction	2-2
Repetition	2-3
Force	2-12
Posture	2-16
Vibration	2-21
Neck or Neck/Shoulder MSDs and the Role of Confounders	2-21
Conclusions	2-22
Tables and Figures	2-24

Chapter 3. Shoulder Musculoskeletal Disorders: Evidence for Work-Relatedness	3-1
Summary	3-1
Introduction	3-1
Repetition	3-2
Force	3-9
Posture	3-14
Vibration	3-23
Role of Confounders	3-25
Conclusions	3-25
Tables and Figures	3-27
Chapter 4. Elbow Musculoskeletal Disorders (Epicondylitis): Evidence for Work-Relatedness	4-1
Summary	4-1
Introduction	4-2
Repetition	4-2
Force	4-6
Posture	4-16
Epicondylitis and the Role of Confounders	4-17
Conclusions	4-18
Tables and Figures	4-20
Chapter 5. Hand/Wrist Musculoskeletal Disorders (Carpal Tunnel Syndrome, Hand/Wrist Tendinitis, and Hand-Arm Vibration Syndrome): Evidence for Work-Relatedness	5-1
Chapter 5a. Carpal Tunnel Syndrome	5a-1
Summary	5a-1
Introduction	5a-1
Outcome and Exposure Measures	5a-2
Repetition	5a-3
Force and CTS	5a-14
Posture and CTS	5a-22
Vibration and CTS	5a-25
Confounding and CTS	5a-27
Conclusions	5a-28
Tables and Figures	5a-29
Chapter 5b. Hand/Wrist Tendinitis	5b-1
Summary	5b-1

Introduction	5b-1
Repetition	5b-2
Force	5b-9
Posture	5b-13
Conclusions	5b-17
Tables and Figures	5b-18
Chapter 5c. Hand-Arm Vibration Syndrome	5c-1
Summary	5c-1
Introduction	5c-1
Evidence for the Work-Relatedness of HAVS	5c-2
Tables and Figures	5c-10
Chapter 6. Low-Back Musculoskeletal Disorders: Evidence for Work-Relatedness	6-1
Summary	6-1
Introduction	6-2
Heavy Physical Work	6-4
Lifting and Forceful Movements	6-13
Bending and Twisting (Awkward Postures)	6-21
Whole Body Vibration (WBV)	6-26
Static Work Postures	6-34
Role of Confounders	6-38
Tables and Figures	6-39
Chapter 7. Work-Related Musculoskeletal Disorders and Psychosocial Factors	7-1
Summary	7-1
Introduction	7-1
Psychosocial Pathways	7-2
Upper-Extremity Disorders (Neck, Shoulder, Elbow, Hand, and Wrist)	7-3
Back Disorders	7-7
Tables and Figures	7-11
References	R-1
Appendices	A-1
A. Epidemiologic Review	A-1
B. Individual Factors Associated with Work-Related Musculoskeletal Disorders (MSDs)	B-1
C. Summary Tables	C-1

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

- C **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.

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

- C **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 <i>Risk factor</i>	Strong evidence (+++)	Evidence (++)	Insufficient evidence (+/0)	Evidence of no effect (-)
Neck and Neck/shoulder				
<i>Repetition</i>		T		
<i>Force</i>		T		
<i>Posture</i>	T			
<i>Vibration</i>			T	
Shoulder				
<i>Posture</i>		T		
<i>Force</i>			T	
<i>Repetition</i>		T		
<i>Vibration</i>			T	
Elbow				
<i>Repetition</i>			T	
<i>Force</i>		T		
<i>Posture</i>			T	
<i>Combination</i>	T			
Hand/wrist				
Carpal tunnel syndrome				
<i>Repetition</i>		T		
<i>Force</i>		T		
<i>Posture</i>			T	
<i>Vibration</i>		T		
<i>Combination</i>	T			
Tendinitis				
<i>Repetition</i>		T		
<i>Force</i>		T		
<i>Posture</i>		T		
<i>Combination</i>	T			
Hand-arm vibration syndrome				
<i>Vibration</i>	T			
Back				
<i>Lifting/forceful movement</i>	T			
<i>Awkward posture</i>		T		
<i>Heavy physical work</i>		T		
<i>Whole body vibration</i>	T			
<i>Static work posture</i>			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	Rose Hagedorn	Marty Petersen
Vanessa Becks	William Halperin, M.D., Sc.D.	Donna Pfirman
Donna Biagini	Anne Hamilton	Linda Plybon
Jenise Brassell	Denise Hill	Faye Rice
Karen Brewer	Suzanne Hogan	Cindy Riddle
Carol Burnett	Hongwei Hsiao, Ph.D.	Kris Royer
Sue Cairelli	Lore Jackson	Walt Ruch
Dick Carlson	Laurel Jones	Steven Sauter, Ph.D.
Shirley Carr	Susan Kaelin	Lucy Schoolfield
Dave Case	Sandy Kasper	Mitch Singal, M.D.
Sharon Cheesman	Aileen Kiel	Paul Schulte
Alexander Cohen, Ph.D.	Diana Kleinwachter	Becky Spry
Marian Coleman	Nina Lalich	Anne Stirnkorb
Barb Cromer	Leslie MacDonald	Naomi Swanson, Ph.D.
Judy Curless	Charlene Maloney	Rodger Tatken
David Dankovic	Diane Manning	Allison Tepper, Ph.D.
John Diether	James McGlothlin, Ph.D.	Julie Tisdale
Clayton Doak	Patricia McGraw	Anne Votaw
Karen Dragon	Alma McLemore	David Votaw
Sue Feldmann	Judy Meese	Thomas Waters, Ph.D.
Jerry Flesch	Matthew Miller	Jane Weber
Larry Foster	Kathleen Mitchell	Joann Wess
Sean Gallagher	Vivian Morgan	Cindy Wheeler
Lytt Gardner, Ph.D.	Leela Murthy	Kellie Wilson
Pamela Graydon	Rick Niemeier	Ralph Zumwalde
Daniel Habes	Andrea Okun	

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.

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

C **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
		3			
House slippers (manufacturing)	3142		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 $\geq 70\%$. 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 epidemiologic 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 Musculoskeletal 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.