Ergonomics and Musculoskeletal Disorders

RESEARCH ON MANUAL MATERIALS HANDLING 1983-1996

Edited by
Waldemar Karwowski
Michael S. Wogalter
Patrick G. Dempsey

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RESEARCH ON MANUAL MATERIALS HANDLING, 1983-1996

Injuries associated with manual materials handling (MMH) represent the single largest source of losses in many industries, costing billions of dollars for workers' compensation, medical care, and lost wages. These losses explain why the research directed toward the prevention of MMH-related injuries in the industrial workplace has been one of the most active areas of the field of industrial ergonomics. This book contains 61 of the best papers (selected from 120 candidate papers) from 14 years of HFES Annual Meeting proceedings, one of the foremost sources of basic and applied research in this area.

About the Editors

Waldemar Karwowski is professor of industrial engineering and director of the Center for Industrial Ergonomics at the University of Louisville, Kentucky. He holds an M.S. (1978) in production engineering and management from the Technical University of Wroclaw, Poland, and a Ph.D. (1982) in industrial engineering from Texas Tech University. He is a Certified Professional Ergonomist. His research, teaching, and consulting activities focus on prevention of low-back injury and cumulative trauma disorders, biomechanics, workplace safety and task analysis, equipment design and evaluation, human and safety aspects of advanced manufacturing, and theoretical aspects of ergonomics. Karwowski is a Fellow of the Human Factors and Ergonomics Society, as well as a member of other professional associations. Karwowski is editor of *Human Factors and Ergonomics in Manufacturing,* co-editor of the *International Journal of Occupational Safety and Ergonomics,* and consulting editor of *Ergonomics.*

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ISBN 0-945289-09-X

9 780945 289098

ISBN 0-945289-09-X

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When citing work from this book, please refer to the **original** proceedings publication, as in the following example:

Gallagher, S., Hamrick. C. A., & Love, A.C. (1990). Biomechanical modeling of asymmetric lifting tasks in constrained lifting postures. In *Proceedings of the Human Factors Society 34th Annual Meeting* (pp. 702–706). Santa Monica, CA: Human Factors and Ergonomics Society.

(Note that in 1993, the Society's name changed to the Human Factors and Ergonomics Society.)

The following HFES proceedings are represented in this book:

1996, 40th Annual Meeting	1991, 35th Annual Meeting
1995, 39th Annual Meeting	1990, 34th Annual Meeting
1994, 38th Annual Meeting	1989, 33rd Annual Meeting
1993, 37th Annual Meeting	1988, 32nd Annual Meeting
1992, 36th Annual Meeting	1987, 31st Annual Meeting

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Library of Congress Cataloging-in-Publication Data

Ergonomics and musculoskeletal disorders : research on manual materials handling, 1983–1996 / edited by Waldemar Karwowski, Michael S. Wogalter, Patrick G. Dempsey.

p. cm.

Includes bibliographical references and index.

ISBN 0-945289-09 X (pbk.)

1. Lifting and carrying. 2. Human engineering. 3. Back--Wounds and injuries--Prevention. 4. Musculoskeletal system--Wounds and injuries--prevention. I. Karwowski, Waldemar, 1953– . II. Wogalter, Michael S., 1955– . III. Dempsey, Patrick G., 1967– .

T55.3.L5E74 1997

620.8'2--dc21 97-31460

CIP

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Note: The original proceedings year and page numbers are given for each paper in parentheses.

Preface

Injuries associated with manual materials handling (MMH) represent the single largest source of losses in many industries, including operations in the manufacturing, service, and distribution sectors. These problems have been researched for more than four decades to provide practitioners with solutions and interventions to stem the associated losses.

This volume contains a selection of the best MMH research that was presented at the annual meetings of the Human Factors and Ergonomics Society between 1983 and 1996. The compilation includes both basic and applied research that can be used by practitioners seeking solutions to MMH problems or seeking insight into the risk factors associated with MMH, by academicians seeking a summary of the last several decades of MMH research, and by students interested in obtaining a fairly broad overview of research and practice in the area of MMH.

Background and Scope of the Problem

The field of industrial ergonomics, which focuses on achieving safety and productivity in the workplace, has grown tremendously in the past two decades. This growth has been spurred, in part, by growing awareness among those in government and industry that focusing on increased productivity without adequate concern for workers' safety and health and the lack of ergonomics considerations in jobs and tasks may result in injury, increased absenteeism, and reduced productivity. This trend continues to expand around the globe as the role of ergonomics in enhancing profitability reaches new audiences.

One of the most important areas of research and application in industrial ergonomics is the prevention of work-related low back disorders (WRLBDs), particularly as related to manual materials handling (which encompasses lifting, lowering, pushing, pulling, carrying, and holding). A significant proportion of WRLBDs is attributed to MMH. Despite increased automation in the workplace, many jobs still require workers to manually handle materials. Considerable research efforts have addressed the responses of the human body to MMH, including acute responses such as energy consumption and tissue stresses, as well as injuries resulting from longer-term exposures to physically demanding tasks. The papers in this collection represent an excellent overview of the research conducted in the past 15 years.

WRLBDs are a major source of economic loss to employers, compensation carriers, and society in general. These losses explain why the research directed toward prevention of injuries associated with manual materials handling in industry has been one of the most active areas in the industrial ergonomics field. In 1980, about one million workers suffered WRLBDs in the United States, and these disorders accounted for almost one-fifth of workplace injuries and illnesses. For eight states providing workers' compensation payment data, almost one-fourth of the expenditures were for injuries to the low back (Bureau of Labor Statistics, 1982). Similarly, Webster and Snook (1994) found that disabling low-back pain cases represented 33% of the costs associated with a large sample of workers' compensation claims costs.

Low back disorders incur costs in the areas of medical care, lost wages, and indirect costs (such as training new workers and production losses; see Snook, 1987). Based on 1980 data from Liberty Mutual Insurance Company, Andersson, Pope, Frymoyer and Snook (1991) estimated that annual workers' compensation costs for WRLBDs in the United States were \$4.6 billion for the year 1980. More recently, Webster and Snook (1994) estimated that total annual workers' compensation costs (medical and indemnity) in the United States totaled \$11.4 billion, an estimate derived from Liberty Mutual's 1989 experiences. According to Andersson et al. (1991), the total estimated costs (direct plus indirect expenses) for WRLBDs in U.S. industry in 1988 were between $26.8 and $56 billion.

A recent antecedent-oriented analysis of a large sample of work-related injury and illness workers' compensation claims indicated that claims attributed to manual materials handling accounted for 32% of the claims and 36% of the costs (Murphy, Sorock, Courtney, Webster, & Leamon, 1996). MMH claims were the single largest source of claims; the next-largest source of claims (slips and falls—same level) accounted for 15% of the costs. This illustrates that the losses associated with MMH far outweigh any other source of injury in the workplace.

MMH Research

Manual materials handling research has been performed by individuals with diverse backgrounds, ranging from orthopedic surgery to industrial engineering. The papers presented at HFES annual meetings have a strong engineering influence, as is illustrated by the papers in this collection.

The design of MMH tasks typically focuses on ergonomics, job placement, training, or a combination of two or all three approaches. The primary focus should be on permanently reducing the risk of injury through task and workplace design (ergonomics), and supplemented with job placement and/or training when necessary. Strong support for training as an effective means of reducing injuries is lacking, however (Kroemer, 1991). This position is reflected here; the majority of papers focus on the influence of task and workplace design on the biomechanical, physiological, and psychophysical responses of the human body. A secondary focus on job placement is also evident.

Not only have the results of research expanded our knowledge, but technology has expanded the possibilities for research and application. For example, the direct measurement of oxygen consumption was once confined to the laboratory. There are now devices that allow for an almost unobtrusive measurement of oxygen consumption as workers perform their tasks. Likewise, faster computers permit timely processing of biomechanical data, which enables the development of more complex and more anatomically correct biomechanical models.

Researchers have advanced considerably in their ability to model the biomechanical stresses the human body undergoes while performing manual materials handling tasks. Static two-dimensional planar biomechanical analyses were once the norm; today a number of three-dimensional analysis techniques are available which incorporate dynamic stresses as well as accommodate MMH activities not occurring in the sagittal plane. Factors such as the advancement of motion analysis technology and a better understanding of electromyographic responses of the body have resulted in more detailed and representative analyses.

Significant advances have also been made in the understanding of the physiological and psychophysical responses to different task designs. There are extensive psychophysical data for assessing a variety of MMH tasks. There is also an increased understanding of how the physiological and psychophysical approaches may conflict. Such conflicts may present problems to practitioners, but they also serve to increase our understanding of the varied approaches.

The National Institute for Occupational Safety and Health (NIOSH) designed an equation to assess manual two-handed lifting in the sagittal plane (NIOSH, 1981). The 1991 revised equation (Waters, Putz-Anderson, Garg, & Fine, 1993) accommodates lifting and lowering activities not performed in the sagittal plane; in addition, it accounts for tasks performed with less-than-optimal hand-to-object coupling. These equations have motivated considerable research activities, and this trend is likely to continue in the future.

Some of the greatest expansion in the area of the prevention of WRLBDs in the past 15 years has occurred in the area of epidemiology. The reality of economic losses has driven an interest in the determinants of musculoskeletal disorders among occupational populations. Although acute responses of the body to work measured in the laboratory provide a wealth of information, the value of epidemiological studies relating workplace exposures to injury outcomes cannot be understated. This trend is sure to continue as researchers seek valid control measures to reduce economic losses in the workplace.

Content and Use of This Collection

This collection contains 61 papers representing basic and applied MMH research and provides an overview of both the theory and practice of MMH from an ergonomics perspective. The collection shows a strong biomechanics influence, followed by psychophysics and physiology. The majority of the papers focus on the ergonomic approach of fitting jobs to the workforce, with preplacement strength and capacity testing a distant second. Unfortunately, investigations of the determinants of musculoskeletal disorders associated with MMH have been too few, so epidemiological studies are underrepresented here.

There are a number of sources of published work on manual materials handling (journals containing archival material, conference proceedings representing current work, and, recently, Internet sites focusing on ongoing work). However, the *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* represent the best basic and applied research in the field. This selection provides a consolidated source of papers that make the material more accessible for those who cannot regularly attend the HFES Annual Meeting, cannot afford to purchase multiple volumes of proceedings, or cannot access the proceedings in libraries. In addition, the quality and brevity of these papers make them excellent teaching tools for undergraduate and graduate students and for new researchers in the area of MMH.

More important, the variety of perspectives represented by the papers in this compilation will provide practitioners with methods and results that can be applied in numerous workplaces.

Paper Selection Procedure

We used a multistage paper selection process that included peer review. First, using liberal selection criteria, we identified 120 relevant papers from the HFES annual meeting proceedings from the years 1982 to 1996. A 15-year span was judged appropriate based on the length constraints for this book.

We sent the selected papers to three referees, primarily HFES members affiliated with the Society's Industrial Ergonomics Technical Group. The referees were asked to rate papers by considering the quality of the work, the current usefulness of the work, whether or not the work was dated, and the focus on manual materials handling. We asked the reviewers to provide an overall rating of the paper between -3 (very poor quality; must not be included) and +3 (extremely high quality; must be included), as well as a justification for the rating. After we received the reviews, we combined the ratings into a single metric (average rating) for each paper. Papers that received an average rating of +1 or higher were selected for inclusion. (The editors neither reviewed nor selected papers of which they were primary author or coauthor.)

Acknowledgments

We gratefully acknowledge the assistance of Renliu Jang, a graduate student in the Industrial Engineering Department at the University of Louisville, for his help in carrying out the

logistics of this project. This collection would not have been possible without the assistance of those that served as referees. In addition to anonymous reviewers, the following individuals served as reviewers:

F. Aghazadeh
P. C. Champney
B. Das
P. G. Dempsey
F. Fathallah
S. Gallagher
R. Goonetilleke
S. Hsiang
J. Jarvinen
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C. J. Kerk
S. Konz
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L. Punnett
L. J. H. Shulze
F. Tayyari
J. Woldstad

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