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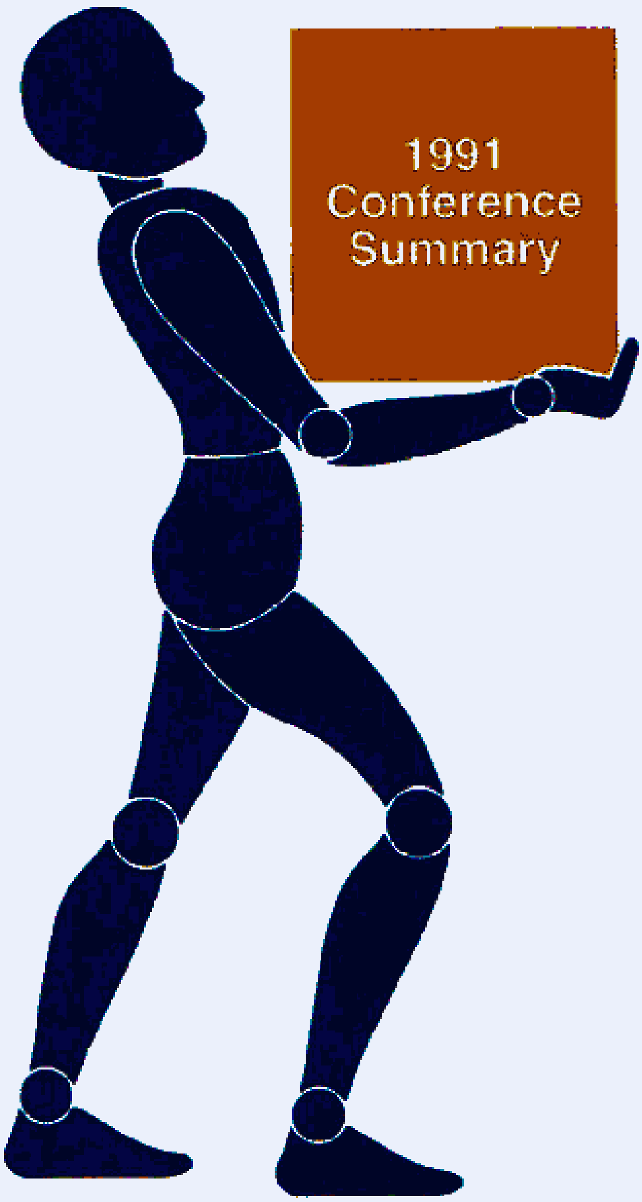

A National Strategy For Occupational Musculoskeletal Injuries:

Implementation Issues And Research Needs

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

1991 Conference Summary

A National Strategy for Occupational Musculoskeletal Injuries – Implementation Issues and Research Needs

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1.0 INTRODUCTION

1.1 Scope of the National Problem

Musculoskeletal injuries include both acute and chronic injury to the muscles, tendons, ligaments, peripheral nerves, joint structures, bones and associated vascular system. *These injuries may be reported as sprains, strains, inflammations, irritations, and dislocations.* In the medical literature, this broad class of physical symptoms or complaints is often referred to as wear-and-tear disorders, overuse or overexertion injuries, osteoarthritis, degenerative joint diseases, chronic microtraumas, repetitive strain injuries and cumulative trauma disorders.

In 1983 the National Institute for Occupational Safety and Health (NIOSH) developed and published a "Suggested List of Ten Leading Work-Related Diseases and Injuries." Severe occupational traumatic injuries such as amputations and lacerations, some of which involve acute musculoskeletal injuries, were separated from other musculoskeletal injuries such as low back pain and carpal tunnel syndrome. While severe traumatic injuries kill and maim workers, the non-traumatic musculoskeletal injuries and disorders were themselves increasingly recognized as major occupational health problems in 1983 because of the following statistics:

- Musculoskeletal injuries then were the leading cause of disability during a person's working years, afflicting 19 million persons, with nearly one-half the workforce affected at some time during their working life.
- Musculoskeletal injuries were ranked first among health problems affecting the quality of life.
- The cost of musculoskeletal injuries based on lost earninigs and workers' compensation payments exceeded that of any single health disorder.
- Musculoskeletal injuries accounted for one-third of annual workers' compensation claims.
- Musculoskeletal injuries were expected to increase with more older workers performing manual labor in certain industries.

Unfortunately, none of the above statistics have improved since 1985. Each year the Bureau of Labor Statistics (BLS) surveys the records of job-related injuries and illnesses of 250,000 employers. The results of the surveys in the 1980s recorded a sharp rise in the musculoskeletal disorders associated with repeated trauma (e.g., conditions due to repeated motion, pressure of vibration). These disorders rose from 18% of all occupational illnesses in 1985, to 52% in the 1989 survey which was reported in 1991. Manufacturing had the largest number of reported cases of repeated trauma-related disorders in 1989 with meat packing plants, poultry processing, and motor vehicle manufacturers having the highest repeorted rates in the manufacturing sector. The data from the BLS, like all surveillance data, has limitations. For example, low back pain is not recorded separately from occupational injuries such as lacerations, and is not included in the repeated trauma category.

Coupled with the large amount of human suffering caused by occupational musculoskeletal injuries is the rapidly escalating cost of diagnosis and treatment, which is born by taxpayers and consumers in terms of higher priced goods and services. Though cost estimates vary greatly, most authorities believe the medical and workers' compensation costs of these disorders are in the range of $20 to $40 billion annually in the United States. The total costs are believed to be at least double the direct costs; and these additional costs do not reflect the reduced quality of products and services produced by a worker who is suffering from such disorders, but who elects to stay on the job for economic and other personal reasons.

The Director of NIOSH, Dr. J. Donald Millar, acknowledged in his opening remarks to the Conference Attendees, that by any epidemiological criteria, occupational musculoskeletal injuries represent a *pan-epidemic problem in the U.S.* with gigantic effects on the quality of millions of peoples' lifes every year. Because the precise organic cause of the pain and functional limitations now being classified as musculoskeletal disorders are not well established in the medical sciences, diagnosis and treatment is often ineffective and expensive, which further substantiates the need to improve our knowledge and use of proven prevention strategies.

1.2 Background—Major Federal Government Initiatives

1.2.1 1970—Occupational Safety and Health Act Passed. The Occupational Safety and Health Act was enacted by the Federal Government to provide five major services:

1. Research which would provide the scientific knowledge necessary for effective identification, evaluation and control (or prevention) of all types of injuries and illnesses in the workplace.

2. Education of professionals in those disciplines necessary to both develop the new knowledge needed, and transfer proven prevention methods to the workplace.
3. A policy making and organization structure that would conduct formal reviews of existing occupational health and safety guidelines, research findings, and other consensus standards, from which to promulgate national standards for the control of specific workplace hazards and substances.
4. An organization of trained health and safety inspectors who would visit the nation's workplaces and evaluate conditions and practices to assure compliance with published standards and general occupational health and safety policies. These Compliance Officers could publicly cite and fine employers for violations of occupational safety and health standards and policies.
5. A formalized procedure by which employers can appeal OSHA citations and/or fines to an independent review commission.

The Occupational Safety and Health Act created three distinct organizations to provide these and other services. The roles of research, professional education, and the development of recommended occupational safety and health standards were delegated to the National Institute for Occupational Safety and Health (NIOSH) within the Department of Health and Human Services. The roles of developing health and safety standards and enforcing compliance with these were delegated to the Occupational Safety and Health Administration (OSHA) within the Department of Labor. A separate Occupational Safety and Health Review Commission was established to review OSHA citations and proposed assessments of penalties that are contested by employers.

1.2.2 1981—NIOSH Releases Report: "Work Practices Guide to Manual Lifting." During the 1970s NIOSH conducted research and hosted various workshops to determine the extent and cause of occupational musculoskeletal disorders. In 1978 enough information existed to support the writing of a technical report describing the need for and procedures to be used to evaluate and prevent musculoskeletal injuries caused by the act of lifting objects when located directly in front of a worker (i.e., simple symmetric lifting). The resulting report entitled, *A Work Practices Guide to Manual Lifting* was issued in 1981, and was immediately one of the most popular documents distributed by NIOSH. Several other professional health and safety organizations have reprinted the report in various forms. As such, it represents the first federal "Guide" specifically targeting an occupational activity (i.e., lifting loads), which was known to cause excessive musculoskeletal injuries. Several other countries have since adopted national standards incorporating all or parts of these NIOSH lifting recommendations.

1.2.3 1986—NIOSH Releases Report: "A Proposed National Strategy for the Prevention of Musculoskeletal Injuries." In 1985 NIOSH and the Association of Schools of Public Health (ASPH) convened a Conference involving 50 expert panelists and 450 other occupational safety and health professionals. The resulting document, released in 1986, summarizes 12 broad tactical approaches, and 23 immediate and future actions needed to understand and prevent a variety of occupational musculoskeletal injuries.

1.2.4 1990—OSHA Releases Report: "Ergonomics Program Management Guidelines for Meatpacking." As a partial response to a substantial increase in the frequency and severity of cumulative trauma disorders in the meatpacking industry, which were documented by a series of OSHA investigations, OSHA issued a document entitled *Ergonomics Program Management Guidelines for Meatpacking Plants.* The guidelines were intended to provide a starting point for design of occupational health programs to prevent work-related musculoskeletal problems by removing their causes from the workplace. The guidelines emphasized the need for management commitment and employee involvement. In addition, they recommended and endorsed the need for worksite analysis to identify the hazardous jobs and exposures by using both health surveillance, and also ergonomic risk factor assessment. Once problems are identified, prevention of the problems is initiated by use of engineering controls and work practices. The guidelines also addressed the need for a comprehensive program consisting of medical management of affected employees, and the training of managers, supervisors, employees and others in ergonomics.

1.2.5 1990s—NIOSH Research and Training Activities. NIOSH has supported a number of extramural-funded research projects ranging from field studies of exposure effect relationships between forceful repetitive work and musculoskeletal disorders, to the development of sophisticated biomechanical models of the spine during lifting. Surveillance and intervention activities undertaken by state health departments have been supported along with projects focusing on model programs to prevent the progression and aid in the rehabilitation of work-related musculoskeletal disorders. NIOSH also has an active intramural research program involving work-related musculoskeletal disorders of the back and upper extremity. Intramural research areas include the use of laboratory studies: to understand the biological mechanism of damage; to identify stressors; and to develop recommended guidelines for overhead work, asymmetrical lifting and data entry tasks. NIOSH epidemiological and field studies have been undertaken by several manufacturing, food processing, service and newspaper industries. Intervention and control projects related to back disorders have been initiated in the nursing homes, beverage delivery, and meat packing industries. NIOSH interest in prevention of occupational musculoskeletal injuries has resulted in their support of related graduate training in ergonomics, occupational medicine and industrial hygiene by individual training project grants and the Educational Resource Center program (ERCs). While a large number of specific projects have been undertaken both extramurally and intramurally, most have been funded modestly in this problem area. NIOSH also has developed and pilot tested an ergonomics training program for practicing professionals.

1.2.6 1991—Year 2000 Objectives. Healthy People 2000 is a statement of national opportunities for improving the health of the national public. Although the Federal Government sponsored its development, it was the product of 22 expert working groups, a consortium of 300 national organizations including the Institute of Medicine, and the National Academy of Science. The Year 2000 objectives are intended to improve the health of the national public. Two objectives (out of fifteen occupational health objectives) directly address issues of work-related musculoskeletal disorders.

Year 2000 Objectives Directed at Work-Related Musculoskeletal Disorders.
First Objective: Reduce cumulative trauma disorders by 40% (compared to BLS 1987 incident rates). **Second Objective:** Increase to at least 50% of the proportion of worksites with 50 or more employees that offer back injury prevention and rehabilitation programs (Baseline: 28.6% offered back care activities in 1985). **Third Objective:** Reduce work-related injuries resulting in medical treatment, lost time from work or restricted work activity to no more than 6 cases per 100 full-time workers (compared to BLS 1987 incident rates). This objective includes both traumatic and nontraumatic injuries. While objectives are important in themselves, perhaps more importantly they signify that many in the nation recognize the importance of these work-related musculoskeletal disorders and injuries.

NIOSH/OSHA Ergonomics Planning.

NIOSH continues to refine the 1981 *Work Practices Guide for Manual Lifting* to enable its application in a broader spectrum of lifting situations. OSHA continues to evaluate the format and scope of a general industry ergonomics standard.

1.3 Objectives and Process used to Develop this Report

Over five years ago NIOSH published its first strategic plan regarding the prevention of occupational musculoskeletal injuries. Because there continues to be a growing interest in the topic, it was deemed appropriate to examine progress towards implementation of the recommendations in the 1986 NIOSH plan. To perform this examination, a one and one-half day Conference was held in Ann Arbor, Michigan in April, 1991. The Conference (A National Strategy for Occupational Musculoskeletal Injury Prevention—Implementation Issues and Research Needs) was promoted and organized by the University of Michigan's Center for Occupational Health and Safety Engineering, with partial funding from NIOSH and the National Institute of Arthritis and Musculoskeletal and Skin Diseases. The objectives for the Conference were to:

- Provide a public forum for experts to discuss:
  a) strategies and resources needed to prevent occupational musculoskeletal disorders.
  b) knowledge base and research needed to provide a scientific basis for preventing occupational musculoskeletal disorders.
- Provide a means for public comment on present strategies and research activities during several panel discussions.

A distinguished group of experts participated as speakers, panel chairs and session chairs for the Conference (see Conference Participants). Approximately 400 people attended the Conference, and during three panel discussion periods they presented relevant information to the experts.

Immediately following the Conference, the invited experts at the Conference, joined by additional health and safety professionals, attended two Workshops.

The goal of the Workshops was to develop a consensus as to the state of scientific knowledge necessary to effectively prevent occupational musculoskeletal injuries. One Workshop focused on the current state of knowledge and future research needed related to the following general questions:

1. Can we correctly identify hazardous musculoskeletal stressors in the workplace (e.g., static exertion levels, postures, frequency of exertions, vibration, temperature, psychological demands)?

2. Do we have the tools needed to measure the type and extent of worker exposures to known or suspected hazardous stressors in the workplace?
3. Are there effective biomarkers indicating the existence of specific neuromuscular-skeletal tissue damage?
4. Do we have the means to identify and protect groups of individuals who may be at special risk of future occupational musculoskeletal injury?
5. Do we understand the biomechanical mechanisms that cause pathological conditions to develop from certain types of stress in the workplace?

The second Workshop group focused on the following types of strategic issues:

6. Are we deploying proven surveillance methods in a way that effectively identifies both hazards to the musculoskeletal system and also the corresponding workplace stressors to prevent injurious exposures?
7. Are we developing effective engineering and administrative methods for controlling and preventing occupational musculoskeletal injuries?
8. Do we know what resources are needed to implement and evaluate the variety of engineering and administrative controls now being proposed?

The process to answer these and other related questions was as follows:

1. A set of issues related to each of the above questions was prepared by the Workshop Chairs and sent to the participants before the Conference.
2. With the assistance of professional Conference Facilitators, the issues sent to the participants were discussed and refined at the beginnning of the Workshops.
3. The revised issues were then rated by the participants to indicate the relative need for further laboratory and field research on each.
4. The results of the ratings were verbally summarized by subgroups of the Workshop participants.
5. The important issues were further discussed by the larger group to better define the relative *importance of each.*
6. Summaries of the discussions were used to form a draft of Sections 5 and 6 in this report.
7. The entire report draft was circulated to the Workshop participants for final comment and revision.

2.0 What is Occupational Musculoskeletal Injury?

2.1 Definition of Acute and Chronic Musculoskeletal Injury

Acute musculoskeletal injury most often develops from a specific mechanical stressor that traumatizes certain musculoskeletal tissues and results in the sudden onset of pain and possibly movement limitation. An example would be when a person slips and falls while walking. The injurious mechanical stress could be of an internal type, when the neuromuscular system quickly contracts muscles to stop the impending fall as the foot slips. This unexpected muscle contraction may tear muscles and tendons in the legs, back and arms, and even dislocate joints. In other cases, the mechanical stress could be external in nature, resulting from the impact of the person with an object or floor during the fall. In this case the impact stress may rupture muscles and ligaments or even fracture bones.

In contrast, the specific site of anatomical damage in most chronic musculoskeletal injuries or disorders is less clear. Chronic work-related musculoskeletal disorders of the upper extremity have been given a number of labels including cumulative trauma disorders, repetitive trauma disorders, repetitive strain injuries, overuse syndromes, and regional musculoskeletal disorders. In cross-sectional examinations of active working groups in jobs with several risk factors for these types of disorders, many workers will report some intermittent hand, arm or shoulder pain during the course of a year. A small minority (3% to 10%) will have symptoms and physical findings consistent with carpal tunnel syndrome, while an approximately equal number will have symptoms and signs consistent with some type of hand or forearm tendinitis. Some workers will have pain and either no definite physical findings or findings not clearly related to specific anatomical sites such as a specific tendon. Many chronic cases of low back pain or neck pain are similar, in that the specific site of the anatomical damage or mechanism is unclear.

Acute and chronic work-related musculoskeletal disorders present a spectrum ranging from conditions such as a prolapsed lumbar disc or carpal tunnel syndrome, where the cause of the pain or loss of function is clear, to other conditions where the specific diagnosis is less clear. These conditions are also quite variable in terms of severity and level of impairment.

The precise number of workers affected each year by work-related musculoskeletal disorders is not known. The magnitude of the problem is very large. For example, in a recent National Health Interview Survey over five million workers reported back pain from repeated activities at work such as lifting; over one million workers reported that they had stopped working, changed jobs, or made a major change in work activity because of hand discomfort not related to an acute injury. In a similar question related to back pain, over two million workers reported they had stopped working or changed jobs because of back pain. Analysis of virtually all data sources confirms that work-related low back disorders represent a major source of human suffering and economic loss for employers, employees and society.

For work-related musculoskeletal disorders of the upper extremity, there has been a marked increase in the number of cases reported by the Bureau of Labor Statistics and a much greater recognition of these disorders by many in our society: government, medicine, media, unions, and employers. There is an active debate over whether this elevation reflects solely an increase in reporting, or changes in work in the 1980s due to an increase in economic competition or technological changes such as the introduction of computers and VDTs into the office. Most likely, the truth lies somewhere between these two explanations. Whatever the cause of this increase, it may well continue into the 1990s, because the factors that may be contributing to the increase do not seem to be diminishing (e.g., an increasingly older work force, increasing international competition for our manufacturing industries). The recognition and prevention has been characterized by Assistant Secretary of Labor for Occupational Safety and Health, Gerard Scannell.

2.2 Anatomical Structures of Concern

The musculoskeletal system provides four basic functions: 1) support of vital organs against gravity, 2) protection against external mechanical stressors (e.g., impact forces), 3) mobility to move about and reach objects within the physical environment, and 4) control of the manual forces necessary to alter performance and the environment. These four functions are made possible by the unique structure and physiological performance capability of the human musculoskeletal system.

The components of the system are arranged such that relatively small movements of muscles allow the extremities to demonstrate large motions. This is accomplished by rotating bones about several joints in a coordinated fashion. Hence, a person is capable of curling up into a small form or extending the arms and torso to reach objects several feet in front, to the side, or over the body. Unfortunately, the same structural form that provides this wonderful mobility also produces very large muscle, tendon, ligament and joint internal forces when reacting to the weight of the body and any other external forces acting on the body (e.g., hand loads). In fact, if one pushes a button with 10 pounds of force on the end of a finger, the finger flexor tendons and more proximal joints, such as the wrist, may be subjected to 50 pounds of force. Likewise, when picking up a 50-pound box from the floor, the low back muscles and spinal discs can be subjected to over 1000 pounds of force, depending on specific postures and precise motions involved.

When the internal forces become very large, as they do in many manual tasks, precise control of several different muscles also is necessary. Otherwise a single muscle, tendon or ligament becomes overstressed, and acute injury results. Further, even at levels of exertion that are well below the short-term mechanical capacity of individual tissues, injuries can occur. This is because these tissues cannot tolerate sustained or highly repeated stresses. In fact, skeletal muscles lose their capacity to contract and precisely shorten when statically contracted for several hours at only 5% of their short-term strength. This muscle fatigue results in acute pain and diminished coordination. Repeated episodes of muscle fatigue may result in chronic changes in either the structure or metabolism of muscle fibers. The precise mechanisms of these hypothesized changes have not been clearly delineated, but may be associated with chronic pain. Chronic localized neck pain, which is most likely due to muscle damage, is common in workers who persistently work for prolonged periods with their heads in a forward flexed posture.

Likewise, with tendons that are repeatedly stressed during low force, tendon fiber tears and inflammation can occur. If a tendon that is subjected to such repeated stresses also passes around or through other supporting tissues at a joint (e.g., synovium or bursa), then these may also become irritated and inflamed (i.e., tendinitis, synovitis and bursitis develops), all of which can produce chronic limitations for the individual. Typically, the resulting pain and motion limitation is progressive with each episode when associated with bouts of repetitive or strenuous exertions. The course and severity of these tendon-related disorders is quite varied. Some are mild and intermittent; others are severe and persist for long periods even after the initial cause has been eliminated. The most common name for these tendon-related disorders is "cumulative trauma disorders" based on the scientific belief that these disorders are due to repeated stresses on the tendons not the result of a single stress. The level of force and repetition that causes the chronic inflammation may not be hazardous if adequate periods of rest or recovery from mild symptoms are used.

If inflammation involves those tendons that pass through the palmar side of the hand (i.e., the finger flexor tendons) the resulting swelling in this region can entrap the median nerve in the wrist. Such entrapment produces chronic pain in the hand with loss of sensation and coordination (i.e., carpal tunnel syndrome develops). These conditions can probably be more accurately identified as work-related musculoskeletal disorders because, in some cases of chronic pain and impairment, the specific mechanism of injury is not known and cause of pain cannot be prescribed to a specific anatomical structure such as a tendon.

The spinal column and associated intervertebral discs appear to be particularly vulnerable to acute and chronic injury, perhaps because we don't readily sense the extremely high mechanical stresses on the column until the discs have already failed (i.e., after the disc outer fibers have torn and inflammation develops). In such cases, the individual may not just develop low back pain, but if the inflammation and bulging of the damaged disc tissues irritate major spinal nerve roots, then lower extremity pain develops along with diminished sensation and motor coordination (i.e., a condition known as sciatica).

Most people suffering from both acute and chronic musculoskeletal injuries will recover from their symptoms within two weeks following the cessation of the offending stresses. Unfortunately for some, particularly if significant structural damage or neural trauma has occurred, the symptoms will persist, possibly for the rest of their lives. In the case of low back pain, approximately 70% of the population report that they have suffered at least one episode of low back pain during their working lives (18-65 years old), and about 20% of the population report that they are currently suffering from low back pain. It is well accepted that once a person has suffered an episode of low back pain, he or she is at elevated risk for a reoccurrence in the next year independent of other risk factors. In other words, the tissues have been injured and recovery may not be complete although the patient is temporarily free of pain.

Many studies have indicated that individuals with the more chronic and persistent injuries tend to have feelings of depression, anger, and loss of self-esteem. They may lose their hope that they will ever be able to work again, and may in a sense give up, becoming totally disabled by their musculoskeletal symptoms. Other individuals with the same apparent level of discomfort or severity of condition will continue to work despite their symptoms. When musculoskeletal complaints persist, health care providers, family, friends and employers often become frustrated and even skeptical about the physical nature and extent of the injury.

It is likely that an individual's reaction to an injury or disorder depends on many things such as his or her ability to adjust to the working environment and to the impairments. In all of these conditions, the longer a person is on sick or disability leave, the smaller the likelihood that the individual will return to work. Partially as a result of this observation, more attention has been placed on earlier comprehensive rehabilitation programs that address all of the potential barriers to returning to work, such as the need for physical reconditioning, psychological counseling, and redesign of the work environment. In addition, these programs attempt to reduce the need for surgery. Very few prospective studies have been undertaken which allow us to understand the complex interaction between the individual psychological reaction to an injury, the severity of the injury, and the nature of the work environment from both a social and physical perspective. One of the most controversial issues is the extent to which psychological causes explain impairment from the musculoskeletal injuries and disorders. Regardless of the precise interactions, in a very real sense, it is accepted that the afflicted individual can become both physiologically and psychologically disabled. This is one reason why musculoskeletal injuries are reported to cause so much loss in the "quality of life."

3.0 What are the Suspected Occupational Risk Factors?

3.1 Multi-Factored Risk Model

Several occupational risk factors have been linked to the incidence of musculoskeletal injuries. The most frequently cited occupational risk factors for disorders such as low back pain and upper extremity cumulative trauma disorders include: repetitive exertions, forceful exertions, awkward postures, mechanical stress, vibration, and cold temperatures. Often, workers are exposed to more than one risk factor. Currently, there are no extensively validated models to precisely determine a worker's risk level without some degree of uncertainty for a specific musculoskeletal disorder, based on his/her exposure to one or more of these occupational risk factors.

Repetitive exertions have been identified as one of the leading workplace risk factors for upper extremity cumulative trauma disorders. The repetitiveness of a lifting task also is associated with an increased incidence of low back pain. The repetitiveness of an operation can be described in several ways including: (1) the number of cycles per hour, (2) the number of lifts per hour, (3) the number of steps (exertions) included in each work cycle, or (4) the total number of exertions per hour.

Forceful exertions performed by the upper extremities in a hand-intensive task or by the whole body in a lifting situation are associated with the development of musculoskeletal injuries. The force requirements of a job are related to the weight of the object lifted or carried, the slipperiness of objects being gripped, and other manual reaction forces such as torque. Work pace, the use of gloves, and hand posture have been shown to increase the force requirements to perform a task.

Awkward postures of the upper extremities and torso have been identified by researchers and linked to the incidence of musculoskeletal disorders. Standing erect with the arms hanging at the side is considered to be a non-stressful posture. Working with the torso bent forward, backward, or twisted can place excessive stress on the low back. Other examples of high stress postures include reaching above mid-chest height, reaching behind the body, elevating the forearms, rotating the forearms, and bending the wrist forward, backward, or side to side.

Mechanical stresses are created when the soft tissues of the body are squeezed between a bone and an object in the work environment, such as when squeezing tools or leaning on a work table. Common sites of mechanical stress concentrations are the palm of the hand, forearm, fingers, elbow, back of the knees and buttocks/low back. Mechanical stress can be produced by pounding with the palm on a tool or work piece, using a tool that presses into the base of the palm, positioning the forearm or elbow on a hard surface, or sitting on an unpadded seat.

Vibration exposure is of primary concern when exposure is continuous or of a high intensity. Workers can be exposed to either whole body vibration or localized vibration. Whole body vibration is experienced by tractor, heavy construction, truck, and bus drivers. Localized vibration exposure of the upper extremities can be caused by the power or impact tools that are used in many materials assembly and maintenance operations.

Cold temperatures reduce manual dexterity and accentuate the symptoms of nerve impairment. Hands can be cooled below 20°C by exposure to environmental temperatures, contact with cold materials, or by exposure to cold exhaust air from a power tool.

More than one risk factor can often be identified for various tasks. In particular, the major cause of low back pain is lifting of loads which are either 1) too heavy, 2) placed in a location that requires an awkward torso posture, or 3) too frequently lifted or carried. Pushing, pulling and twisting of the torso also are considered hazardous to the low back in certain situations. It is estimated that perhaps as many as one out of three jobs in the U.S. require strenuous exertions which could be considered hazardous to a person's back.

Because it is not simply the weight of an object being lifted that causes over-stress of the low back, hazardous lifting conditions can only be recognized when several different job factors are considered. For example, lifting a 50 pound object held close to the body may impose less stress on the low back than lifting a 20 pound object at arms' length. If an object is lifted at the side of the body in a manner that requires the torso to be twisted or when the load is moved quickly, much higher back stresses can result than if lifted with both hands in front of the body or in a slow smooth motion. Similarly, repeated lifting of objects, such as on a production line, can cause muscle fatigue that produces low back pain. Stress on the low back can also be created by working in awkward postures when the body must support the weight of the torso alone without a load.

The upper extremity (and particularly the hand and forearm) also appears to be highly vulnerable to repeated forceful exertions. If manual tasks are performed in postures that concentrate the injurious stresses on specific shoulder, elbow, or wrist tissues, than those regions will deteriorate. Hence, working for prolonged periods with the arms raised above the shoulder causes upper back and shoulder pain, muscle fatigue, tendinitis, and bursitis. Similarly, turning the lower arm about its long axis, such as when screwing or unscrewing objects, while the elbow is in an extended position can produce elbow tendinitis. Repeatedly flexing and extending the wrist while forcefully squeezing a hand tool will result in tendinitis, tenosynovitis and even median nerve entrapment (i.e., carpal tunnel syndrome) at the wrist.

If a person is exposed to vibration, from either using a powered hand tool or riding in a vehicle without adequate suspension, the vibration energy is absorbed by the musculoskeletal system. When the vibration is of a certain magnitude and frequency it can combine with other stressors (e.g., postures, forces and repetitive exertions) to over-stress the musculoskeletal system. Likewise, cold temperatures may act in a synergistic fashion to increase musculoskeletal stress.

Psychosocial factors also are being linked to the incidence of musculoskeletal injuries. The most important psychosocial factors are related to time pressure, level of control, role of ambiguity, and job security. The effect of these factors on an individual depends not only on the level of the stressor, but also on a person's opinion concerning medical care, coping strategies, self-esteem, social support at home and at work, and family or financial problems. Though the evidence that psychosocial factors cause musculoskeletal injuries is circumstantial at this time, there is no doubt that they play a major role in determining the amount of suffering and disability incurred by an individual.

When a manual task is studied to identify the risk factors associated with the development of musculoskeletal disorders, it is necessary to look for the presence of multiple risk factors for each body joint. Examples of jobs which contain multiple risk factors will be discussed below.

Operations containing occupational risk factors

EXAMPLE 1. In a manufacturing facility, workers transfer a 54-pound cylinder head from a multi-level pallet to a 32-inch conveyor. 325 heads are transferred per hour. The operator loads cylinder heads for one hour and then has lighter duty tasks for 30 minutes. The heads are placed 16 per tier, and are stacked in five tiers on the pallet; the pallet is placed on a platform that is 23 inches above the floor, and the top height is 50 inches when there are five tiers of cylinder heads on it. The operator uses a special tool to pull distant heads closer to the front of the tier, but he/she still reaches as far as the middle of the tier to pick up the heads. Figure 1 depicts a worker lifting a cylinder head from the bottom tier. Among the most important risk factors associated with this operation include: (1) stressful torso and shoulder posture when picking up the head; (2) repetitive exertions, and (3) forceful exertions when picking up and transferring the head.

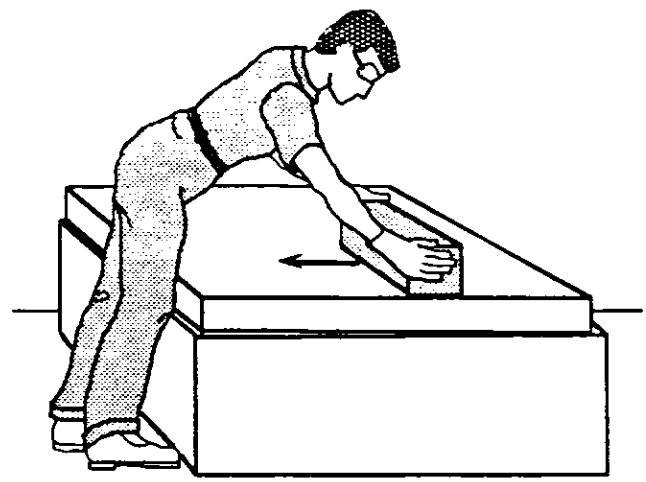


FIGURE 1
Transferring a 54-pound cylinder head from a multi-level pallet to a conveyor.

EXAMPLE 2. In another manufacturing facility, workers are seated at a conveyor and secure a metal plate to a small engine (see Figure 2). Workers use an air-powered pistol shaped tool to drive four screws and then fasten two connectors. 327 cycles are performed per hour. Among the most important risk factors associated with this operation include: (1) awkward wrist posture when driving the screws, (2) repetitive exertions, (3) forceful exertions to fasten the connectors, (4) vibration exposure while using the screwdriver, (5) mechanical stress concentrations on the hand from the sharp edges of the tool and the connectors, and possibly (6) exposure to cold temperatures if the connection between the tool and the air line is not secure.

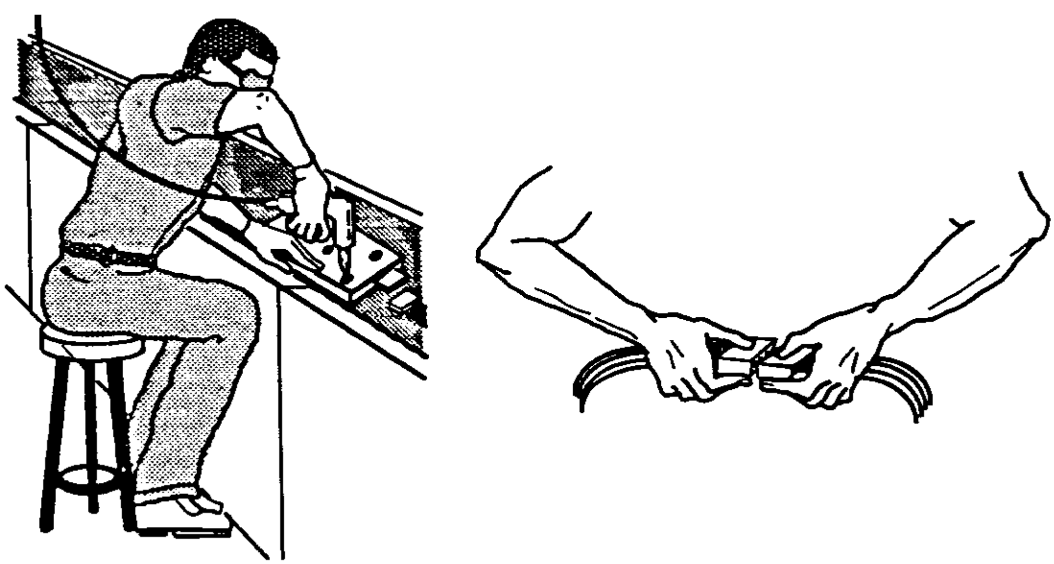
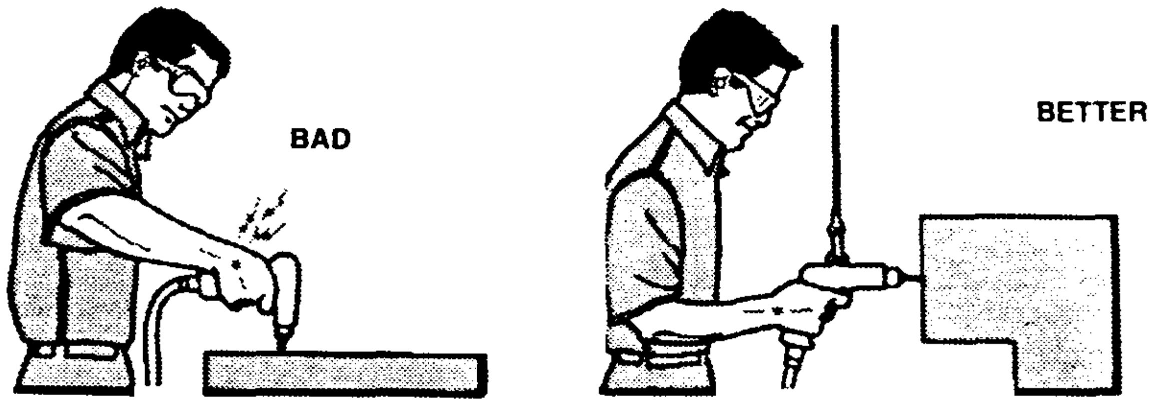


FIGURE 2
Workers secure a metal plate and fasten connectors.

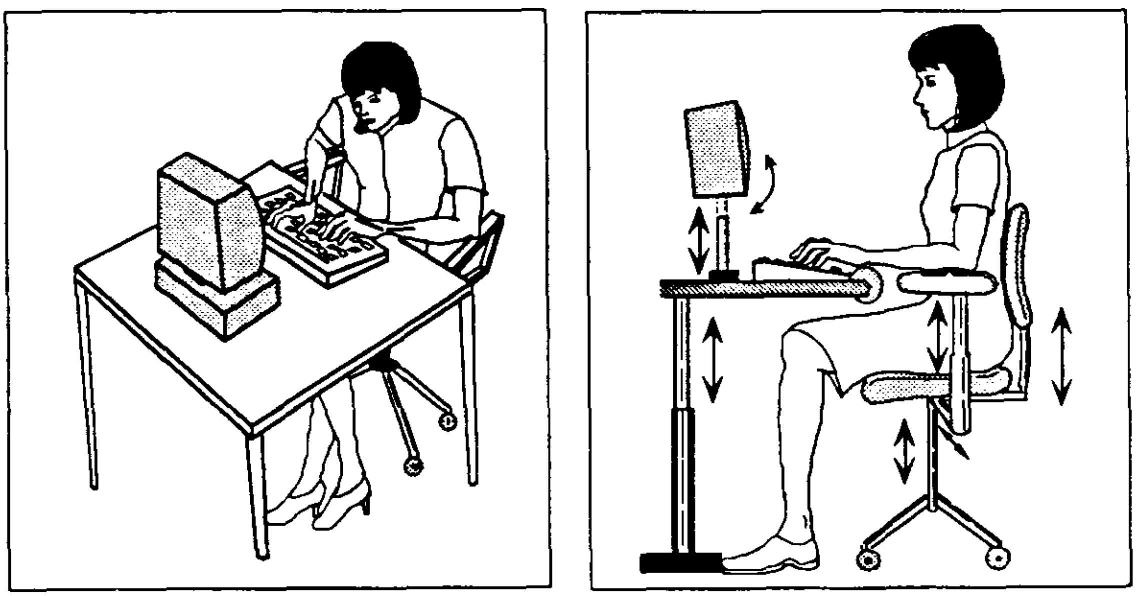
EXAMPLE 3. The worker drives screws with a pistol shaped tool on a horizontal surface that is located at elbow height. In this posture, the worker has a deviated wrist, and an elevated elbow and upper arm (see Figure 3a). Other risk factors associated with this task are repetitiveness and forcefulness. The posture requirements of the job can be improved by using the pistol tool on a vertical surface (see Figure 3b).



(a) (b)

FIGURE 3
Worker drives screws with a pistol tool on a horizontal surface (a) and a vertical surface (b). (Adapted from Armstrong, 1986)

EXAMPLE 4. The word processor who types all day at this computer work station has her elbows resting on arm rests that are too far apart, elevated forearms, and wrists bent forward while resting on a hard tabletop (see Figure 4a). The risk factors associated with this operation include posture stress, repetitiveness, and mechanical stress locations on the forearm. Figure 4b illustrates some of the changes that can be made to this computer work station to reduce the impact of the risk factors. In this example a chair with adjustable and padded arm rests, seat pan height, and back rest height was introduced together with an adjustable table, an adjustable monitor, and a wrist rest.

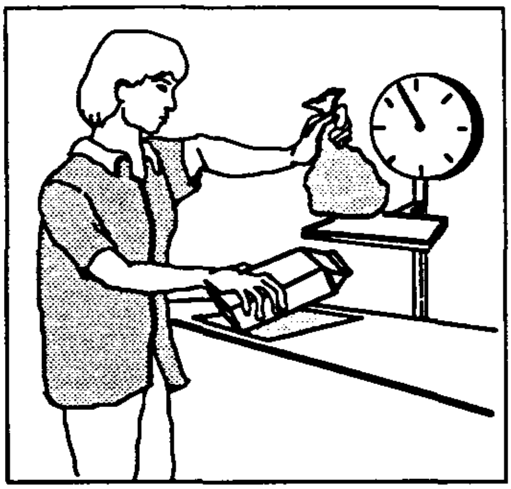


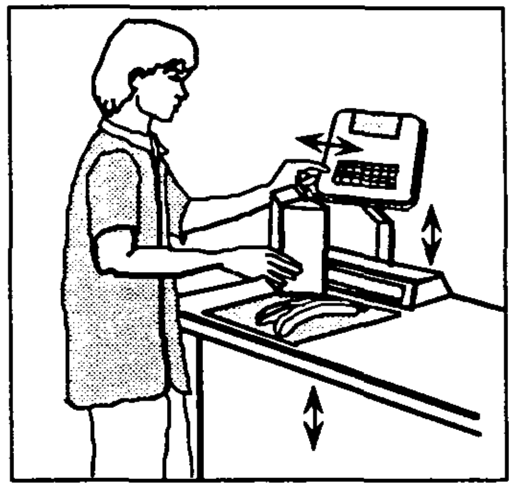
(a) (b)

FIGURE 4
A keyboard operator uses a work station that contains several risk factors (a) and an improved work station with many adjustable features (b).

EXAMPLE 5. Cashiers scan 20 items per minute and the work pace is averaged over the entire work time (i.e., bagging and receipt of payment is included in total time). Consequently, the cashiers are actually scanning faster than 20 items per minute. The cashier in Figure 5a is using a horizontal scanner. Awkward wrist postures are present when scanning cans, milk, and other items. Grocery items often weight up to 20 pounds. The scale is often placed at the cashier's mid-chest height and this creates an elevated elbow and forearm when weighing fresh vegetables and fruits. A work station with an adjustable vertical scanner and a scale directly in front of the cashier that is installed in the work surface (see Figure 5b) can help reduce some of the stress associated with the job.

(a)





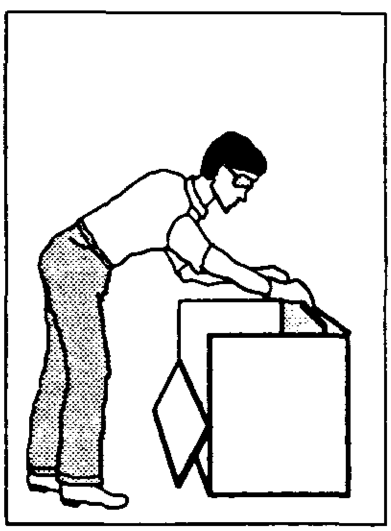
(b)

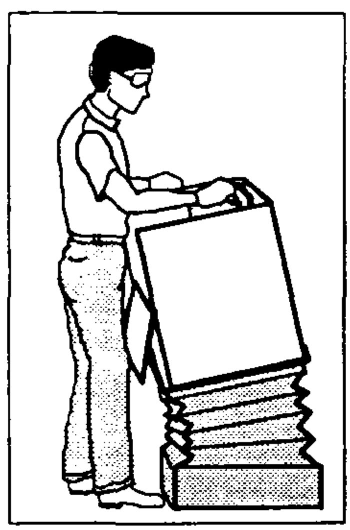
FIGURE 5

A grocery cashier scans items using a horizontal scanner (a) and an adjustable vertical scanner with the scale positioned on the work surface (b).

EXAMPLE 6. The assembly worker lifts a 15-pound glass window from a bin (see Figure 6a). The glass is positioned in slots to avoid sliding forward and consequently breaking. Because the worker must reach across the bin to pick up the glass windows, there is a large horizontal distance from the worker's ankles to his hands at the beginning of the lift. The lift originates at knuckle height and the window is placed into the car door at mid-chest height. One lift per minute is performed. By positioning the bin on an adjustable tilt table, the worker can keep the glass closer to his body and have an erect posture as he lifts the glass out of the bin (see Figure 6b).

(a)





(b)

FIGURE 6

Worker lifts windows from a bin that is positioned on the floor (a) a bin that is located on an adjustable tilt table (b).

EXAMPLE 7. The assembly worker loads a 25-pound apron from a conveyor into a welding fixture. 450 loads per hour are performed (see Figure 7a). To load the apron, the operator must spend much of his day bent forward. By reducing the distance between where the operator must stand and the locating pins onto which the apron is positioned, the amount of forward bending is reduced (see Figure 7b).

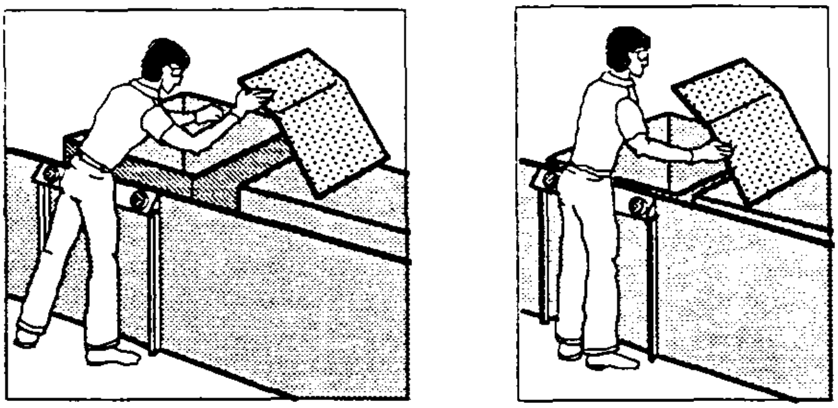


FIGURE 7
Worker loads an apron into a welding fixture that requires forward bending (a); and forward bending is reduced by locating the conveyor and bin closer to the worker (b).

In summary, it should be apparent that many different conditions can over-stress and injure the musculoskeletal system and that these are:

1. prevalent in the workplace,
2. complex and multifactorial in nature, and
3. require comprehensive programs to recognize and control.

The next section will discuss methods for identifying various job hazards.

3.2 Methods for Identifying Job Hazards

A systematic approach to job analysis is often used to document the whole task and work environment, and then identify the occupational risk factors. In the first stage, job documentation is accomplished through discussions with workers, supervisors and engineers, and by direct observation of a job. Job documentation should contain the work objective, work standard, the elements or steps required to be completed, the tools and equipment used, the physical characteristics of the work station, and the environmental conditions. The job documentation is then used to determine the existence of each occupational risk factor. In a detailed ergonomic assessment, each work element is examined to determine if any of the occupational risk factors are present. Once a risk factor is identified, the work characteristics that effect the potential severity of the risk factor are documented. Checklists have been developed to help lead the analyst through the job documentation and ergonomic assessment process.

Several computer and analytical models have been developed to estimate the physical requirements of work. Both a *two-dimensional* and *a three-dimensional static strength prediction model* have been developed to estimate low back spinal compression forces and to predict static strength requirements of manual material handling tasks such as lifts, pushes or pulls. Dynamic biomechanical models have been developed and validated in laboratory settings. These indicate that peak stressors created during certain types of manual exertions could cause increased risk of injury. A *metabolic energy expenditure prediction model* estimates the energy requirements of a wide variety of manual material handling jobs. The model predicts the energy expenditure associated with each element and the entire job. *Posture analysis* can be performed to identify the awkward postures present in each job cycle and the percentage of the cycle that the worker spends in all the identified postures. The *NIOSH Work Practices Guide for Manual Lifting* determines the allowable weight of a load that can be lifted for a specific condition.

Computer aided design in conjunction with anthropometric manikins can be used to view the interaction of the worker with the work station before a new job is actually constructed or current job is redesigned. These mock-ups can be used for early identification of potential occupational hazards.

Researchers are beginning to combine various prediction models into integrated software packages.

One system combines three-dimensional static strength and back compression models, a metabolic energy expenditure prediction model, the NIOSH *Work Practices Guide for Manual Lifting*, a low-level motion time prediction model, a posture prediction algorithm, and a three-dimensional computer graphics manikin. A database of tasks for a particular operation is created, and then the appropriate models can be used to estimate the physical stress of specific tasks, or the physical stress for the entire operation.

New instrumentation is now available to estimate the stress of an occupational task while the worker is performing it. *Electromyography* (EMG), recording the electrical impulses of the muscles, can be used to estimate the force requirements of a job. *Goniometers* and other *motion analysis systems* can be used to measure postures as people are working.

Discomfort questionnaires have been successfully used to identify work station parameters that need to be changed. A discomfort questionnaire usually consists of a body diagram in which workers shade the areas of the body at which they feel discomfort while working. Then workers rate the severity of the discomfort at each identified body part. Based on the discomfort ratings and observation of the job, the tasks that lead to the discomfort can be identified and modified. After the modifications to the work station are complete, the discomfort questionnaires can be used again to measure the change in worker discomfort.

Questionnaires have also been developed to measure *psychosocial stress* experienced at work. These surveys attempt to quantify a worker's mood; perception of control; relations with supervisor, management and co-workers; and other variables associated with the psychosocial stress at work.

4.0 Non-Occupational Factors and the Risk of an Occupational Musculoskeletal Injury

The epidemiological studies of musculoskeletal disorders or injuries of the type that are commonly associated with work factors are still at an early stage and have tended to focus more on low back pain than on disorders of the upper extremity. Results of surveys done on active workers in high-risk industries may differ from those done on the general population. The former tend to identify most clearly the role of the work-related factors while the latter tend to identify the non-occupational factors. In both workplace and community studies, preexisting medical conditions rarely explain the majority of new cases of musculoskeletal disorders or injuries such as low back pain or shoulder pain. Examples of these preexisting conditions are rheumatoid arthritis, diabetes mellitus, and myxedema (very low thyroid function), all of which have been associated, for example, with carpal tunnel syndrome.

Musculoskeletal injuries or disorders such as low back pain and carpal tunnel syndrome can be caused by non-occupational factors or exposures. While epidemiological studies of low back pain the general population have, in general, failed to identify factors which are strong predictors or correlates of low back pain, there is some evidence that cigarette smoking, number of births or pregnancies, distance traveled to work, and perhaps heavy alcohol consumption are modestly related to the risk of developing low back pain. Psychological factors often affect the reporting of and recovery from back pain although it is difficult to determine whether the psychological factors predate the onset of back pain or are the result of it. Some occupational factors such as lifting, twisting, prolonged sitting, and driving, of course, occur during recreational activities and may be a cause of low back pain. Medical evaluation of low back pain conducted by primary care physicians often fails to identify the specific cause of the low back pain.

The work-related disorders of the upper extremity are a diverse group of conditions ranging from carpal tunnel syndrome and rotor cuff tendinitis to regional pain which cannot be related to a specific anatomical structure. The diversity of these conditions, most of which have not been studied epidemiologically, makes it difficult to generalize about nonoccupational causes of these conditions. Non-occupational activities, such as sports activities, certainly can cause a variety of tendinitis of the upper extremity. The best studied non-occupational causes of carpal tunnel syndrome are co-existing medical conditions such as rheumatoid arthritis, acute trauma, and pregnancy.

The community and workplace studies have also addressed whether the rate of musculoskeletal complaints, disorders or injuries vary by gender and age. In community-based studies, the prevalence of low back pain is not strongly related to age after the age of 30, or to gender. In 1988, the National Center for Health Statistics conducted the National Health Interview Survey in an effort supported by NIOSH. It inquired about back and hand pain in national representative samples of 60,000 Americans to assess the relative magnitude of work-related pain. In this survey the prevalence of back pain was similar in men and women (18% and 17%) and varied little with age. Men had a somewhat lower prevalence of hand discomfort than did women (8% versus 11%). The prevalence of hand discomfort increased with age from a rate of 6% for those less than 35, to 14% for those over 55. In workplace studies conducted by NIOSH, age is generally not a strong predictor of hand discomfort or work-related disorders.

One of the upper extremity disorders that has been studied both in the community and in the work force is carpal tunnel syndrome. While most clinical series of carpal tunnel surgery report a ratio of about one to three (men to women), studies from the workplace do not consistently report a higher risk for women. In a study of occupational carpal tunnel syndrome based on the workers' compensation system in Washington State, the mean age and female/male gender ratio differed substantially from the population-based studies (work-related—37 years and F:M=1.2:1; and population-based all cases—51 years and F:M= 3:1).

From biomechanical studies it is logical to hypothesize that some personal characteristics of an individual such as the strength of the muscles of the trunk or the size of the carpal tunnel might be associated with the risk of developing a musculoskeletal disorder or injury. General studies, however, have not consistently demonstrated that there are any reliable or strong personal predictors of upper extremity disorders or injuries. Although it is reasonable to assume that individuals with work-related disorders who return to the same jobs that caused or triggered their initial injury have an increased risk of developing a second disorder, this has not been studied for upper extremity disorders. There is evidence that a history of recent low back pain is associated with a modest increase in the future risk of additional episodes of low back pain. With regard to low back pain, there is some evidence that stronger individuals may be at a lower risk of developing low back pain when performing lifting tasks over the period of a year. However, there is also some evidence which also suggests that muscle strength and tissue resistance to future stresses may not be strongly related. In a ten-year prospective study of both white and blue collar workers, there was no relationship between the strength of trunk flexors or extensors and the ten-year incidence of low back disorders. However, this and similar studies are limited because the specific job demands were not related directly to the workers' individual characteristics, as was done in earlier, short-term studies that found a positive relationship between job related strengths and injury rates.

5.0 What Fundamental Research is Needed to Understand the Causes of Occupational Musculoskeletal Injuries?

What follows in this and the next section are summaries of recommendations for specific research needed to understand and prevent occupational musculoskeletal injuries. These recommendations represent the consensus of the attendees from the two different Workshops. They are presented within the framework developed by the NIOSH Board of Scientific Counselors. One workshop dealt with research issues, and their results are summarized in Section 5.0. The second workshop discussed prevention strategies, and their recommendations are contained in Section 6.0. The topics in the two sections are as follows:

Section 5.1	Identification of Potentially Hazardous Job Stressors
Section 5.2	Measurement of Worker Exposures
Section 5.3	Identification of Individuals and Populations at Special Risk
Section 5.4	Mechanics of Occupational Musculoskeletal Injury
Section 6.1	Effective Hazard Surveillance and Related Injury Identification
Section 6.2	Development of Effective Injury Control and Prevention Strategies
Section 6.3	Effective Use of Controls

5.1 Identification of Potentially Hazardous Job Stressors

It should be clear from the preceding information that the human musculoskeletal system is vulnerable to a variety of stressors common to many different occupations. One goal of prevention programs is to be better able to identify those activities that act singularly or in combination to produce a significant stress on the musculoskeletal system.

The Workshop participants recognized that overt and strenuous physical acts, such as those associated with lifting, carrying, and handling of heavy loads, can be reasonably well identified by contemporary job analysis procedures, though these procedures may not be widely used (see subsection 6.0). It is much more difficult to recognize tasks that may stress specific musculoskeletal components due to repeated but less forceful exertions performed sometimes in awkward postures. The Workshop participants believed that it is very important to have improved methods by which a large variety of manual tasks can be objectively studied in a variety of manufacturing and service industries. The participants proposed that new or improved job stress analysis methods are needed which will identify musculoskeletal stressors associated with:

1. work performed in pace with a machine, or when extra pay is provided to encourage a worker to exceed normal production rates (e.g., piece pay incentives);
2. physical movements performed at high speeds and with high precision;
3. static exertions performed for long periods (e.g., while maintaining an awkward posture or while working at a video display terminal); and
4. localized mechanical stresses that compress musculoskeletal tissue and compromise circulation (e.g., when sitting on a hard chair

without adequate seat pan padding or with poorly designed back and arm supports).

The Workshop participants also expressed concern that some job requirements may act in synergy with other factors to over-stress the musculoskeletal system. The following were cited as examples wherein certain stressors may not be identified as unusual by themselves, but when associated with other manual exertions, the combination may be hazardous, and should be identified for further evaluation:

1. low level exertions that are repeated quite frequently (e.g., VDT keyboard entry tasks);
2. an adverse psychosocial climate at work as characterized, for example, by ambiguous work roles, insufficient supervisory support, lack or work autonomy, job insecurity, etc.;
3. extended work days and/or changes in one's work shift;
4. vibration that is either localized (e.g., from hand tools) or affecting the whole-body (e.g., from vehicles);
5. heat and/or cold work environments.

Chemical exposures at work and other exposures such as cigarette smoking might be important determinants of musculoskeletal disorders. Studies are needed to determine whether these non-physical exposures substantially increase the risk of exposures to other occupational factors.

5.2 Measurement of Worker Exposures

The preceding section has listed a variety of specific work conditions wherein research is needed to develop and validate methods that can be used to correctly identify harmful stresses on the musculoskeletal system. To enable such stressors to be quantified, the Workshop participants urged that research be performed to improve the technology needed to accurately and reliably *measure* (quantify) the following job and work performance attributes which singularly, and in combination, may produce damage:

1. repetitive motions of small body segments (e.g., finger and hand motions used in fast keying operations);
2. extreme work postures (e.g., reaching, twisting, bending);
3. internal muscle exertion levels associated with different types of manual work that are estimated using electromyographic, acoustical myographic, and other yet to be identified methods;
4. external force, torque and pressure requirements of a variety of manual jobs (e.g., as caused by grasping, lifting, pushing and pulling of objects);
5. vibration levels and frequencies on jobs caused by hand tools, vehicles and other moving equipment;
6. varied work/rest periods throughout the work shift, and prolonged work hours as well as rotating shift work.

It also was recommended that the above job and work attributes be measured by statistical sampling methods where possible. Developing and using such sampling plans will reduce future need to perform continuous monitoring of workers. Statistical sampling methods can also provide an efficient means to include larger numbers of workers and jobs in future job stress surveys.

As the preceding recommendations indicate, there was agreement that we need to improve the methods used to identify and measure job stressors that may be hazardous to the musculoskeletal system. In this context, the role of biomarkers and histological data to confirm the presence of specific tissue damage was discussed. Though laboratory research to refine such tests and procedures for improved diagnostic purposes was supported in general by the Workshop participants, at this time, this type of effort was not deemed to be as important to prevention of musculoskeletal injuries as the other actions recommended in this section.

5.3 Identification of Individuals and Populations at Special Risk

The capacity of individuals to perform most physically stressful tasks without harm varies substantially in any normal population. As a result, the probability that a given task may over-stress a particular individual depends on the specific characteristics of the individual. In this context, the Workshop participants proposed that both laboratory and field based research is needed to improve the various methods and procedures needed to assess individuals who may be at elevated risk due to prior injuries or restricted work capacities. In this regard, it was proposed that the research should concentrate on improving those worker evaluation methods that are *directly related* to specific job requirements, as opposed to generic physical performance tests of strength, flexibility and endurance. Generic physical performance tests were recognized to be of benefit in determining the general physical fitness of an individual relative to peer population norms, but such information has not been shown to be important in assessing an individual's risk level when assigned to a specific job or manual task. It was concluded that individual risk assessment is a much more complex matter that will necessitate comprehensive research programs based on knowledge of both job and worker attributes. One of the principal reasons that valid individual risk assessments are difficult to establish scientifically is the need to measure on a long-term basis the changes in an individual's capacities, job demands, exposure to non-occupational factors and health outcomes. Though expensive and time consuming to conduct, the need to develop and validate job-related physical ability tests that will accurately predict the risk of future musculoskeletal injuries is supported. Information from such tests will also provide a basis for better design of the work environment to accommodate older workers and those with acknowledged impairments. The recently passed American with Disabilities Act will encourage wider spread use of job-related testing and evaluation technologies. A more accurate ability to predict future risks should not be used as justification for failure to adopt preventive strategies that rely on primary prevention, however.

5.4 Mechanics of Occupational Musculoskeletal Injury

Though it is possible to develop effective prevention strategies based on epidemiological studies that result in a positive statistical association between certain job and/or worker characteristics and increased incidents of musculoskeletal injury, it is always desirable to understand how a particular job stress actually injures specific musculoskeletal tissues. Since the insult to musculoskeletal tissue is normally of a mechanical nature (i.e., the force or stress on a tendon, muscle, ligament, or cartilage exceeds the tissues' tolerance), the Workshop participants strongly urged that *fundamental biomechanics research* be supported to understand how specific occupational stressors cause tissue trauma and disability. In this context, the following types of basic research were recommended for increased support:

1. Worker population physical stress tolerances (strain limits) for different musculoskeletal tissues must be more precisely determined through both biomechanical and psychophysical (discomfort rating) studies.
2. Biomechanical models now being developed to simulate and predict the physical stressors associated with manual jobs need to be improved to more accurately predict internal tissue stresses on specific muscles, tendons, nerves, and joint structures. These models need to include normative tissue failure limits (from research in 5.4.1 above), thus being able to predict the risk of certain types of musculoskeletal injuries when individuals perform specific manual tasks.
3. Anatomical regions in need of further fundamental occupational biomechanics research are (in descending order of importance):
   - Back and Shoulder/Neck Complex
   - Upper Extremity (including elbow and wrist)
   - Lower Extremity (including hip, knee and ankle).

   The importance of job related biomechanics research on the lower extremity is expected to increase as more older workers comprise certain job categories that require prolonged standing and walking.
4. Empirical laboratory and field studies are needed to verify biomechanical model predictions of musculoskeletal stress. Though animal studies may be of some value, the Workshop participants supported the development and use of newer sophisticated physiological measurement techniques (e.g., EMG, Acoustic Myography, tissue pressure) with human volunteers for such studies. Also needed are epidemiological studies that include the evaluation of newer biomechanical model stress predictions and physiological measurements.

6.0 What Research is Needed to Provide the Most Effective Prevention Strategies?

The recommendations is the preceding Section 5 are meant to guide research toward better understanding of the causes of occupational musculoskeletal injuries. This section presents recommendations that emphasize the need to develop, implement and evaluate a variety of prevention strategies.

6.1 Effective Hazard Surveillance and Related Injury Identification

Currently, most surveillance systems fail to collect information simultaneously on job hazards (the level of exposure to stressors) and health outcomes. Research into the design and evaluation of surveillance systems that effectively collect, analyze, and utilize this combined information to target intervention activities is needed.

Hazard Surveillance

One of the challenges is to develop and validate effective tools for assessing the presence of job risk factors. Since hazard surveillance may not require a high level of quantification or precision in assessing exposure, simple tools like checklists may be effective. Checklists may be a valuable tool because they can be used by people with limited ergonomics training but with great knowledge of the job, and require a small amount of time to evaluate a job task. One of the exposure parameters which will require the most careful validation is the estimation of force. This will require considerable methodological development and evaluation.

In addition, simple surveillance tools are desirable to assess segmental and whole body vibration, localized mechanical stresses, and postural variability in workers performing the same tasks. Surveillance tools are needed to tackle two other areas of job exposures that are likely to be of increased importance in the future; these are psychosocial factors which currently are measured strictly by the use of questionnaires, and the effect of micro pauses and rest work cycles. If simple methods can be developed for jobs without complex and highly variable tasks, then the challenge will be to extend the methods to the more difficult situation of complex and variable job tasks.

In addition to checklists, a continuing area of interest is the clarification of the roles of the worker and supervisor questionnaires. While not useful in quantifying risk factors, questionnaires may be useful in determining whether risk factors are present or absent. Questionnaires may be most applicable to jobs that involve a large number of varied and complex tasks. Psychophysical scaling of perceived risk factors may be more useful than checklists when the jobs are complex and varied. Workshop participants gave top priority to studying the integration of subjective perception of risk with direct objective methods of assessing risk factors or exposure conditions. Workshop participants recognized that some methods for job analyses such as checklists, questionnaires, the Ovaco Working Posture System (OWAS), and others, have already been developed for both research and surveillance purposes. The limitations and strengths of each possible approach for effective hazard surveillance need to be evaluated. These studies need to focus not only on how accurately these systems identify job risk factors, but also whether these methods are feasible surveillance tools. For an approach to be feasible, it should require only a modest amount of user training and not be too time consuming to use. It will be important to determine user acceptability for new proposed surveillance tools. The proper tools will not only need to consider the type of exposures, but also the size of the exposed population.

Health Surveillance

While job hazard surveillance is an important area, the Workshop had some recommendations regarding health surveillance or the identification of injuries and disorders. Health surveillance activities at the national, state, corporate, and plant level are based on the use of existing records. Examples of this passive surveillance are workers' compensation records or the OSHA log. Current consensus contends that passive surveillance data can be useful to trigger follow-up investigations. Evaluation of such passive data systems is needed to examine whether or not this is valid. One of the features of existing systems that need further standardization is the recording and detection of adverse health outcomes. One approach is the development of improved case definitions, however, this will be difficult until there is the development of more precise and accurate clinical diagnostic techniques for many musculoskeletal regional syndromes such as low back, neck or hand-forearm pain. Workshop participants proposed that surveillance data may be useful in research to determine whether the success of rehabilitation of workers with injuries is related to the duration and intensity of their past exposure to stressful work. In addition, research is needed to determine if surveillance techniques, which include a history of a workers' past injuries from previous jobs and specific information about a person's functional limitations, might provide better information about predisposition to future injury.

6.2 Development of Effective Injury Control and Prevention Strategies

Workshop participants identified four areas for injury control and prevention: 1) engineering controls, 2) personal protective equipment, 3) administrative controls, and 4) adequate treatment that includes rehabilitation of the injured worker. Although a division between engineering and administrative controls was cited, many felt that this separation may be detrimental to an effective prevention program.

Engineering Controls

Engineering-based specifications and designs determine a job layout and process, which in turn creates the hazardous exposures of a specific job. Engineering controls are designed to reduce or entirely eliminate the hazardous exposures. However, following the installation of controls, it is rare to reevaluate the new exposure conditions to examine if the risks have been substantially reduced. The Workshop recommended that studies should be undertaken to investigate the effectiveness of existing and proposed engineering controls. Some of the evaluation approaches are not complex. For example, the use of the workers' assessment of discomfort and mild symptoms before and after engineering changes can be very useful.

Additionally, these studies should also examine the approaches used to determine if engineering controls are required, and to suggest specific engineering solutions. For example, we have had tools for over ten years to predict the risk of lower back pain and injury (e.g., NIOSH *Work Practices Guide to Manual Lifting*), but these tools have not been extensively validated in industry. Basic biomechanics research is still needed in the area of developing new engineering controls for low back injury and Upper Extremity CTD (see Section 5.0). In addition, field studies are needed to compare the variety of methods of controls now being proposed and developed.

Mechanical aids to lift and transport objects (e.g., hoists, articulated arms) are also used in industry. Research is needed to determine their effectiveness in preventing injury, and to identify possible additional stressors they may cause if improperly designed or used.

Personal Protective Equipment

Although Workshop participants strongly preferred the use of engineering controls to eliminate jobs hazards, personal protective equipment (PPE) such as gloves, padding, wrist splints, wrist rests, and weight lifting belts, are commonly used by workers in an attempt to reduce injury. Many Workshop participants strongly felt that workers and companies are using PPE in place of good workplace design and other engineering controls. Some participants felt that resources should be immediately directed to determining the efficacy of PPE-based approaches, since claims of injury prevention are often made, but rarely substantiated by scientific studies.

Administrative Controls

Workshop participants strongly cited a need to determine if job rotation, schedules, and varied work/rest cycles reduce worker stressors. For highly repetitive jobs (e.g., keyboard entry work), further research is needed to determine how to best control the stresses on specific musculoskeletal tissues.

Workshop participants recognized a great need for objective and quantitative standards or guidelines for evaluation of hazardous workplaces. Substantial research may be needed to justify the scientific basis of quantitative risk assessments of the relationship between exposure and injury or disorder. Priority should be given to common work situations or processes such as video display terminal work. One important issue in further research is selecting the best measures of exposure, so that exposures in a diverse industry can be studied to delineate better effect-response relationships.

Adequate Treatment and Rehabilitation

The principal focus of preventive activities should be directed at primary prevention, which relies on reducing or stopping exposure. Nevertheless, many work-related musculoskeletal injuries and disorders will continue to occur for some time, and many similar disorders will be common in the workforce because they have non-work etiologies. To reduce the human suffering and economic burden on individuals and society, research is required on the development and evaluation of effective treatment and rehabilitation programs. The rehabilitation process must include a comprehensive approach. Adequate attention to all aspects of the problem is needed. This includes reconditioning of the injured worker, which may comprise of a work hardening program, evaluation and counseling regarding the psychological and emotional consequences of pain and disability, and an assessment of the total work environment where the worker will return after his or her care is completed. It is also recommended that a case follow-up mechanism be in place.

6.3 Effective Use of Controls

The successful implementation of a control program undoubtedly requires more than the identification of high-risk jobs by use of hazard or health surveillance data and the understanding of the engineering principles required to redesign the hazardous jobs. It requires management commitment, training of employees and supervisors, employee involvement, and incorporation of ergonomic considerations into the design of new work processes. Determining the best methods to ensure the inclusion of each of these key elements into a control strategy will entail additional research to evaluate each of these elements. These evaluations of the effectiveness of control programs should study a wide range of outcome variables including: health outcomes, symptoms, and the rate of recurrences; employee acceptance or satisfaction of job redesigns; effects on productivity; and managements' evaluation of the impact of the control program. Research into understanding more effective ways to disseminate control information and train employees and supervisors is also highly desirable.

To disseminate information about ergonomic controls, studies are necessary to determine the utility of management and worker training and other means of communication. Two exemplary ways to study the effectiveness of information dissemination would be to: 1) investigate organizational parameters, and 2) test workers and supervisors about ergonomic control information. Both basic research and field work are needed to assess the evaluation of control information dissemination.

7.0 Summary and Recommendations

There is little doubt, based on the data and experiences summarized by the participants in both the

Conference and Workshops, that Occupational Musculoskeletal Injuries (OMIs) encompass the most costly types of injuries (est. $100 billion annually) and affect several million workers each year. Low back pain episodes continue to represent the more severe and disabling form of such injuries across all industries. More recently, upper extremity cumulative trauma disorders (UECTDs) have been found to be prevalent and a large cause of work disability in a diverse number of occupations and industries. Both low back pain and upper extremity disorders are characterized by a wide range of severity from minor and infrequent episodes to permanent disability. The economic and human cost to society, employers and employees is very substantial.

It has become very clear to all involved in prevention of all forms of OMIs that a great deal of new knowledge is needed, both to understand the cause of specific types of OMIs, and to develop and validate effective, work-centered prevention and rehabilitation strategies. In this context, the following general recommendations are delineated, based on the specific results of the process summarized in Sections 5.0 and 6.0 of this document:

1. An improved capability to **identify hazardous job stressors** is needed that recognizes how sometimes subtle physical exertions on jobs combine with other risk factors (such as awkward postures, high repetition, long work cycles, cold temperatures, vibrations, or high amounts of psychosocial stress) to create musculoskeletal tissue trauma, pain and disability.

2. An improved ability to **objectively measure and quantify job stresses** believed to cause OMIs is needed. In particular, we must develop more sensitive measurement systems, capable of accurately describing small body motions, and static and dynamic forces now required in many jobs that are known to cause localized tissue trauma and disability.

3. Most participants believed that there is a rapidly growing need to develop objective medical tests to **identify people who may be at special risk** of OMIs when exposed to certain job conditions. Such tests need to be carefully constructed to be safe, reliable, accurate and efficient (low operational time cost); to be directly related to the job requirements; and to be highly predictive of an individual's risk level when required to perform a specific manual task in a job. Other participants were concerned about the feasibility for this type of testing in a prevention program from a policy or scientific perspective.

4. Much **more fundamental biomechanical and other types of research** are needed to understand why for the majority of the OMIs the specific nature of the damage to the body cannot be conclusively established during routine clinical evaluations. Worker population biomechanical tolerance data are needed to specific tissue and musculoskeletal structures. In addition, biomechanical models that more accurately predict tissue stress levels during work are needed, as well as empirical studies to validate the output from these models.

5. **Job hazard surveillance and OMI reporting systems** need to be improved. These should be easily implemented (user friendly) systems that link job hazard data (from job evaluations, checklists, psychophysical effort reports, and worker questionnaires) to medical injury and illness reports in a timely fashion.

6. A variety of OMI control procedures and equipment are available today. These **controls need to be carefully evaluated** to determine their effectiveness in preventing future OMIs, and the operational conditions under which they are effective. Additional research is recommended to refine the effectiveness of early comprehensive medical interventions and rehabilitation strategies.

7. The design of various **industrial planning and social/organizational issues** need to be studied to understand how these impact the implementation of various control strategies. For example: What level of ergonomics training is needed? Who should be involved in implementing ergonomic changes? Will progressive reduction in ergonomic hazards be associated with improvements in productivity and quality?

Occupational musculoskeletal injuries are now being recognized for the harm they cause to both workers and organizations. Unfortunately, both the science and technology needed to prevent these injuries is not completely developed or disseminated. This has resulted in a myriad of different types of preventive strategies being proposed by many different organizations, with varying degrees of scientific basis. The need to critically evaluate these approaches as well as provide a more basic understanding of the prevention of OMIs must now be vigorously pursued.

8.0 CONFERENCE OUTLINE AND WORKSHOP PARTICIPANTS

8.1 Conference Outline

Monday, April 8

7:30 AM - Registration, Rackham Building

8:30 AM ***Session: Occupational Musculoskeletal Injuries—National and International Perspective***

Welcome

Session Chair: *Don B. Chaffin, Ph.D.*, Professor & Director, Center for Ergonomics, The University of Michigan

Welcome & Congressional Interest in Injury Prevention
Cynthia Hudgins for Hon. Carl Pursell, U.S. House of Representatives

Strategic Role of NIOSH
J. Donald Millar, M.D., Assistant Surgeon General; Director, NIOSH

Strategic Role of OSHA
Gerard Scannell, Director, OSHA

The Swedish Strategy
Carl Asklöf, Director, Swedish Work Environment Fund, SWEDEN

11:00 Panel Discussion,
Panel Chair: *J. Donald Millar,* Chair

11:45 Luncheon, Michigan League Ballroom

1:00 PM ***Session: Defining the Scope of the Problem and Some Current National Intervention Strategies***
Session Chair: *Tom Bender, M.D.,* Director, Division of Safety & Research, NIOSH

Epidemiology and Cost of Occupational Low Back Pain
Stephen L. Gordon, Ph.D., Musculoskeletal Diseases Program Director, National Institute of Arthritis and Musculoskeletal and Skin Diseases

Epidemiology and Cost of Upper Extremity Cumulative Trauma Disorders
Lawrence J. Fine, M.D., Dr.P.H., Director, Division of Surveillance, Hazard Evaluations and Field Studies, NIOSH

Using the 1981 NIOSH "Work Practices Guide for Manual Lifting" As the Basis for Engineering Materials Handling Jobs
Gary Herrin, Ph.D., Professor, Industrial & Operations Engineering, The University of Michigan

Revisions in NIOSH Guide for Manual Lifting
Vern Putz-Anderson, Ph.D., Section Chief, Psychophysiology & Biomechanics, Division of Biomedical and Behavioral Science, NIOSH

2:20 PM Break

2:40 PM ***Session: Prevention Methods—Do We Know If They Work?***
Session Chair: *Janet Haartz, Ph.D.,* Director, Division of Biomechanical & Behavioral Science, NIOSH

Redesign of Materials Handling Jobs
M.M. Ayoub, Ph.D., Professor Industrial and Biomechanical Engineering, Texas Tech University

Redesign of Jobs for Controlling Upper Extremity Cumulative Trauma Disorders
Thomas J. Armstrong, Ph.D., Professor, School of Public Health, The University of Michigan

Occupational Stress in Musculoskeletal Disorders
Steven Sauter, Ph.D., Section Chief, Motivation and Stress Research, Division of Biomedical and Behavioral Science, NIOSH

3:40 PM Panel Discussion
Panel Chair: ***Steven Gordon, Ph.D.***

5:00 PM Adjournment

Tuesday, April 9

8:00 AM
Session Chair: *John Treibwasser, M.D.,* Corporate Medical Director, Ford Motor Company

Evaluation of High Risk Workers
Gunnar Andersson, M.D., Ph.D., Professor, Orthopaedic Surgery, Rush Institute, Chicago, IL

Multidisciplinary Rehabilitation of Work-related Upper Extremity Disorders
Michael Feuerstein, Ph.D., Center for Occupational Rehabilitation, University of Rochester Medical Center

Worker Training & Rehabilitation Methods
Margareta Nordin, RPT, Ph.D., Program Director, Ergonomics & Occupational Biomechanics, New York University, and Director, Occupational and Industrial Orthopaedic Center, Hospital of Joint Diseases

Worker Involvement Programs
Barbara Silverstein, Ph.D., Manager, Safety and Health Assessment Research Program, State of Washington

9:40 AM ***Session: Organizational Intervention Strategies***
Session Chair: *Frank Mirer, Ph.D.,* UAW

Development of and Experience with OSHA "Ergonomics Program Management Guidelines for Meat Packing Plants"
Ray Donnelly, Director, Office of General Industry Compliance Assistance, US/DOL, OSHA

Insurance Company Programs
Stover Snook, Ph.D., Liberty Mutual Insurance Company

Occupational Medical Programs
Bruce Dickerson, M.D., Past President, ACOM and Retired Medical Director, IBM

Organized Labor Programs
David LeGrande, Communication Workers of America

Panel Discussion
Panel Chair: ***Lawrence J. Fine, M.D., Dr.P.H.***

Conference Summary
Don B. Chaffin, Ph.D.

12:00 PM Adjournment of Conference

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Marvin Parnes, M.S.W.-Moderator
Susan Palmiter, Ph.D.-Recorder

R = Research Strategies Workshop
Don Chaffin, Ph.D.-Chair
Christine Black, B.A.-Moderator
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9.0 List of General References

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