CENTERS FOR DISEASE CONTROL AND PREVENTION

NORA
National Occupational Research Agenda

National Occupational Research Agenda for Musculoskeletal Disorders

Research Topics for the Next Decade
A Report by the NORA Musculoskeletal Disorders Team

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
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NIOSH

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INTRODUCTION

Work-related musculoskeletal disorders (MSD), such as low back pain, tendinitis, hand-arm vibration syndrome and carpal tunnel syndrome, account for a major component of the cost of work-related illness in the United States. Recent estimates of the costs associated with work-related musculoskeletal disorders range from $13 to $54 billion annually. Regardless of the estimate used, the problem is large both in health and economic terms. The enormous scope of the problem is confirmed by statistics from the Annual Survey of Occupational Injuries and Illnesses, conducted by the Bureau of Labor Statistics (BLS). For those cases involving days away from work, BLS reports that in 1997 approximately one third of the total, or 603,096 cases, were the result of overexertion or repetitive motion. Specifically:

- 297,317 of these injuries involved lifting; 75,896 were associated with pushing or pulling tasks; and 60,588 were related to holding, carrying, or turning objects.
- Approximately 63 percent of overexertion injuries affected the back.
- The median time away from work due to overexertion injuries was six days for lifting, seven days for pushing/pulling, and six days for holding/carrying/turning.
- 75,188 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. Sixty-eight percent of these affected the wrist, followed by 9 percent affecting the shoulder, and 7 percent affecting the back.
- The median time away from work was 17 days as a result of injuries or illnesses due to repetitive motion.

The National Institute for Occupational Safety and Health (NIOSH) recognizes that addressing a problem of such magnitude requires coordination and cooperation among its many external partners. This philosophy underpins NIOSH's National Occupational Research Agenda (NORA), a collaborative effort between NIOSH and its partners to guide occupational safety and health research in the 21st century. As part of the NORA process, a team of experts representing a broad range of industry, labor, and government interests has been assembled to evaluate the status and define future research needs in the area of work-related MSD. (Team members are listed at the front of this document.) This team has developed a National Occupational Research Agenda for MSD that should serve as a blueprint for building a national research program by identifying high priority research problems and influencing the allocation of resources. Implementation of the agenda will be an ongoing effort requiring an active exchange of information among all interested partners.

Current Status of Research

During the past decade, approximately 4,000 articles that focused on occupationally-related MSD were published. The findings from many of these publications have been summarized in various literature reviews (Anderson 1995; Buckle and Devereux 1999; Frank et al. 1995; Frank et al. 1996a, b; Katz et al.1998; Krause et al. 1998; Moore 1992; Rempel et al. 1998; Szabo 1998; Viikari-Juntura and Silverstein 1999; NIOSH 1997; Ferguson and Marras 1997, NRC 1999). Based on a synthesis of the findings from these publications, a simple conceptual framework of factors that can contribute to MSD can be formulated (see Figure 1). In this model, initial loads are applied to the musculoskeletal system either by external forces or by internal forces resulting from dynamic and gravitational effects on the mass of the body segments. These applied loads create internal tissue responses in the muscles, ligaments, and at the joint surfaces. Depending upon the magnitude of the load and other individual, organizational, or social factors, one or more outcomes may result. These may include adaptation effects (such as increases in strength, fitness, or conditioning) or potentially harmful outcomes (such as pain or other symptoms, and structural damage to tendons, nerves, muscles, joints, or supporting tissues) that may result in symptoms, impairment, or disability. Whether the exposure leads to an MSD depends upon the physical demands of the job, the adaptation response of the worker, and other individual physical and psychological factors. These in turn may modulate the effects of the external load.

Interventions designed to reduce risk of MSD can be implemented anywhere along this pathway. Engineering interventions that reduce intensity, frequency, and duration of exposure are often effective.

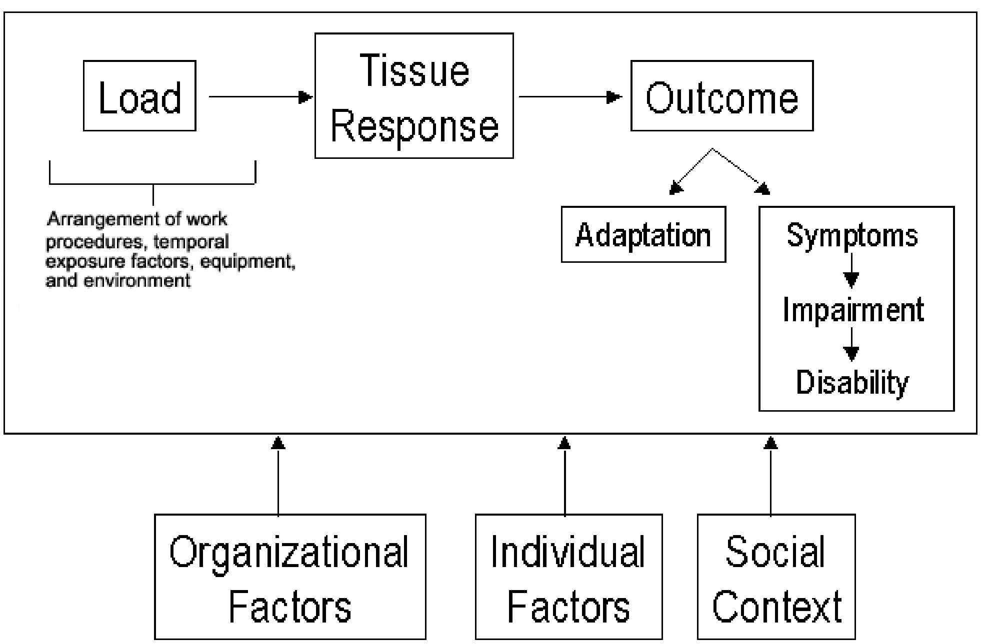

Figure 1. Conceptual model of factors that potentially contribute to musculoskeletal disorders.

Obtaining Input for the National Research Agenda

To obtain maximum input from practitioners, academic and corporate researchers, and organizations sponsoring research, the team adopted a multi-phase approach for seeking input on the national research agenda. The first phase involved sponsorship of three regional focus group meetings where practitioners from a wide range of industry sectors were asked a series of questions regarding research gaps, intervention effectiveness, surveillance, and implementation needs. The three meetings included representatives from light and heavy manufacturing, warehouse and transportation, office environments, acute and long-term health care, forest products, construction and maritime, agriculture, and food processing. During the second phase, academicians and researchers participated in a workgroup meeting using the findings from the practitioner focus groups as the basis for further discussions.

Findings From the Focus Groups

Three practitioner *focus groups* were held in Chicago, Seattle, and Washington, D.C., and a *researcher workgroup* meeting was held in Houston. Overall, there were more than 150 focus group attendees in the three meetings (in 16 groups) and over 50 researchers (in five workgroups) at the Houston meeting. The Chicago focus group included representatives from agriculture, food processing, light manufacturing, office work environment, warehouse and transportation, health care, and heavy manufacturing. The Seattle focus group included representatives from forest products/agriculture, construction/maritime, health care, heavy manufacturing, office work environment, and transportation/warehousing/light manufacturing. The Washington D.C. focus group included representatives from two major areas of the health care industry organized into three general health care groups and one long-term health care group. The Chicago, Seattle, and Washington D.C. focus groups attendees were asked to respond to three basic questions:

- **Surveillance** What methods do you think need to be developed to improve your ability to identify hazardous jobs (or working conditions) in your company or industry?

- **Research Gaps** What are the ergonomic problems in your workplace for which there was insufficient research to address the problems?

- **Intervention** What methods have you used that appear to be most effective or promising in reducing the frequency and/or severity of MSD in your workplace and deserve further research and development?

Analysis of Focus Group Findings

NORA MSD team members reviewed the transcripts and flip charts from each of the three practitioner focus group meetings and summarized them using a criteria-based extraction process. These assessments resulted in the development of listings of research issues by industry sector and a short summary statement reflecting the main topics of discussion. The focus group summaries were further analyzed using a manual search and extraction process by combining the results into a single file and then extracting and organizing the material into four listings of research issues by topic area: 1) Surveillance of Musculoskeletal Disorders and Related Hazards, 2) Etiologic and Medical Research, 3) Intervention Research, and 4) Improving the Research Process. Each of the four sections were then edited to consolidate ideas that were similar.

In addition, new ideas contributed by the academicians and researchers at the Houston workgroup meeting were added to the listings. The resulting four lists of research issues are provided in Appendix A. These lists are designed to provide comprehensive inventories of the issues only and do not provide any indications about what the NORA MSD team believes about the priority or importance of individual research issues. Some of the issues identified in the focus groups applied to more than one industry, while others were primarily applicable to specific industries. The selected industry-specific topics are listed in Appendix B. The Houston workgroup was asked to identify research topics where progress seemed most likely in the next five years. Those ideas are listed in Appendix C.

March 1998 Chicago NORA Focus Group Meeting

NORA TEAM AGENDA

Based on the responses from *three focus groups*, the NORA MSD team developed an agenda of the most important research gaps in four primary topic areas. These included surveillance, etiology, intervention, and improving the research process. The *Houston workgroup* was not asked to develop a list of the most important priorities. The goal in developing the agenda for the four primary topic areas was to synthesize the responses, eliminate duplication, and highlight the most important gaps identified in each area. In some cases, the NORA MSD team also added their viewpoints on the priorities for research. The listings of research issues identified by the focus groups for each topic can be found in the Appendices of this document. There are some issues discussed in more than one topic area.

Surveillance Research Agenda

Surveillance is the ongoing systematic collection, analysis, interpretation, and dissemination of MSD health and hazard information in order to identify trends, develop prevention strategies, and evaluate the effectiveness of those strategies.

The following are the most significant priorities for surveillance research activities identified by the NORA Team:

- Develop user-friendly, standardized workplace surveillance tools for use by both the non-expert and the expert;
- Increase collaboration with federal, state, and non-governmental organizations (insurers, employers, unions, and academics) to encourage comparability of data collection methods;
- Conduct an ongoing national hazard survey targeting physical workplace factors.

Collection of Data for Surveillance

Surveillance Systems Additional research is needed on how surveillance information can be collected, using existing passive surveillance data (billing records created when employees seek medical care) or active surveillance data (annual symptoms surveys of all employees in manual handling jobs). Evaluation of the different roles for active and passive systems are also needed.

Case Definition Develop and validate standardized case definitions for MSD and key variables, including the levels of symptoms to be included in the definitions (distinguish “ever experienced back pain” from “radiating back pain in the last 3 months with a duration of more than a month with moderate to high intensity”). Medical information on cases should include measures of severity of the disorder. This is particularly important in evaluating progress of disease and effectiveness of interventions over time. Validity and reliability of new surveillance case definitions should be tested and reported.

Methods for High Risk and Changing Jobs New surveillance methods are needed to identify high-risk jobs or tasks when the relationship of the worker to the workplace is changing, such as an increase in temporary workers or workers with multiple jobs with different exposures.

Surveillance Information Analysis and Tools

Evaluation of Surveillance Tools Evaluate the validity, reliability, and accuracy of hazard surveillance instruments to be used, recognizing that surveillance instruments usually trade simplicity and speed for precision. Make these tools usable by experts and nonexperts.

More user-friendly exposure assessment tools are needed. Devices are needed that are efficient, portable, rugged, flexible, and capable of measuring multiple exposure variables simultaneously and simple enough for those with minimal training to use.

Validation of Surveillance Systems Validate existing or new surveillance systems in terms of usefulness, representativeness, timeliness, simplicity, acceptability, predictive value, and cost.

Development of New Surveillance Tools Research is needed to develop or evaluate surveillance tools to be used for data at the local or national level, and to be applied to various stages of the MSD development process.

Interpretation Issues

Non-health Indicators Determine whether non-health indicators, such as rates of job transfer, absenteeism, reduced productivity, and early retirement, are effective in identifying jobs with elevated risk of MSD.

Background Rates Efforts should be directed toward developing county, state, industry or occupation denominators and rates that can be used for comparison purposes.

Additionally, collaboration with other groups, such as software system collaborators, insurers, employers, unions, and government groups (NHIS, NHANES), should be encouraged to develop comparability of definitions in data collection.

Etiologic and Medical Research Agenda

Many risk factors associated with development of MSD have been identified or suggested. Biomechanical risk factors include exposures to excessive force, awkward posture, movement, and vibration. These can be characterized in terms of their magnitude and temporal factors, such as frequency, repetition, duty cycle, and duration of exposure (See Figure 1). Psychological and social factors include work organization arrangements (extended work hours, shift work, piecework, machine pacing), lack of training, inadequate conditioning, and cognitive or emotional stress. Personal factors include variables associated with size, strength, age, gender, cultural factors, and history of injury. Research is needed to better describe the relationship between exposure to these risk factors, both singly and in combination, and the development of disease and disability.

The most significant priorities for etiologic and medical research activities identified by the NORA Team are to:

- Refine instruments to detect and quantify the contribution of these factors to the disease process;
- More clearly define stages of the MSD process, develop precise diagnostic tools, and provide guidelines for effective treatment and return to work; and
- Clarify the interplay of the factors of different stages of causation, development, and treatment of MSD and measurement of risk factors.

Risk Factors

Field Research Contribution of Risk Factors Several biomechanical, psychosocial, and personal risk factors have been identified in connection with the MSD process. Research is needed on factors, such as posture, movement, and force within the context of temporal factors (duration and frequency). Research is needed to improve limits for exposure to physical demands and mechanical stresses. This research needs to integrate personal, psychological, and social factors. Research is also needed to develop and validate more predictive exposure assessment tools.

Laboratory Research Models Conceptual models of the MSD development and recovery process need to be tested and refined in the laboratory (Figure 1). Such models should link exposures, tissue changes, physiologic responses, adaptation, and disease. Mathematical and animal models are needed to help understand individual variables. Multi-factorial models are also needed to describe relationships between biomechanical and physiological factors. These models will provide useful information on the disease and recovery process that could be tested in the field.

Individual Variation Variation in individual response and adaptation needs to be investigated. Factors that need to be studied include demographic profiles (age, race, gender), personal history (cultural background, work and injury history), disease states (neurological, endocrine, or circulatory diseases), and work organization factors (work arrangements, time on the job, training, compensation and benefit structure). These need to be considered in the context of biomechanical factors, such as load or repetition.

Childhood Exposures Studies are needed on children at work, and the relationship between childhood exposures to biomechanical factors and later development of MSD (video games or computers, or carrying heavy backpacks).

Fatigue Role Research is needed to determine the impact of whole body fatigue and local muscle fatigue on the development of MSD. New methods for assessing fatigue should be developed, such as human performance testing and biomonitoring.

Disability Research is needed to evaluate the impact of workers' compensation, disability benefits, and wage replacement strategies on effective recovery and return to work. This research, should account for physical factors when studying psychological or social factors that impact the length of disability.

Healthy Populations Research is needed to define a healthy musculoskeletal state and to identify optimal stress and activity levels. Healthy populations who have not developed disease despite exposure to risk factors should be studied.

Exposure Measurement

Predictive Ability of Tools Predictive ability of biomechanical, organizational, and workplace psychological and social exposure assessment tools needs to be evaluated and improved. Greater precision, accuracy, repeatability, and validity of measurements are needed.

Other Assessment Tools Assessment tools need to be developed and evaluated to identify hazards associated with non-stereotypic work, such as jobs in transient or seasonal industries (construction and agriculture). Consideration of multiple exposure changes in temporal patterns over the course of the workday or workweek should be included in these assessment tools.

Use of Data Research is needed to evaluate the trade off between observation, self reports, and direct measurements in predicting risk. The health-related data sources (OSHA logs, workers' compensation, disability, and health insurance records) need to be evaluated for usefulness in identifying disease patterns (evaluation of reporting bias, over-reporting, under-reporting, and legal and medical criteria). This research would be an additional resource for improving surveillance.

Diagnosis and Treatment

Case Definition Work is needed to develop standard clinical definitions for MSD which include clear endpoints. Definitions are needed for stages of the disease process characterized by such terms as discomfort, pain, injury, disability, and recovery.

Diagnostic Tools Effective diagnostic tools are needed. Existing diagnostic tools and procedures need to be evaluated, including use of MRIs and microsensors. It is particularly important to find good early indicators of the disease process, including biochemical and bioimaging markers. It is important to develop effective tools for establishing an individual baseline for medical monitoring.

Predictive Tools Tests, such as electrodiagnostic testing (NCS) or functional disability evaluation tools, should be studied for their ability to predict the onset and outcome of MSD. Research is needed to identify and validate practical screening tests that can detect individual physical conditions or biological markers indicative of the MSD process. Tests should be useful for periodic monitoring of individuals for comparison to baseline status. Research is also needed to determine whether changes in biological markers indicate reversible or permanent change; to develop/validate/evaluate tools to assess functional disability; and to determine if structural changes are related to the course or progression of MSD. Populations studies need to be conducted to determine normal population values or ranges for subsequent useful inferences for the MSD process. Criteria for work-related illness should be evaluated.

Treatment Strategies Evaluation of treatment protocols, rehabilitation programs, and return to work strategies is needed.

Intervention Research Agenda

Research is needed to develop and evaluate new and existing intervention strategies for preventing or reducing the incidence, severity, and disability associated with work-related MSD. A large amount of research has been conducted over the past few decades, but because of the wide variability between individuals and the complexity of causal and contextual factors and their interactions, there is a need for more research on which interventions are the most effective. Moreover, intervention research is difficult to conduct because adequate comparison controls are often not available and because very large sample sizes are needed to show that an intervention is effective in reducing health outcomes. In many cases, it is not possible to conduct studies aimed at reducing health effects, so studies must rely on demonstrating reduced exposure. Interventions can be tested in the laboratory where confounding factors can be controlled, or tested in the field. Effective control technology should work well in both environments.

The most significant priorities for intervention research activities identified by the NORA Team are to evaluate the effects of the following on development and prevention of MSD:

- Alternative (product and/or tool) design criteria (force, spatial requirements of work);
- Optimization of mechanical work demands (force, movement, and posture) and temporal patterns of exposure;
- Manual handling alternatives in posture, movement, force, productivity, and quality;
- Ergonomic training and education;
- Costs and benefits of ergonomics intervention;
- Evaluate job assignment, selection, and choice on development of MSD; and
- Emerging technologies.

Engineering Control Technologies

Mechanical Environment Research should investigate the mechanical environment factors that affect posture, movement, force, exertion, and the interface between the worker and the equipment or the task. Such mechanical environment factors include workplace arrangements, equipment, and tool design, as well as the design of the products and components that are routinely handled by people. For example, research into alternative seating arrangements or human interactions with semi-automated material-handling devices would be useful.

Force Factors More engineering research is also needed to identify and evaluate the factors that affect the force required by the worker. For example, intelligent material-handling devices are being developed that compensate for different loads. Research is also needed to measure the versatility, operator acceptance, protective capabilities, and safety aspects of these devices. In the area of manipulation of tools and smaller objects, as in assembly work, food processing, retail, and dentistry, additional engineering research is needed to provide the optimal balance between the force requirements for the efficient completion of the work task and the prevention or reduction of MSD.

Dynamic Forces More research is needed to develop interventions directed at reducing the dynamic demands of work tasks (kinematic or motion parameters and kinetic or force parameters), such as redesigned workspaces and tools that minimize required forces and movements.

Specific Industries Work is needed to develop additional engineering solutions for several industry-specific problems, including fork truck design and health care, warehousing, construction, maritime, agriculture, meatpacking, and poultry processing.

Work Organization

Participatory Approaches Research is needed on when and how participatory programs work to prevent/reduce MSD.

Work Interaction Research is needed to increase knowledge of the interactions between the cognitive, environmental, social, organizational, economic, and political contexts of work which can be used to develop interventions aimed at preventing MSD.

Job Content and Scheduling Further research is needed in the areas of task assignment and work/rest schedules, job rotation, job enlargement, and length of the workday. Research is needed on the effect of worker control of pace (piece rate and incentives) and job content.

Behavioral Intervention Studies are needed to determine what factors are effective in getting workers to incorporate modification in work methods, such as increasing use of assistive equipment, taking regular rest breaks, or avoiding hazardous activities, such as heavy lifting or lifting from the floor.

Safety and Fitness Effects Research is needed to determine the effectiveness of general safety, wellness, and fitness programs and their impact on work-related MSD.

Accommodation and Functional Capacity Research is needed to determine the effectiveness of interventions directed at matching the individual characteristics, capability, and vulnerability of workers to the work demands. Such research would cover issues of selection, training, work hardening, rehabilitation, and restricted work assignments. In addition, because of the indication that a history of musculoskeletal illness and injury is predictive of future episodes, more intervention guidance is needed regarding the assignment of particular individuals to particular jobs.

Protective Equipment

Personal Protective Equipment Personal protective equipment may be used to modulate the interface between the body and external forces or to restrict joint movement. Interventions of the former type, such as gloves and kneepads, are generally accepted, although there may be an opportunity to evaluate the effectiveness of personal protective devices in the attenuation of vibration from hand tools. Further research could evaluate a wider range of work environments to determine if there is a role for joint restraint devices in MSD treatment protocols.

Other Interventions

Training and Education Research is needed to develop and investigate effective training and educational interventions to diverse audiences. These include workers or management in the workplace and students in vocational, engineering, occupational health, and management programs. Such interventions include: programs in the workplace, ergonomics material in grade school, engineering and business curricula, extension of specialist education, and professional certification. Educational interventions may have far-reaching effects on reduction of the incidence and severity of work-related musculoskeletal disorders.

Exposure Guidelines and Regulations Research is needed to determine the effectiveness of voluntary exposure guidelines and regulations. Studies are needed to determine the difference in impact between voluntary guidelines and regulations and the impact of varying exposure criteria.

Compensation More research is needed to determine the prevention role of the workers compensation system and how it could be used more effectively to reduce MSD.

Cost Benefit Evaluate the impact of ergonomic interventions on non-health-related outcomes such as quality and productivity. Develop business models that quantify the costs and benefits of ergonomic programs.

Improving the Research Process

Participants indicated that the research process could be improved by strengthening communication between those who conduct research and those who apply research. Researchers expressed frustration at the difficulties associated with gaining access to industrial sites to conduct research, and management and labor felt the need for more input into the research process. Some participants suggested that research might be more applicable to industry if management and labor reviewed research proposals and had a say in funding and prioritization. For example, workforce representatives expressed disappointment that researchers often did not have a thorough knowledge of the workplace process being studied, or performed their research under “best case” scenarios.

There seemed to be general agreement that improvements in dissemination of research results were needed. Most of the dissemination problems were attributed to inadequate communication between the parties involved in the research process. More effective methods of dissemination are needed to improve the application of research findings in the workplace. Furthermore, when valuable research data were obtained, the method of dissemination made it difficult to apply in the workplace.

The NORA Musculoskeletal Team considers coordination of research activities and information dissemination to be of prime importance in this area. As suggested by several of the focus group participants, coordination of studies through partnerships involving government agencies, university researchers, private industry, and labor unions could be extremely beneficial in bridging communication gaps, developing efficient research strategies, and improving the dissemination of information.

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APPENDIX A: PRACTITIONER LISTING OF RESEARCH ISSUES

Appendix A contains bullets which were abstracted by NORA Musculoskeletal Team members from focus group meetings. In this abstraction process, the team members attempted to accurately describe the ideas being presented. No effort was made to evaluate the ideas in terms of relative priority, likelihood of success, or resources required to accomplish the research priority, or to eliminate the diversity in proposed research topics. There is some overlap between bullets within each major section.

Surveillance

Health Surveillance Data Collection

- Incorporate into state and national reporting systems more clinical information on musculoskeletal disorder cases.
- Develop a standardized work history surveillance form for individual workers related to medical end points.
- Incorporate measures of severity of the specific health outcomes into surveillance systems.
- Improve diagnostic reliability of surveillance data through health care provider training.
- Consider specific populations for inclusion in existing or new surveillance systems, including workers with chronic pain or permanent disability, arthritis, and cartilage damage (especially to knees and lower extremities).
- Modify and update the 1995 OSHA ergonomic workplace checklist for surveillance use.
- Evaluate process hazard review and hazard control review as surveillance methods.
- Develop tools which account for inter- and intraperson variability in task performance.
- Develop different sets of survey tools for different uses, such as national surveys, hazard identification, known “problem” work areas, injury and symptom surveillance, early detection or preclinical phase, job transfer, absenteeism, functional impairment, productivity, and retirement summaries.
- Develop hazard surveillance checklists and other tools usable with minimal training for use by health and safety committees, employees, and medical personnel and compare them with detailed exams/interviews and exposure assessments to evaluate trade-offs in simplicity and precision.

- Update the list of high-risk jobs and industries and ensure that new occupations and industries are included in older, established surveillance systems.

- Develop standardized case definitions of musculoskeletal disorders and "key variables" for inclusion in different surveillance tools, such as state workers' compensation systems.

- Coordinate uniform reporting requirements, such as the OSHA 200 log, ICD codes, workers' compensation, and defined health endpoints. Facilitate retrieval of all records (OSHA 200 log, medical reports, etc.) related to an injury.

- Conduct a hazard survey modeled after the NIOSH National Occupational Exposure Survey (NOES).

- Consider surveillance of specific worker populations, such as computer users, nurses, workers excluded from the Bureau of Labor Statistics data (office workers and federal workers), and workers with long cycle jobs, such as those in the construction industry.

- Survey companies to identify measures of organizational health, possibly using QS 9000 and ISO 9000 (quality standards of work processes) registries at the national level.

Hazard Surveillance Tools

- Develop surveillance tools that capture "expert judgement," but include "decision trees" which allow the nonexpert and expert to arrive at similar conclusions.

- Determine the validity, reliability, and accuracy of surveillance tools.

Interpretation and Data Use Issues

- Develop easy access to denominators, such as improve state-based surveillance through the use of county business patterns or census data for denominators.

- Determine whether workplace accommodations of injured workers have changed over time and affected MSD reporting.

- Determine the impact that changes in workers' compensation laws or management/ employee relations have on reporting and seeking treatment.

- Utilize existing data sources, such as employers, unions, government surveys (NHIS, NHANES), workers' compensation, physician reports, hospital emergency departments, health maintenance organizations, health care insurers, disability reports, physical therapy reports, or other individualized state sources, to encourage comparability of data collection.

- Use surveillance systems to determine the validity of Bureau of Labor Statistics data by comparing them to an independent audit of company reports, especially in industries suspected of undercounting.

- Use surveillance systems to determine the economic costs of MSD.

- Use surveillance systems to determine whether there has been a trend in restricted work.

- Use surveillance systems to determine whether gender affects response to hazards.

- Use surveillance systems to determine the efficacy of participatory or grass-roots interventions and ergonomic programs.

Etiological Research

Relation between Risk Factors and Development of MSD

Physical

- Examine the link between exposure to varying intensities of biomechanical stress and the occurrence of MSD. Biomechanical exposures may include repetition, force, static and awkward postures, duration, and vibration. Research is needed to determine how much is too much.

- Evaluate physical demand limits for the hands and wrists on sub-assembly operations for the incidence of hand disorders.

- Evaluate differences in the incidence of MSD among operations with sitting/standing postures versus standing postures.

Non-Physical

- Investigate the effects of psychological, psychosocial, and work organizational factors on the occurrence of MSD. These studies should examine the effects of hours of work, shift work, paced work, piecework, teamwork, alternate work sites (telecomuting), temporary work, extended hours, and other supervisory or management arrangements.

- What is the impact of downsizing, labor shortages, or increased overtime on the occurrence of MSD? Why do some solutions work in one plant but not in another?

- Assess the physiological response to mental and/or emotional stress. Do physiological changes occur as a result of mental stress?

- Evaluate whether environmental, social, and psychological stressors contribute to fatigue.

Personal

- Investigate the relative effects of age, gender, physical condition, biological characteristics, cultural differences, diurnal variation, genetics, and history of previous injury/illnesses (acute, cumulative, or chronic) on the development of MSD. Investigate why individuals respond differently.

- Study adaptation to repetitive work—determine the body's normal physiological adaptive response and the pathophysiologic responses requiring intervention.

Multi-Factorial

- Studies are needed to examine physical, non-physical, and personal variables separately and in combination.

- Examine how physical, environmental, and mental stresses affect workers off the job.

Injury and Illness Models

- Develop, evaluate, and refine theoretical models of musculoskeletal disease and injury that link exposures, tissue changes, and disease manifestation.

- Determine when work becomes illness-producing (the transition between normal work and excess load). Establish acceptable levels of repetition and force.

Study Design Issues

- Identify antecedent factors by looking both at injured and healthy workers (examine jobs that do not cause problems). Study long-term workers who have not been injured to learn more about optimal activity levels and contributing physical, personal, and behavioral factors.

- Utilize a variety of study designs, including both experimental and natural or observational (longitudinal, retrospective, and cross-sectional). Longitudinal studies are important because they follow workers throughout their careers and after retirement and allow assessment of why workers change jobs. Cross-sectional studies are not sufficient; it is important to include ex-workers. New epidemiological methods may be needed to track transient employees. Develop mathematical and/or statistical methods for dealing with enormous amounts of data.

- Study low- and medium-risk exposures to understand the subacute process, as well as high-risk exposures.

- Study specific diseases and quantified exposures rather than generic. Study continuous exposure variables as preferred to dichotomous.

- Although human models are preferable, good animal models for MSD are also needed.

Special Populations

Aging Workers

- Research musculoskeletal effects and changes in risk factor tolerance for an aging work force.

- Incorporate what is known from the field of exercise physiology about the effects of aging (for example, whether it is harder to recover from MSD at older ages than younger).

- Produce anthropometric data related to age, and conduct anthropometry studies on industrial populations so tool designers have information on how anthropometric variables change with age.

Co-Morbidity and Other Conditions

- Evaluate whether workers with chronic or infectious diseases are at increased risk for MSD. For example, does the high prevalence of diabetes among some groups place them at increased risk? What about workers with past or present exposure to toxic chemicals, including childhood lead exposure or pregnancy?

Children

- Evaluate occupational and non-occupational exposures of children, such as extensive computer work, agricultural work, grocery store baggers, and other jobs. Although they have less strength, they are often exposed to the same physical factors as adults. Determine if childhood exposures cause problems in adulthood.

Improvement of Exposure Assessment Tools and Methods

- Develop/establish standardized definitions for exposure terms, such as *force, vibration, pressure, frequency,* and *repetition*.

- Systematically evaluate the precision and accuracy of existing exposure assessment tools and methods. Test the tools to ensure they are comparable and used the same way by all users.

- Develop tools with greater specificity—many current analytic tools may be too sensitive but not specific, meaning they rate too many situations as stressful.

- Improve exposure assessment tools by making them portable, easy to use by non-experts, telemetric, non-invasive, and able to detect a wide range of exposures. They should be capable of measuring multiple exposure variables simultaneously.

- Develop new instrumentation for assessing exposure to physical and non-physical factors (for measuring non-lifting force applications, such as arm, shoulder, hand grip, and pinch forces).

- Develop methods that rely on non-traditional approaches, e.g., use of surface temperature as an indicator of strain on the hand/wrist during keyboarding or during high impact activities. New exposure methods should incorporate individual differences, such as size, gender, and anthropometry.

- Develop new methods for assessing jobs with multiple tasks and variable task characteristics, as in the construction, agriculture, and warehouse industries. These tools should be capable of assessing work load in real-time with minimal expertise.

- Determine the effectiveness of dynamic biomechanical models versus static models in the prediction and control of MSD.

- Develop procedures for job task analysis through actual job site measurements that can catalogue stressors, evaluate workload risk and analysis, and use existing ergonomics check lists and data sources. These methods should allow the user to evaluate a variety of different factors (including vibration) simultaneously to determine overall workload.

- Develop tools for determining both physical and psychosocial factors that are easy to use like the NIOSH lifting equation. For example, in an office environment, include such factors as keying rate, breaks, postures, and work and personal psychosocial factors.

Diagnosis and Treatment

Identification of MSD

- Develop standard definitions for work-related MSD, risk factors, and for terms, such as *discomfort, pain, injury, disease, disability,* and *recovery*. Establish endpoints that are clear, definitive, valid, and reliable.

- Develop better diagnostic tools for MSD, including its early stages.

- Establish approved methods and objective tests to diagnose and evaluate whether an injury is physical, psychological, or psychosocial.

- Standardize diagnostic physical examinations.

- Evaluate available high-technology imaging tools, such as microsensors and magnetic resonance imaging (MRI), for the diagnosis of MSD, and design new diagnostic tools specifically for ergonomic research.

- Develop and validate biochemical markers to identify injured workers and to follow their recovery.

Treatment and Return-to-Work

- Conduct research (clinical trials) to evaluate the efficacy of various forms of treatment for MSD, including surgery and rehabilitation. Evaluate the impact of workers' compensation and disability benefit availability and other factors on treatment and outcome.

- Delineate the natural history of MSD (pathogenesis and recovery).

Miscellaneous Topics

- Quantify the time of symptom onset to the time of injury or disorder progression, and study the relationship between these two variables.

- Study muscle fatigue, strain, and injury, and quantify variables where possible. Use biomonitoring to determine fatigue, possibly involving muscle testing and grip strength tests. Combine research on performance with fatigue, muscle, and physiology factors. Obtain more information on workers' strength while in movement for use in design.

- Compare cumulative exposures from the effects of repetitive activity on muscles, tendons, or nerves and the role of infrequent or rapid exertion when performing primarily sedentary jobs.

- Study pain occurring after an injury. Assess what factors make individuals respond to pain in different ways. Study the occurrence of sensitization (decrease of pain threshold) in the central nervous system after injury.

- Study whether the central nervous system is affected by repetitive activity and injury. Do workers develop maladaptive patterns of movement by doing repetitive tasks?

- Study problems with lower extremities, especially knees, using field research and animal models.

Intervention

Engineering Controls

Posture

- Evaluate the effectiveness of equipment, such as chairs and power tool handles, used to control risk factors for MSD.

- Evaluate the effect of warning devices, such as those for posture and keystroke counters, on prevention or reduction of MSD.

- Studies are needed to determine the effectiveness of using sit/stand seating and footrests to reduce the postural stress associated with continuous standing at work.

Force

- Evaluate the biomechanical risk imposed by infrequent heavy workloads on several parts of the body.

- Validate the effectiveness of fasteners and palm buttons in controlling upper extremity MSD.

Training

- Evaluate different training modalities, delivery methods, and materials that are correlated with a reduction of MSD.

- Evaluate who should be trained and duration and frequency of training.

- Evaluate effectiveness of the content and methods of training programs.

General

- Determine the best intervention(s) to use for work environments where engineering solutions are difficult to implement and for “unpredictable” situations that happen in the workplace, such as machine or equipment breakdowns or slips and falls.

- Determine the effectiveness of incorporating ergonomic principles at the design stage versus retrofitting or fixing high-risk jobs.

- Determine why similar interventions instituted in similar plants have widely varying results.

- Determine the cost effectiveness of designing jobs using ‘ergonomic’ principles in the design phase in comparison to the reactive strategy of fixing jobs after MSDs are observed.

- Determine the effectiveness of designing jobs to meet recommended exposure limits defined by job assessment methods (e.g., the NIOSH lifting equation, 3-D computer based biomechanical models, psychophysical databases, risk prediction models, and upper extremity evaluation methods).

- Determine the effectiveness of traditional and new engineering solutions (e.g., manual handling devices, workspace layout, tools, containers, etc.).

Administrative Controls

- Compare the effectiveness of general wellness and fitness programs versus engineering strategies in preventing MSD.

- Evaluate the effects of job rotation, job enlargement, rest, and shift work patterns in reducing MSD.

- Evaluate injury reporting trends among operations with and without job rotation.

Organizational Controls

- Identify and validate the primary elements of effective early screening programs in the reduction of MSD.

- Determine significant differences in injury reduction between early medical intervention techniques and behavioral change techniques.

- Assess the impact on injury prevention of using alternative job placement programs for different age groups.

- Validate the use of pre-placement screening as an indicator of an individual risk of MSD.

- Compare the effectiveness of engineering interventions versus organizational interventions in reducing the rate of MSD.

- Evaluate whether early warning programs that use symptom and discomfort surveys are effective in the prevention of MSD.

- Determine if there is a high correlation between time of day, level of experience, under-staffing, and the incidence of MSD.

- Determine the impact and effectiveness of safety incentives and behavior-based safety programs in the reduction of MSD.

- Validate and standardize basic elements of a medical management program directed toward the reduction of MSD.

- Identify and validate a business model criteria that quantifies costs and benefits of ergonomic programs. Assess the benefits of establishing an ergonomics program in terms of productivity, product quality, workers' compensation, and medical costs. Develop better measures of productivity.

- Determine which segments of society currently carry the economic burden of MSD (employee, employer, government, family, social services, etc,.).

- Evaluate the effects of risk communication to workers.

- Assess use of confidential employee surveys to collect more useful information on near-miss 'accidents', under-reporting of hazards or disorders, and possible solutions to hazardous exposures.

Personal Protective Equipment

- Evaluate the effectiveness of personal protective equipment (PPE) in the prevention or reduction of MSD.

- Evaluate the effect of PPE on reporting MSD.

Cultural Factors

- Assess how cultural factors may affect adoption of ergonomic improvements.
- Evaluate whether cultural factors affect an individual's participation in symptom and discomfort surveys.
- Evaluate the communication strategies used for non-English speaking employees in agriculture, construction, fishing, and forestry.

Improving the Research Process

Communication of Research Results

- Foster partnerships among government agencies, private employers, and unions. Coordination of studies among organizations or agencies may help improve communication and the dissemination of results.
- Disseminate information to both academics and practitioners about completed and continuing studies, particularly successful studies. Put the results for practitioners in less technical language, explaining all design information and how the findings apply to real situations. A user advisory group could be formed to interpret and disseminate information in a practical and usable fashion. Small businesses could be reached via information clearinghouses, Internet websites, conferences, and speakers bureaus.
- Develop a user-friendly, employer-accessible intervention database (including industry benchmarks and case histories) on topics applicable to a wide variety of settings, in addition to industry-specific solutions. Employers could use the database to identify interventions for their specific hazards.
- Create practical software for designing good workplaces that practitioners can use in their work and which would also help bridge the gap between researchers and practitioners who do not speak the same language.
- Create incentives for companies to publicly disseminate their research results because companies sometimes consider this information to be competitive or proprietary.
- Initiate a public awareness campaign stressing ergonomic success stories, prevention of MSD, and ergonomics as a standard part of doing business.

Practitioner Input into Research Selection

- Encourage collaboration using a multi-disciplinary team approach (engineers, ergonomists, clinicians, academicians, industry, and labor). NIOSH-sponsored centers could be a model.

- Facilitate a dialogue between labor, management, practitioners, and researchers. Insure that practitioners have a role in prioritizing/funding research.

- Ensure that investigators have a thorough knowledge of the workplace process before designing studies, including the best and worst case scenarios.

Reducing Barriers

Improving Access

- Address companies' and unions' concerns about the utility and value of research.

- Create a task force to link researchers and industries to show industries how research will benefit them.

- Create new incentives for industry to participate in ergonomic studies. Private organizations, NIOSH, or OSHA could initiate programs to recognize companies with exemplary ergonomics programs or that cooperate in research. Ensure that ergonomic research leads to immediate benefits for the participating company, such as improvements in productivity or training programs.

- Garner management and union support by working with researchers whom both sides trust.

- Hold "research fairs" to create forums for researchers to meet with companies and funding agencies to facilitate access to sites and funding.

- Experienced researchers could tutor new researchers about effective methods for obtaining access.

- Access by NIOSH-sponsored researchers may be enhanced by an educational campaign explaining NIOSH's mission.

Facilitation of Research

- Piggyback ergonomic medical tests onto large, pre-existing longitudinal studies like those of NHANES or the Institute of Aging.

- Improve the research proposal process by encouraging collaboration among researchers, particularly regarding competing theories and methods.

- Reduce workers' objections to participating in research by replacing painful tests; assuring proper and confidential handling of sensitive data, including biological specimens, medical information and responses to study-relevant questions; and requesting workers' permission when videotaping.

- Enlist the aid or secure the support of labor, insurance companies, and other companies that are interested in ergonomic research and will contribute funds.

- Coordinate funding and research among federal agencies (e.g., NIOSH, the National Institutes of Health, the National Science Foundation, the National Institute for Aging). Consider an approach like that of the National Science Foundation, which partially funds research with industries; the EPA-industry collaborative Health Effects Institute; or the Center for VDT Research. Enhance the awareness of non-NIOSH, Federal, intramural research groups of occupational etiologies, and encourage them to do relevant basic and transnational research.

- Ensure that funding sources commit to supporting longitudinal studies over many years because of their scientific merit. They should also fund smaller, individual studies that together will build the requisite, sequential steps to answer the big questions.

- To address perceptions of bias, develop mechanisms that might provide oversight and/or funding of research projects, e.g., independent advisory boards, multi-stakeholder funding consortia, etc.

- Improve the initial and continuing education of practitioners on research methodology. Topics could include how to collect data, how to define control groups, how to deal with jobs that change in the middle of a research project, standards for best practices, statistics and experimental design, and setting "gold standards" for biomechanical factors and diagnosis of MSD.

APPENDIX B. SELECTED INDUSTRY-SPECIFIC PRACTITIONER RESEARCH ISSUES

These topics were identified during the practitioner focus group meetings in Chicago, Seattle, and Washington, D.C. Some of the issues identified in the focus groups applied to more than one industry, while others were primarily applicable to specific sectors or industries. Selected examples of these specifics topics are listed in this appendix.

General Industry

Fork Truck Design

- Study the design and use of ergonomic and anti-vibration seats to reduce the risk of MSD. Redesign seats in fork trucks to prevent twisting. Review the ergonomic problems with seatbelts. Study the use of ergonomically designed controls on fork trucks.

Locating, Loading, and Unloading Product

- Study the use of: 1) ramps and two-wheeled carts to manually unload trucks; 2) ergonomic rack designs (such as push-back [self-fronting], self-running, rotating, and height-limiting storage racks); 3) pull tools for pulling product closer to the lifter; 4) cherry pickers for retrieving objects stored at higher heights; 5) bar-coding to improve the efficiency of locating stored items in the warehouse; 6) automatic and locking dock plates; 7) different container designs; and 8) color-coding or labeling products to identify weight or weight category.

Health Care

Patient Transfer

- The health care industry faces many unique issues related to patient transfer, which is responsible for many MSD. Solutions must be devised for the range of health care settings, including hospitals and nursing homes, ambulances, and home health care. Further research is needed, as the occurrence of MSD has continued even after the incorporation of training, lifting teams, and lifting equipment. More research is needed on: 1) patient issues (weight, disruptiveness, unpredictability, acceptance of the transfer, and risks to the patient from the transfer); 2) the use and limitations of lifting patients and equipment in different settings (institutions, ambulances, home care); 3) the use, makeup, and limitations of lifting teams; 4) effective training in patient transfer to avoid MSD; 5) the economic benefit and feasibility of a 'no-lift' program; and 6) the commitment of management to effective interventions.

Equipment and Tools

- Design retractable monitors for ICU and CCU that obviate the need for awkward neck postures or extended arm reaches.

- Conduct more research on the ergonomic impact and design of medical equipment, such as dental tools, surgical instruments, design B transducers, ultrasound equipment, bronchoscopes, pipettes, stopper removers, respiratory therapy equipment, microscopes, old anesthesiology equipment, and patient-lifting equipment. Conduct research on opening medication that is unit-dose wrapped.

Job Evaluations

- Evaluate ergonomic factors related to various jobs, including health care food services, custodial workers, X-ray technicians, dentists and dental workers, and surgeons.

Construction and Maritime

- Conduct more research on the ergonomic impact and design of tools and equipment (anti-vibration gloves, adjustable tables, stress-reducing tools, adjustable paint roller poles, fiberglass ladders, power tools, vice manual tools, lift trucks instead of manual labor, drills with levers to reduce force required during overhead work, stools with wheels, magnetic lifts, and smaller forklifts).

- Evaluate administrative interventions, such as rotating the crew, rotating work tasks (skills cross-training within trade/craft classifications), or working in teams with job rotation within teams.

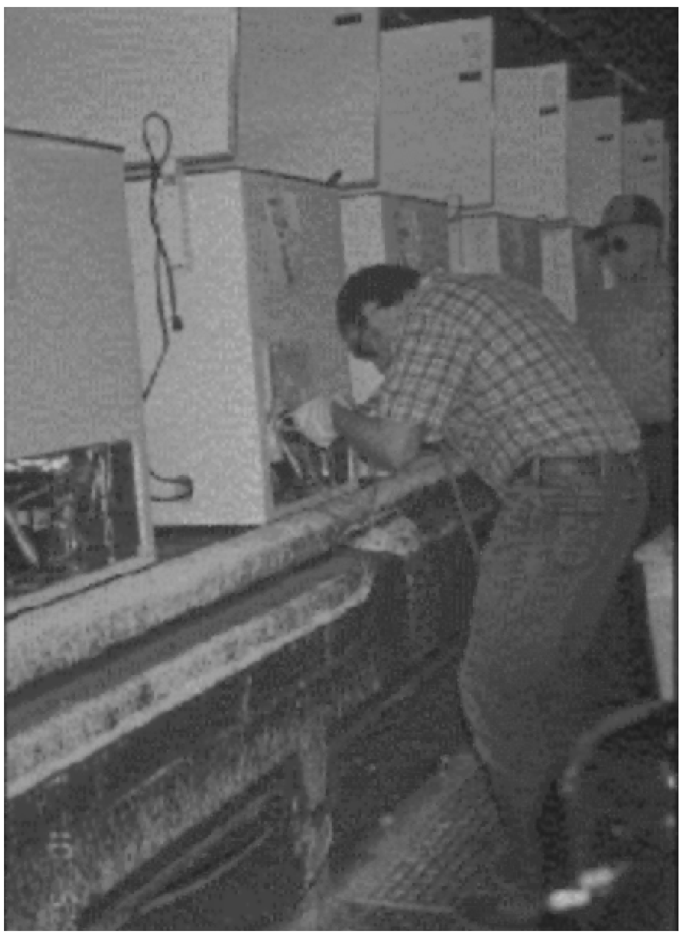
- Evaluate effective training and safety programs for apprentice programs, including safety and ergonomic information, education on MSD, lifting, micro-breaks, and tool selection. Include in training programs planning for specific hazardous tasks (proper equipment, personnel, logistics, safety, and job hazard analysis) and the potential for MSD due to fatigue or increased susceptibility. Review safety incentive programs based on hazard recognition and continuing education.

Forest Products and Agriculture

- Conduct more research on the ergonomic impact and design of tools and equipment (pruning shears for nursery workers).

- Evaluate how ergonomic improvements can be made considering the natural, immutable factors that agricultural workers must deal with (weather and the natural positioning of produce in the field either overhead or below the worker's knees).

- A unique issue in agriculture and food-processing is that the product is living or perishable. This impacts work pace, environmental conditions (temperature and wet or dry conditions), and other factors. Research is needed on ways to mechanize handling jobs in food-processing facilities to avoid repetitive motion disorders; this is a difficult issue because the product is often soft or fragile, and automated methods may damage it.



APPENDIX C. ACADEMIC INPUT ON WHAT IS POSSIBLE IN THE NEXT FIVE YEARS

These six topics are consolidated from those identified by the five academic workgroups that met in Houston, where attendees were asked to identify the research topics from Appendix A or other topics where progress seems most feasible in the next five years. They did not discuss the surveillance topics listed in Appendix A.

Risk Factor Identification

- Initiate a new prospective ergonomics study. Although the length of the study may be longer than a few years, the initial cross-sectional and longitudinal data would be valuable.

- Develop accurate risk assessment models. Develop a comprehensive, multi-factorial model of the predominant causes of repetitive motion disorders. For example, for wrist disorders, address all the contributing causes, including personal variables, like demographics and medical history, work factors, off-the-job factors, and physical and psychosocial factors. Develop job simulation models to predict stress on the job.

- Study workers in understudied industries, such as agriculture and construction. Investigate task performance, capabilities, tolerances, and limitations among special worker populations, such as older workers, pregnant women, and those exposed to lead as children. Address the question of why workers respond differently to interventions; focus should be on the workers who do well.

- Acquire more information by age and gender on grip strength norms for the industrial population or the adaptations that occur in repetitive work as reflected in grip strength. Include different postures, not just one regular grip strength posture.

- Study the relationship between acute trauma and chronic disorders, particularly whether an acute injury of the back, hand, shoulder, or neck predisposes a person to a chronic disorder. Study how self-reported symptoms relate to acute and chronic disorders.

- Retain a balance between controlled laboratory studies and field studies; both have their place. Conduct research on participatory versus nonparticipatory ergonomics research to evaluate the value of participatory research.

Improvement of Exposure Assessment Tools and Methods

- Develop a "gold standard" for measuring biomechanical factors.
- Improve the scientific basis for predictive tools, like the NIOSH lifting equation, and evaluate their effectiveness.
- Develop simple, validated assessment tools for hazard surveillance and intervention.
- Initiate effort to develop an upper extremity equation similar to the NIOSH lift equation.
- Acquire more data on human capacities.
- Develop methods to identify and quantify physical stress.
- Use state-of-the-art technology to develop better exposure assessment tools, using dynamic biomechanical models.
- Develop good tools to assess exposure/effect relationships at the target tissue level. Develop better quantitative tools for tissue load assessment, especially for field studies.

Medical Research

- Develop standardized and validated definitions for the gamut of adverse health effects (ranging from biochemical markers to preclinical effects, symptoms, and permanent disability) and better health effect assessment methods.
- Develop a gold standard for diagnosis of MSD. Conduct basic research into injury mechanisms and models.
- Define effective return-to-work strategies, and define what causes "bad" outcomes.

Intervention

- Conduct intervention studies.
- Identify and replicate effective ergonomic programs in specific businesses or industries.
- Institute intervention activities on lower extremity problems.

- Conduct research on back belts.
- Evaluate whether shoe inserts work.

Dissemination of Information about Ergonomics

- Create a publication database and a detailed solutions database.
- Develop guidelines or a handbook for process and product engineers and designers to incorporate ergonomic principles into their work.
- Improve training and education tools and methods, including those for children.
- Develop a public awareness campaign to explain ergonomics to the general public.

Removal of Barriers to Research

- Develop a task force to facilitate research by linking researchers and industry and by encouraging industry to participate in ergonomic research efforts.
- Identify means of "immunizing" industry for participation. Provide anonymity for corporations with industry-wide studies and surveillance and other methods.
- Develop a mechanism to support multi-disciplinary research efforts. Create ergonomic research centers. Foster collaborative associations (researchers, clinicians, industry). Create a common ergonomics language that is used by engineers, health professionals, and industry. Ergonomics is interdisciplinary, yet currently the different disciplines cannot talk to each other.
- Piggyback ergonomic medical tests onto large, pre-existing prospective studies like those of NHANES or the Institute of Aging. While these would never be comprehensive in scope, they could provide valuable benchmarks or reference values on a variety of basic physiological functions and human capacity profiles. For example, include a few hand function maneuvers, like grip strength measures.

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