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E. Glossary and List of Acronyms

1. Glossary

Acceleration—time rate of change in velocity (expressed as m/sec^2 or as gravity); the second derivative of displacement with respect to time. Intensity of vibration is measured by acceleration.

Afferent nerves—sensory nerves supplying information, including movement, position, and other sensation, to the central nervous system.

Articular—referring to the joint or, more specifically, to the particular surfaces at the ends of bones that meet (separated by cartilage) in the joint.

Atheromatous—producing plaques or atheroma in arteries.

Autonomic dysfunction—abnormalities of the involuntary or autonomic nervous system. In vibration studies, the term usually refers to abnormal sympathetic nerve response resulting in abnormal vascular musculature response.

Axonopathies—nerve abnormalities affecting the fibers that carry nerve impulse from the nerve cell body to the next nerve cell or effector muscle.

Biomechanical stressor—the physical aspects of workstation, work piece, tools, and work process that exert stress on the body. Biomechanical stressors are distinct from psychosocial or work organization risks, which are not addressed in this document. The document uses ''biomechanical stressors'' instead of the commonly employed ''ergonomic stressors.'' The term ''ergonomics'' refers to ''fitting the work to the worker,'' a much broader concepts that includes all aspects of the worker/task/work environment interaction: biomechanical stressors and psychosocial stressors, human factors concepts of information exchange and ease of use, and higher-level constructs of organizational structure and culture.

Carpal tunnel—an anatomic tunnel in the wrist through which the median nerve and nine digital flexor tendons pass. It is formed by the wrist bones and a dense trans-carpal ligament. Pressure on the median nerve in the carpal tunnel causes carpal tunnel syndrome.

Cartilage—a thick, white connective tissue that attaches to the articular surfaces of bones, forming a low-friction cushion. It is structurally more rigid than tendon.

Central and peripheral nervous systems—the central nervous system includes the brain and spinal cord; the peripheral nervous system consists of nerves linking the central nervous system to muscles (via efferent motor nerves) and sensory receptors (via afferent sensory nerves).

Concentric contraction—muscle contraction in which tension is greater than external load, resulting in muscle shortening.

Demyelination—a loss of the myelin sheath. Myelin is a fatty tissue that surrounds large and medium-size nerves and speeds the rate of electrochemical conduction through the nerve. In the setting of work-related injury, demyelination is usually caused by nerve compression and entrapment.

Dermatome—an area of the body innervated by a specific nerve or nerve branch.

Dorsal wrist compartments—hand tissue areas divided by fascia that represent hydraulic cushions. The first dorsal compartment contains tendons that extend the thumb.

Dysesthesias—abnormal nerve sensations.

Eccentric contraction—muscle contraction in which tension is less than the external load, resulting in muscle elongation against contractile force. Muscles in eccentric contraction can develop the highest tension and are thus the most vulnerable to rupture.

ECRB—the extensor carpi radialis brevis, a muscle that extends the wrist and inserts at the lateral elbow.

Efferent nerves—motor nerves effecting and coordinating voluntary and reflexive muscle activity.

Efferent nerve axons—motor nerves effecting and coordinating voluntary and reflexive muscle activity.

Endothelial—in vascular studies, referring to the inner lining of blood vessels (more broadly, the term refers to tissues derived from embryonic endothelial cells).

Epicondylitis—elbow pain at the site where the proximal flexor or extensor tendons insert at the lateral or medial epicondyles (bony prominences on the inside and outside of the elbows).

Etiology—the cause or origin of disease or study of the causes of disease.

Exposure—an epidemiological concept used to describe the particular risk factor experienced by the worker, with its particular profile of modifying factors: intensity, time characteristics, and duration.

Fibroblasts—cells that produce connective tissue such as ligaments and tendons.

Fibrocartilage—cartilage that contains dense bands of connective tissue, having elements of rigid support and flexibility.

Fibrosis—the replacement of normal tissues by fibrous scar tissue at the site of injury.

Frequency—number of oscillations per unit of time; 1 hertz (Hz) = 1 cycle/sec.

Gamma muscle spindles—specialized nerve afferents that send signals to the central nervous system indicating muscle stretch (thus providing information on body segment position).

Glabrous pads—the fatty pads at the fingertips and toetips.

Humerus—the long bone of the upper arm.

Hydrophilic—reactive with water.

Hypertrophic—referring to a growth or increase in tissue mass.

Ischemia—the condition of restricted blood flow to an area, resulting in insufficient oxygen and nutrients for tissue function and reduced clearance of CO_2 and metabolites.

Isometric contraction—muscle contraction in which tension equals the external load, resulting in a constant muscle length.

Isotonic contraction—muscle contraction in which a constant internal force is developed, usually resulting in concentric contraction.

Mechanoreceptors—specialized nerve endings and sense organs that convey the senses of touch, spatiality, and pressure.

Median nerve—the nerve suppling most of the sense of sensation to the first through fourth fingers. The median nerve can be entrapped in carpal tunnel syndrome.

Metaplasia—non-neoplastic change in the form and function of cell, usually due to an external stimulus.

Mitochondria—the bodies within cells that conduct oxidative metabolism, the oxygen-dependent, energy-producing chemical reactions that are essential for muscle contraction.

Musculoskeletal disorder (MSD)—an injury or illness of soft tissues of the upper extremity (fingers through upper arm), shoulders and neck, low back, and lower extremity (hips through toes) that is primarily caused or exacerbated by workplace risk factors, such as sustained and repeated exertions or awkward postures and manipulations.

Since the Health Effects Section deals only with work-related disorders, the abbreviation ''MSD'' is equivalent to the term ''work-related musculoskeletal disorder'' (WRMSD or WMSD) found elsewhere in the literature. MSDs, as discussed in this document, are assumed to arise out of regular work processes as acquired disorders and exclude acute traumatic injuries, such as falls or amputations. The term ''MSD,'' however, does not exclude acute injuries that arise out of occasional or atypical work processes, such as handling particularly heavy or poorly balanced materials. MSDs include disorders of the following tissues: muscles; tendons, paratendons, and retinaculum; ligaments; peripheral nervous system (including the sympathetic and parasympathetic nervous system); cartilage and synovium (including joints, intervertebral discs, and fibro-cartilage complexes); bone; and blood vessels. The term ''MSD'' is used to maintain consistency with current practice and nomenclature, and does not imply a hierarchy or emphasis on injuries to muscle and bone in contrast to other soft tissues. In fact, injuries to muscle and tendon are distinctly more common than injuries to bone. Subordinate terms like ''neuromuscular disorders'' and ''musculotendonous disorders'' are used to emphasize a particular, tissue-based etiology.

''MSD'' is used in place of ''CTD'' (cumulative trauma disorder) or ''RSI'' (repetitive strain injury) because it does not necessarily presuppose etiology from accumulation or repetition of trauma, and it does not imply a category of medical diagnoses. For establishing a standard and for recognizing hazards, persistent symptoms, clinical signs, or clinical diagnoses are sufficient to establish the existence of MSDs.

Myelin—the external lining of large and medium size nerves with a fatty sheath, enhancing nerve conduction velocity.

Nocioceptors—nerve fibers, usually C fibers, responsible for the sensation of pain.

Odds ratio—relates the odds of being a case to those of not being a case. It is the odds of being a case given the risk factor is present divided by the odds of being a case given the risk factor is not present. If the following table is used the odds ratio is:

OR = (A/B)/(C/D)

Risk Factor Classification	Cases	Noncases
Risk Factor Present	A	B
Risk Factor Absent	C	D

Oscillation—rhythmic variation in the position of an object in reference to the starting point, measured over time.

Paresthesias—abnormal sensations of tingling and numbness.

Proprioception—the conduction of sensory nerve signals that indicate muscle and joint position to the central nervous system.

Raynaud's phenomenon—a painful condition affecting the fingers or toes, caused by compromised circulation. It is provoked by the cold. Raynaud's causes the digits to turn white from lack of blood supply.

Risk factor (stressor)—a characteristic of the work environment that research has shown to be associated with an elevated occurrence or severity of MSDs. Risk factors can involve purely external exposures, such as shock or percussion, that act on the musculoskeletal system. They can also involve intrinsic response to a load or task, such as lifting or rapid and awkward movement. The effect of a risk factor may be modified by personal characteristics, such as anthropometry and physical conditioning, or by concurrent or previous non-work exposure. Risk factors can also involve work organizational or social factors.

The Heath Effects Section uses the terms ''stressor'' and ''risk factor'' interchangeably.

Root mean square (RMS)—the square root of the arithmetic mean of the squares of a series of numbers.

Sarcomere—the basic skeletal muscle cell.

Skeletal muscle—striated muscle constituting the major muscle groups in the body that are responsible for voluntary and reflex movement of body segments.

Subchrondral bone—bone located beneath the cartilaginous lining of a joint.

Synoviocytes—the matrix cells of the synovial membrane.

Synovium—a lubricating tissue located at the sheaths of joints, in bursae and as the innermost layer of joint capsules. High-usage tendons, such as the finger flexor and extensor tendons, are also surrounded by lubricating synovial tissue.

TFCC—the triangulate fibro-cartilage complex, a structure of cartilage and tendons that holds the ulna (forearm bone) to the bones of the wrist.

Transmural pressure—pressures resulting from increased volume or force in an anatomic structure that is no longer expandable (such as a blood vessel, or a muscle encircled by surrounding tissues).

Transverse—operating across different planes.

Ulnar nerve—an important bundle of sensory and motor nerve fibers to the arm, particularly to the hand. Its sensory fibers innervate the fifth and part of the fourth fingers.

Uniaxial—operating in a single plain along a single axis.

Vaso-occlusion—blocking of an artery by a fixed obstruction, often caused by clot or degenerative disease.

Vasospastic—referring to reversible arterial occlusion caused by sympathetically mediated constriction of arteries.

Vibration—oscillation or periodic motion of a rigid or elastic body from equilibrium.

Vibrotactile threshold—different classes of mechanoreceptors are sensitive to specific frequencies of vibration. The vibration amplitude at which conscious perception occurs is the vibrotactile threshold.

Vibrotactile thresholds—different classes of mechanoreceptors are sensitive to specific frequencies of vibration. The acceleration amplitude at which the vibration is consciously perceived is the vibrotactile threshold.

Viscous strain—refers to the biological incapacity of a tissue to retain its fluidity due to extremely rapid deformation. Viscous strain is usually distinguished from elastic strain, the mechanical incapacity of a tissue to regain its resting position.

Weighted curves—the progressive filtering or downweighting of accelerations, due to presumed reduction in physiological effect, as they exceed 16 Hz.

Work-related disease—a disease caused by or exacerbated by stressors encountered during work. More precisely, the World Health Organization (1985) defines disease as work-related if work procedures, equipment, or environment contribute significantly to its causation.

Z-lines—microscopically observed divisions in functioning muscle cells.

2. List of Acronyms

A

ADP: adenosine diphosphate
ALL: anterior longitudinal ligament
ANSI: American National Standards Institute
APL: abductor pollicis longus
ATP: adenosine triphosphate
ASC: total ascorbate
ASOII: Annual Survey of Occupational Injuries and Illnesses

B

BMI: body mass index

C

CAT: computerized axial tomography
CCR: cervico-collic reflex
CL: Chinese line
CMC: carpal-metacarpal
CNS: central nervous system
COS: Clearwater Osteoarthritis Study
CT: computed tomography
CTD: cumulative trauma disorder
CTP: carpal tunnel pressure
CTS: carpal tunnel syndrome

D

DIP: distal interphalangeal
DPC: desktop PC

E

ECRB: extensor carpi radialis brevis (see glossary entry)
ECRL: extensor carpi radialis longis
ECU: extensor carpi ulnaris
EDC: extensor digitorum communis
EGM: electrogram
EGPT: erythrocyte glutamic pyruvic transaminase
EMG: electromyography
EPB: extensor pollicis brevis

F

Fc: compression forces
FCR: flexor carpi radialis
FCU: flexor carpi ulnaris
FDP: flexor digitorum profundus
FDS: flexor digitorum superficialis
FPL: flexor pollicis longus
FTE: full-time equivalent

G

GAG: glycosaminoglycan

H

HANES: Health and Nutrition Examination Survey
HANES I: First National Health and Nutrition Examination Survey
HAVS: hand-arm vibration syndrome
Hz: Hertz

I

IP: interphalangeal
ISO: International Standards Organization

J

JSI: job severity index

K

kPa: kilopascal

L

LMM: Lumbar Motion Monitor

M

MAF: maximum acceptable frequency or maximum acceptable force
MAT: maximum acceptable torque
MAW: maximum acceptable weight
METS: metabolic equivalents
MP: metacarpophalangeal
MPF: mean power frequency
MR: magnetic resonance
MRI: magnetic resonance imaging
MSD: musculoskeletal disorder
MVC: maximum voluntary contraction
MVIS: maximum voluntary isometric strength
MVPS: maximum voluntary pinch strength

N

N: Newtons
Nm: Newton meters
Nm/s: Newton meters/second
NAS: National Academy of Sciences
NCHS: National Center for Health Statistics
NHIS–OHS: National Health Interview Survey
NIOSH: National Institute for Occupational Safety and Health
NPC: notebook PC
n.s.: not significant

O

OCD: occupational cervicobrachial disorder
OR: odds ratio

P

PCID: prolapsed cervical intervertebral disc
PDTS: predetermined time systems
PE: physical examination
PEL: perceived exposure limit
PHD: peak handle displacement

PHV: peak handle velocity
PINS: posterior interosseous nerve syndrome
PIP: proximal interphalangeal
PLL: posterior longitudinal ligament
PLP: pyridoxal 5′-phosphate
PPT: pressure pain thresholds
PRR: prevalence rate ratio

Q

QCT: quantitative computed tomography

R

RMS: root mean square (see glossary entry)
ROM: range of motion
RPE: range of perceived exertion
RPM: revolutions per minute
RR: relative risk
RSD: reflex sympathetic dystrophy
RSI: repetitive strain injury

S

SCTL: spinal compression tolerance limits
SHR: Standardized Hospitalization Ratio
SL: Swedish line
SMPS: sympathetically maintained pain syndrome

T

TCL: transverse carpal ligament
TFCC: triangulate fibro-cartilage complex (see glossary entry)
TLV: threshold limit value
TOS: thoracic outlet syndrome
TTS: tarsal tunnel syndrome

V

VAS: visual analog scale
VDT: video display terminal
VWF: vibration-induced white finger

W

WMSD: work-related musculoskeletal disorder
wpm: words per minute
WRMSD: work-related musculoskeletal disorder

VI. Preliminary Risk Assessment

A. Introduction

The United States Supreme Court, in the Benzene decision (*Industrial Union Department, AFL–CIO* v. *American Petroleum Institute,* 448 U.S. 607 (1980)), has ruled that the OSH Act requires, prior to the issuance of a new standard, that a determination be made that there exists a significant risk of health impairment and that issuance of a new standard will substantially reduce that risk. The Court stated that ''before he can promulgate any permanent health or safety standard, the Secretary is required to make a threshold finding that a place of employment is unsafe in the sense that significant risks are present and can be eliminated or lessened by a change in practices'' (448 U.S. 642). The Court also stated that ''the Act does limit the Secretary's power to require the elimination of significant risks' (448 U.S. 644).

Although the Court rejected the use of cost-benefit analysis in setting OSHA standards in the Cotton Dust case (*American Textile Manufacturers Institute* v. *Donovan,* 452 U.S. 490 (1981)), it reaffirmed the position it had previously taken in the Benzene decision that a risk assessment is not only appropriate but required to identify significant health risks in workers and to determine if a new standard will reduce those risks. Although the Court did not require OSHA to perform a quantitative risk assessment in every case, the Court implied, and OSHA as a matter of policy agrees, that assessments should be put into quantitative terms to the extent possible.

The weight of evidence presented in the Health Effects section of this preamble indicates a causal relationship between exposure to workplace risk factors and work-related musculoskeletal disorders. As discussed in that section, the major workplace risk factors include exposure to repetitive motions, forceful exertions, vibration, contact stress, awkward or static postures, and cold temperatures. The Health Effects section also demonstrates that the risk associated with occupational exposure to these risk factors increases with frequent or prolonged exposure.

OSHA believes there is ample evidence that exposure to physical stresses at work can cause or contribute to the development of MSDs and that reductions in these stresses can reduce the number and severity of these work-related MSDs. The underlying evidence falls into three broad categories:

—Studies of groups of workers showing a relationship between exposure to risk factors in the workplace and an increased incidence or prevalence of MSDs;
—Biomechanical studies that show that adverse tissue reactions and damage can occur when tissues are subjected to high forces and/or a high number of repetitive movements; and
—Case studies that demonstrate that workplace interventions designed to reduce exposures to risk factors are effective in reducing the incidence and severity of MSDs.

There are hundreds of studies of the incidence or prevalence of MSDs in groups of workers who are exposed to risk factors in their jobs. In most of these studies, the MSD prevalence of a group of exposed workers is compared to that in another worker group that is not exposed to the risk factors of interest. If the exposed group shows a higher MSD prevalence than does the reference group, the study provides evidence of an association between exposure and an increased risk of developing MSDs, particularly if the study is of good quality and adequately controlled for potentially confounding factors (such as age and gender) and biases.

These epidemiological studies were recently reviewed by the National Institute for Occupational Safety and Health (NIOSH) to evaluate the strength of the evidence for a causal relationship between several types of MSDs and workplace risk factors. More than 600 peer-reviewed studies were critically reviewed, making this one of the largest human data bases ever built to examine work-related adverse health outcomes. NIOSH found that for most combinations of MSDs and risk factors, the evidence in humans that a causal relationship existed between workplace exposure to risk factors and the development of MSDs was either ''sufficient'' or ''strong.'' For a few MSD/risk factor combinations, there was insufficient evidence of a causal relationship, but in no case did NIOSH determine that there was evidence for the absence of a relationship between exposure to workplace risk factors and the development of MSDs. NIOSH concluded that ''* * * a substantial body of credible epidemiologic research provides strong evidence of an association between MSDs and certain work-related physical factors when there are high levels of exposure and especially in combination with exposure to more than one physical factor * * *''. (NIOSH 1997, ES p. xiv, Ex. 26–1).

A similar conclusion was reached by the experts participating in a workshop conducted by the National Academy of Sciences/National Research Council (NRC) (Ex. 26–37. For the NRC report, a panel of experts critically reviewed the methods used to select and evaluate the human studies relied on in the 1997 NIOSH study (Ex. 26–1). The 1998 NRC report concluded as follows:

''[the association between MSDs and exposure to risk factors at work that have been] identified by the NIOSH review * * * as having strong evidence are well supported by competent research on heavily exposed populations.''

''There is a higher incidence of reported pain, injury, loss of work, and disability among individuals who are employed in occupations where there is a high level of exposure to physical loading than for those employed in occupations with lower levels of exposure.'' (Ex. 26–37)

That exposure to workplace risk factors can cause or contribute to MSDs is made more plausible by the growing body of studies of biomechanical effects, which are designed to explore how tissues react to mechanical stress and how those reactions are related to disease processes. Although all soft musculoskeletal tissue can tolerate certain physical loads, these tissues will respond adversely if the load becomes excessive. Muscles, ligaments, tendons, and tendon sheaths can become inflamed with repetitive or prolonged loading, cartilage can deteriorate when subjected to abnormal loads, and nerves can exhibit dysfunction and eventually permanent damage if compressed or subjected to extended tension. Other studies have shown that the kinds of risk factors present in many industrial occupations can impose internal forces on soft musculoskeletal tissue sufficient to cause the kinds of physiologic responses described above. The relationships between external and internal loads have been demonstrated using both biomechanical models and direct measurement and observation in the workplace.

Finally, evidence of the work-relatedness of MSDs comes from several studies and case reports that document the effectiveness of ergonomic interventions in reducing exposures to risk factors and the successes of individual companies' ergonomics programs in reducing the incidence or prevalence of MSDs and the severity of MSDs among their workers. After reviewing intervention studies, including both field and laboratory studies, the NRC (1998, Ex. 26–37) concluded that ''* * * specific interventions can reduce the reported rate of musculoskeletal disorders for workers who perform high-risk tasks. No known single intervention is universally effective. Successful interventions require attention to individual, organizational, and job characteristics, tailoring the corrective action to those characteristics.''

In addition to biomechanical risk factors present at work, the risk of developing an MSD is also influenced by individual, organizational, and social factors. Factors that affect individual susceptibility include age, general conditioning, and pre-existing medical conditions. Although some of these individual factors have been identified in human studies as being statistically significant predictors of disease, they are generally much weaker predictors than are biomechanical factors (NRC 1998, Ex. 26–37) of force, repetition, posture, and vibration. Organizational factors that have been linked to MSDs include poor job content (*e.g.*, lack of job variety) and job demands (*e.g.*, excessive or highly variable workload and time pressure). The importance of poor job content is difficult to evaluate since this factor can coexist with biomechanical factors (for example, excessive workload can result in a worker needing to increase repetitive movement and/or force). Social factors refer to a lack of social support from management and supervisors, which can lead to psychological stress and dissatisfaction with work, both associated with an increased prevalence of MSDs. However, according to the NRC review (1998, Ex. 26–37), neither organizational nor social factors have proven to be strong predictors of these disorders. Thus, although individual, organizational, and social factors may have some relationship to the observed increases in the incidence of MSDs among workers exposed to risk factors, their contribution does not compare with the contribution of work-related physical risk factors to increased risk.

OSHA believes that the human epidemiologic studies, the biomechanical and physiological studies, and the studies of the effectiveness of workplace ergonomic interventions together constitute a compelling body of evidence that demonstrates that exposure to risk factors at work is a major factor in the development of MSDs, and that reducing or eliminating exposures to these risk factors will reduce the number and severity of these MSDs.

Although the epidemiological data base that describes the associations between exposure to workplace risk factors and increased prevalences or incidences of MSDs is vast, the nature of the available data have not permitted OSHA to construct generalized quantitative exposure-response relationships, as is usually done to assess occupational risks from chemical exposures. There are many reasons for this, in particular the complex interactions among different kinds of exposures that lead to tissue injury and disorders and the difficulty of defining exposure metrics that apply across a wide range of industries and operations. This is not to say that exposure-response relationships have not been observed or cannot be defined in specific circumstances; in fact, there are many cases in which the risk of MSDs has been quantitatively related to the degree and intensity of exposure. In the Health Effects section of this preamble, OSHA describes several scientific studies that demonstrate a positive association between the magnitude and/or duration of exposure to workplace risk factors and the prevalence of MSDs, including upper extremity disorders and back injuries. OSHA believes that these studies provide compelling evidence of the work-relatedness of MSDs since a finding of positive exposure-response trends is one of the key findings necessary to establish a causal relationship between exposure and disease. The lack of generalized quantitative exposure-response relationships for work-related MSDs, however, does not limit the Agency's ability to quantify risk. Using data on the incidence of work-related MSDs, risk can be quantified using a population-based approach similar to the one used by OSHA to quantify the risk of Hepatitis B among workers with frequent occupational exposure to blood and other potentially infectious material (56 FR 64004). For the proposed ergonomics program rule, OSHA uses a similar approach in its preliminary risk assessment. In this assessment, OSHA relies on data from the Bureau of Labor Statistics (BLS) to estimate the annual incidence of work-related MSDs in different industry sectors and occupations, by type of injury and type of exposure. A description of these data and OSHA's analytical approach are described in section B below, and the results of this analysis appear in section C. Information on the effectiveness of ergonomics programs is important to evaluate the extent to which the standard as proposed is likely to reduce significant risk in the covered worker population. This information comes from a variety of published studies and unpublished data that describe the degree to which ergonomics programs have reduced injury rates and decreased the numbers of lost workdays caused by MSDs. OSHA's discussion of these data appears in section D below.

B. Data Sources and Analytical Approach

The annual Survey of Occupational Injuries and Illnesses conducted by the Bureau of Labor Statistics (BLS) is the principal data source for evaluating the risks to employees of developing a work-related musculoskeletal disorder. This survey is a Federal/State program that collects workplace injury and illness data from about 165,000 private industry establishments. The survey requests information only on non-fatal injuries and illnesses, and excludes the self-employed, farms with fewer than 11 employees, private households, and employees in Federal, State, and local government agencies.

For this survey, selected employers are required to provide statistics on the total number of injuries and illnesses recorded on the OSHA Form 200, as well as information describing the nature and causes of their lost workday injuries and illnesses. Thus, according to BLS, the data provided by employers ''* * * reflect not only the year's injury and illness experience, but also the employer's understanding of which cases are work-related under current recordkeeping guidelines of the U.S. Department of Labor.'' Information is provided in sufficient detail to permit BLS to systematically code each reported case and develop estimates of the numbers and incidence of each specific type of LWD injury and illness for the United States as a whole, by industry sector and by occupation.

Although the BLS data are the best available data on the number and kinds of job-related injuries and illnesses occurring among U.S. workers in any given year, they are not easy to use for risk assessment purposes. In other words, there is no single BLS-reported number that represents all employer-reported musculoskeletal injuries and illnesses occurring in that year. Instead, employer-reported injuries and illnesses are coded by BLS according to a classification system that categorizes each incident by type of injury or illness and by nature of the exposure event leading to the injury or illness (BLS 1992, Ex. 26–1372). The types of disorders that are addressed by the proposed standard fall into several of these BLS injury and illness categories.

To use these data, OSHA identified the kinds of cause-specific injuries and illnesses, as coded by BLS, that are believed to reflect MSDs of the kinds that will be covered by the proposed ergonomics program standard. An OSHA panel, which included an occupational physician and two professional ergonomists, examined the BLS listing of occupational injury and exposure event codes and their definitions from the manual provided to State personnel who code the data from the BLS employer survey. The table contained in Appendix VI–A to this Preliminary Risk Assessment provides the list of injury categories that were initially selected by this panel as being likely to include at least some work-related MSDs. From this initial list, the panel selected a subset of injury categories that predominately included work-related MSDs; these categories appear in Table VI–1. Of the injury categories selected, OSHA chose to base its analysis on only six injury categories that were deemed by these experts to be most relevant and most likely to represent a large proportion of lost workday MSDs. These injury categories include:

—Sprains, Strains, and Tears;
—Back Pain, Hurt Back;
—Soreness, Hurt, except back;
—Carpal tunnel syndrome;
—Hernia; and
—Musculoskeletal and connective systems diseases and disorders.

In addition, only those injuries and illnesses attributed to overexertion, repetition, or bodily reaction (which includes only the subcategory of ''bending, climbing, crawling, reaching, twisting'') are included in OSHA's analysis because injuries and illnesses caused by these risk factors represent chronic exposures that have the potential to cause musculoskeletal damage (the BLS definitions for these exposure event categories appear in Table VI–2). Thus, musculoskeletal injuries and illnesses caused by acute events, such as slips, trips, falls, or being struck by objects, are excluded from the data relied on in OSHA's risk analysis.

Table VI–1.—BLS Injury Categories Consisting Predominately of Employer-Reported Musculoskeletal Disorders

BLS CODE	NATURE OF INJURY	DESCRIPTION
021	Sprains, strains, tears	This nature group classifies cases of sprains and strains of muscles, joints tendons, and ligaments. Diseases or disorders affecting the musculoskeletal system, including tendonitis and bursitis, which generally occur over time as a result of repetitive activity should be coded in Musculoskeletal system and connective tissue diseases and disorders, major group 17. Includes avulsion, hemarthrosis, rupture, strain, sprain, or tear of joint capsule, ligament, muscle, or tendon. Excludes hernia (153), lacerations of tendons in open wounds (034), torn cartilage (011).
0972 0973	Back pain, hurt back Soreness, pain, hurt, except the back	Subcategories under nature group 097, Nonspecified injuries and disorders, which includes traumatic injuries and disorders where some description of the manifestation of the trauma is provided and generally where the part of body has been identified. Subcategory 0972 includes hurt back, backache, low back pain.
1241	Carpal tunnel syndrome	Subcategory under nature group 124, Disorders of the peripheral nervous system, which includes the nerves and ganglia located outside the brain and spinal cord.

Table VI–1.—BLS Injury Categories Consisting Predominately of Employer-Reported Musculoskeletal Disorders—Continued

BLS CODE	NATURE OF INJURY	DESCRIPTION
153	Hernia	This nature group classifies hernias of the abdominal cavity. Includes: femoral (1539), esophageal (1539), hiatal (1532), inguinal (1531), paraesophageal (1539) scrotal (1531), umbilical (1539), and ventral (1533) hernias. Excludes: herniated disc (011), herniated brain (1231), and strangulations (091).
17	Musculoskeletal system and connective tissue diseases and disorders	This major group classifies disease of the musculoskeletal system and connective tissue.
170	Musculoskeletal system and connective tissue diseases and disorders, unspecified.	
171	Arthropathies and related disorders (arthritis)	This nature group classifies joint diseases and related disorders with or without association with infections. Includes: ankylosis of the joint, arthritis, arthropathy, and polyarthritis. Excludes: disorders of the spine (172), gouty arthropathy (1919), rheumatic fever with heart involvement (131).
172	Dorsopathies	This nature group classifies conditions affecting the back and spine. Includes: spondylitis and spondylosis of the spine (1729); intevertebral disc disorders, except dislocation (1723); sciatica (1721); lumbago (1722); and other nontraumatic backaches (1729). Excludes: dislocated disc (011), curvature of the spine (1741), fractured spine (012), herniated disc (011), ruptured disc (011), traumatic sprains and strains involving the back (021), and other traumatic injuries to muscles, tendons, ligaments, or joints of the back (02), and traumatic back pain or backache (0972).
173	Rheumatism, except the back	This nature group classifies disorders marked by inflammation, degeneration, or metabolic derangement of the connective tissue structure of the body, especially the joints and related structures of muscles, bursae, tendons and fibrous tissue. Generally, these codes should be used when the condition occurred over time as a result of repetitive activity. Includes: rotator cuff syndrome (1739), rupture of synovium (1739), and trigger finger (1739). Excludes: rheumatism affecting the back is included in code (172), traumatic injuries and disorders affecting the muscles, tendons, ligaments and joints (02).
174	Osteopathies, chondropathies, acquired deformities	This group is comprised of diseases of bones, diseases of cartilage, and acquired musculoskeletal deformities. Includes: osteomyelitis, periostitis and other infections involving bone; and acquired curvature of the spine.
179	Musculoskeletal system and connective tissue diseases and disorders, n.e.c.	This nature group classifies musculoskeletal system and connective tissue diseases and disorders that are not classified elsewhere.

Source: Occupational Injury and Illness Classification Manual, Bureau of Labor Statistics, December 1992 (Ex. 26–1372).

For several reasons, risk estimates based on the BLS data are likely to understate the true risk of incurring a work-related MSD posed to employees who are exposed to workplace risk factors that are associated with the development of MSDs. First, the BLS data include only those lost workday (LWD) cases that resulted in at least one day spent away from work, and thus do not capture either non-lost workday MSD cases nor MSD cases that resulted in the employee being temporarily reassigned to another job. Second, some LWD MSDs reported to the BLS by employers are likely to have been coded in BLS injury categories excluded from OSHA's with overexertion, repetition, and bodily reaction (bending, climbing, crawling, reaching, twisting). Finally, the incidence of MSDs reported by the BLS is the reported incidence of MSDs among *all* production workers in the industries surveyed; that is, the incidence for each industry sector is calculated by BLS as the number of cases reported in 1996 divided by the total number of production employees in that industry sector in 1996. Expressing the incidence in this way has the effect of diluting the estimated incidence of disorders that are actually occurring predominately among those employees who are routinely exposed to workplace risk factors that have been associated with the development of work-related MSDs. The risk to those employees who are exposed to the workplace risk factors considered relevant by OSHA is expected to be higher than the risk reflected by the BLS estimates of MSD incidence, since most of the injuries reported to the BLS will in fact have occurred among the subset of production employees whose jobs expose them to these risk factors (that is, the incidence that would be calculated among exposed employees will reflect a much smaller denominator that reflects the number of exposed employees, resulting in a higher incidence estimate). Evidence that workers exposed to workplace risk factors are at substantially higher risk than other workers in their industry comes from the large data base of formal scientific studies of exposed worker populations and a few studies that have demonstrated a positive analysis (*e.g.*, unspecified disorders of the peripheral nerves) even though they were associated e relationship between exposure to workplace risk factors and the relative risk of developing an MSD (see the Health Effects section of this preamble). These studies show that the prevalence of MSDs among exposed employees is often 2- or 3-fold higher, and can be as much as 10 to 20 times higher, than the prevalence among workers who are not so exposed. Thus, OSHA believes that the risk to exposed employees in each industry sector is in fact several-fold higher than is reflected by the BLS estimates of injury incidence.

Table VI–2.—Description of BLS Exposure Event Categories Corresponding to Workplace Risk Factors Associated With Work-Related Musculoskeletal Disorders

BLS CODE	NATURE OF EXPOSURE EVENT	DESCRIPTION
21	Bodily reaction [a]	Codes in this major apply to injuries or illnesses resulting from a single incident of free bodily motion which imposed stress or strain upon some part of the body. Generally, codes in this major group apply to the occurrence of strains, sprains, ruptures, nerve damage or other internal injuries or illnesses resulting from the assumption of an unnatural position or from voluntary or involuntary motions induced by sudden noise, fright, or efforts to recover from slips or loss of balance (not resulting in falls). This major group includes cases involving musculoskeletal or internal injury or illness resulting from the execution of personal movements such as walking, climbing, bending, etc. when such movement in itself was the source of injury or illness. Group does not include falls.
210	Bodily reaction, unspecified.	
211	Bending, climbing, crawling, reaching, twisting.	
212	Sudden reaction when surprised, frightened, startled.	
213	Running—without other incident.	
214	Sitting.	
215	Slip, trip, loss of balance—without fall.	
216	Standing.	
217	Walking—without other incident.	
219	Bodily reaction, n.e.c.	
22	Overexertion	Overexertion applies to cases, usually non-impact, in which the injury or illness resulted from excessive physical effort directed at an outside source of injury or illness. The physical effort may involve lifting, pulling, pushing, turning, wielding, holding, carrying, or throwing the source of injury/illness. Free bodily motions that do not involve an outside source of injury or illness are classified either in major group 21, Bodily reaction, or in major group 23, Repetitive motion.
220	Overexertion, unspecified.	
221	Overexertion in lifting.	
222	Overexertion in pulling or pushing objects.	
223	Overexertion in holding, carrying, turning, or wielding objects.	
224	Overexertion in throwing objects.	
229	Overexertion, n.e.c.	
23	Repetitive motion	Repetitive motion applies when an injury or illness resulted from bodily motion which imposed stress or strain upon some part of the body due to a task's repetitive nature. Instances of carpal tunnel syndrome (CTS) from typing or any type of keyentry, including the use of calculators or nonscanning cash registers are coded 231. CTS resulting from cutting with a knife, repeated use of a power tool should be coded Repetitive use of tool (232). If an injury or illness resulted from prolonged vibration in long distance driving, the event should be coded in event group 061, Rubbed, abraded, or jarred by vehicle or mobile equipment vibration.
230	Repetitive motion, unspecified.	
231	Typing or key entry.	

Table VI–2.—Description of BLS Exposure Event Categories Corresponding to Workplace Risk Factors Associated With Work-Related Musculoskeletal Disorders—Continued

BLS CODE	NATURE OF EXPOSURE EVENT	DESCRIPTION
232	Repetitive use of tools.	
233	Repetitive placing, grasping, or moving objects, except tools.	
239	Repetitive motion, n.e.c.	

[a] The subcategory of ‘‘Bending, climbing, crawling, reaching, twisting’’ is the only subcategory from the Bodily Reaction category used by OSHA to define MSDs.

Source: Occupational Injury and Illness Classification Manual, Bureau of Labor Statistics, December 1992 (Ex. 26–1372).

C. Preliminary Results

OSHA has obtained summary data from the annual BLS surveys for the years 1992 through 1996. Table VI–3 provides the BLS estimates of the number of injuries and illnesses reported nationwide by employers for 1996, by nature of injury and type of workplace exposure, for all injury and exposure event categories deemed by OSHA as representing MSDs. Overall, OSHA estimates that there were a total of 647,344 lost workday MSDs that occurred in 1996, as derived from employer reports of those illnesses and injuries. These disorders represent about 34.4 percent of the 1.88 million LWD Table VI–3 injuries and illnesses reported by employers in 1996 (BLS press release 97–453, 12/17/97).

Table VI–3.—Estimates of the Number of Lost Workday Musculoskeletal Disorders (MSDs) in 1996, by Nature of Injury and Type of Workplace Exposure

NATURE OF INJURY	BLS CODE	TYPE OF WORKPLACE EXPOSURE					
		TOTAL FOR ALL EXPOSURES	OVER-EXERTION	REPETITION	SUBTOTAL (O AND R)	BODILY REACTION [a]	SUBTOTAL
Total for all lost workday injuries			526,594	73,796	600,390	79,475	679,865
Musculoskeletal Disorders							
Sprains, Strains, Tears	021	819,658	424,290	12,872	437,162	66,068	503,230
Back Pain, Hurt Back	0972	52,046	28,046	861	28,907	4,646	33,553
Soreness, Hurt, except back	0973	73,542	17,984	5,811	23,795	2,896	26,691
Carpal tunnel syndrome	1241	29,937		29,809	29,809		29,809
Hernia	153	29,624	25,819	322	26,141	670	26,811
Musculoskeletal and connective system diseases and disorders	17	35,238	7,761	18,278	26,039	1,211	27,250,
Total Number of MSDs		1,040,045	503,900	67,953	571,853	75,491	647,344

[a] Data from BLS included only those injuries reported to have been associated with ‘‘Bending, climbing, crawling, reaching, twisting.’’

Source: BLS-reported estimates for BLS nature-of-injury codes 021, 0972, 0973, 1241, 153, and 17, and for BLS exposure events of overexertion, repetition, and bodily reaction (1996).

To determine whether the injury categories selected by OSHA's panel of experts (representing the disciplines of occupational medicine and ergonomics) were in fact predominately comprised of work-related musculoskeletal disorders, OSHA closely examined those injuries coded by BLS as ‘‘sprains, strains, and tears,’’ by far the largest single ‘‘nature of injury’’ category for the purposes of this study. About 66 percent of the estimated number of MSDs reported to the BLS in 1996 were categorized by BLS coders as ‘‘sprains, strains, and tears’’ due to overexertion. To evaluate the extent to which the injuries in this category represent MSDs, OSHA obtained from the BLS a breakout of the estimated number of injuries, by body part and by type of overexertion event. This breakout appears in Table VI–4 and shows that about 89 percent of these sprain, strain, and tear injuries (379,615) are comprised of injuries due to lifting/lowering, pushing/pulling, holding/carrying, or throwing, all of which are manual handling activities that can lead to work-related MSDs. For the remaining 11 percent of the BLS-coded sprain, strain, and tear injuries, the exact nature of the overexertion exposure was either not reported by the employer or did not fall into any other exposure classification under the BLS system. Of the 379,615 injuries for which the nature of the overexertion exposure was reported, the majority (88 percent) affected body parts that are consistent with the kinds of injuries addressed by the proposed standard, such as upper extremities, neck and shoulder, lower extremities, and back. Fifty-two percent of these injuries represent back injuries due to lifting or lowering. Only a small proportion (12 percent) of sprain, strain, and tear injuries reported by the BLS in 1996 affected body parts that are not relevant to MSDs; these represent 6.9 percent of all MSDs estimated for 1996. Therefore, OSHA is confident that the vast majority of BLS-coded sprain, strain, and tear injuries are appropriately included in the estimated number of MSDs for 1996, and that the judgment of the OSHA expert panel in selecting appropriate BLS injury and event categories for the risk analysis is, in fact, borne out.

Table VI–4.—Number and Percentage of All BLS-Reported Sprain, Strain, and Tear Injuries That are Work-Related Musculoskeletal Disorders (*i.e.,* Caused by Overexertion), by Body Part and Nature of Exposure, 1996

BODY PART AFFECTED	TYPE OF OVEREXERTION EXPOSURE						
	LIFTING/ LOWERING	PUSHING/ PULLING	HOLDING/ CARRYING	THROWING	UNSPEC-IFIED	NOT ELSE-WHERE CLASSI-FIED (NEC)	TOTAL EX-CLUDING NEC AND UNSPEC-IFIED
Shoulder	20,728	8,639	6,895	395	2,277	2,177	36,657
Back	174,107	33,805	35,358	888	15,625	9,811	244,158
Neck	4,844	1,984	1,812		810	720	8,640
Arm	7,012	2,717	2,451	66	751	807	12,246
Wrist	6,567	2,608	2,787		712	866	11,962
Hand	1,417	443	403		210	87	2,263
Finger, fingernails	849	496	319		133	205	1,664
Upper extremities, nec		59					59
Upper extremities, unspecified							0
Multiple upper extremities	1,085	308	342		326	142	1,735
Legs	6,074	4,195	2,426		743	969	12,695
Ankles	829	717	320		126	460	1,866
Foot	236	382	36		65	48	654
Toes		16					16
Lower extremities, unspecified							0
Lower extremities, nec	37						37
Multiple lower extremities	218	61					279
Total all Work-Related MSDs	224,003	56,430	53,149	1,349	21,778	16,292	334,931
Total for Other Body Parts	29,698	8,030	6,843	113	3,304	2,749	44,684
Total Sprains, Strains, Tears	253,701	64,460	59,992	1,462	25,082	19,041	379,615
Percent of Injuries Representing Work-Related MSDs	88	88	89	92	87	86	88

The data summarized above have been broken out by the BLS both by industry sector and by occupation code. In addition, the BLS provided OSHA with estimates of the incidence of MSDs, as defined above by injury type and cause, for each 2-digit SIC. As explained above, the BLS-calculated incidence estimates are based on the incidence among all production employees in each industry sector, and therefore understate the true incidence of work-related MSDs occurring among workers who are exposed to workplace risk factors. Nevertheless, OSHA believes that the incidence estimates are useful for characterizing industry-specific MSD risks and for comparing the extent of the problem between industry sectors covered by the ergonomics program standard as proposed. Table VI–5 provides estimates of the number and incidence of LWD MSDs in each general industry 2-digit SIC group for which BLS provided data. Industries having the highest incidence of MSDs include the following:

—Air transportation (36.6 cases/1,000 workers);
—Local and suburban transit (14.7 cases/1,000);
—Motor freight transportation and warehousing (14.4 cases/1,000);
—Health services (13.8 cases/1,000);
—Transportation equipment (13.4 cases/1,000); and

—Food and kindred products (12.2 cases/1,000).

Table VI–5.—Estimated Number of Lost Workday MSDs IN 1996 and Annual Incidence per 1,000 Workers, by 2-Digit SIC

TWO DIGIT SIC	INDUSTRY SECTOR	ESTIMATED NUMBER OF LWD MSDs	INCIDENCE PER 1,000 WORKERS
45	Transportation by air	34,150.0	36.580
41	Local and suburban transit and interurban highway passenger transportation	4,617.3	14.671
42	Motor freight transportation and warehousing	23,800.1	14.438
80	Health services	103,478.7	13.847
37	Transportation equipment	24,524.0	13.420
20	Food and kindred products	20,540.1	12.242
24	Lumber and wood products, exc. furniture	9,228.5	12.166
34	Fabricated metal, exc. machinery & transportation equipment	17,751.1	12.121
33	Primary metals	8,940.0	12.099
30	Rubber and misc. plastics	11,982.7	12.069
25	Furniture and fixtures	5,892.1	11.741
32	Stone, clay, glass, concrete products	6,316.4	11.444
53	General merchandise stores	22,395.6	11.152
52	Building materials, hardware, garden supply, mobile home dealers	8,621.9	10.699
54	Food stores	25,268.9	10.191
44	Water transportation	1,537.1	9.959
51	Wholesale trade-nondurable goods	24,768.4	9.792
31	Leather and leather products	856.4	9.226
39	Misc. manufacturing industries	3,375.8	8.997
21	Tobacco products	322.9	8.308
70	Hotels, rooming houses, camps, other lodging	11,241.0	8.216
35	Industrial and commercial machinery & computer equipment	17,124.5	7.946
23	Apparel and other finished products made from fabric	6,379.6	7.869
83	Social services	13,755.1	7.483
50	Wholesale trade—durable goods	26,782.1	7.235
57	Home Furniture, Furnishings, And Equipment Stores	6,016.1	7.136
26	Paper and allied products	4,865.2	6.921
27	Printing, publishing, and allied industries	9,195.3	6.547
36	Electronic and other electrical, exc. computer equipment	10,782.5	6.506
76	Miscellaneous Repair Services	2,274.4	6.506
49	Electric, Gas, And Sanitary Services	5,712.1	6.478
79	Amusement And Recreation Services	5,805.4	5.857
22	Texile mill products	3,483.4	5.626
59	Miscellaneous Retail	10,043.2	4.857
65	Real Estate	5,882.8	5.113
55	Automotive dealers and gasoline service stations	10,347.3	4.847
38	Measuring, analyzing, and controlling instruments; photo, medical, optical; watches, clocks	4,036.9	4.785
75	Automotive Repair, Services, And Parking	4,347.9	4.422
48	Communications	5,708.2	4.398
72	Personal Services	3,527.2	3.865
40	Railroad Transportation	932.0	3.702
73	Business services	16,706.8	3.564
28	Chemicals and allied products	3,641.2	3.507
47	Transportation Services	1,263.1	3.262
56	Apparel And Accessory Stores	2,439.1	3.132
29	Petroleum refining and related industries	432.1	2.956
58	Eating and drinking places	14,457.5	2.830
86	Membership Organizations	1,838.5	2.745
82	Educational Services	2,926.6	2.681
87	Engineering, Accounting, Research, Management, And Related Services	5,653.6	2.114
63	Insurance Carriers	2,659.1	2.968
67	Holding And Other Investment Offices	297.6	1.579
81	Legal Services	1,264.4	1.524
60	Depository Institutions	2,487.7	1.355
61	Non-depository Credit Institutions	399.3	0.810
64	Insurance Agents, Brokers, And Service	472.2	0.733
62	Security And Commodity Brokers, Dealers, Exchanges, And Services	276.7	0.533

Source: Estimates provided by BLS for disorders classified by injury types and exposure events shown in Table VII–3.

Note: Estimates include sprain, strain, and tear injuries that are not likely to represent MSDs since data on the estimated number of these injuries were not available by SIC; these injuries represent 6.9 percent of the total number of MSDs.

Table VI–6 provides estimates of the number and incidence of LWD MSDs by occupation code for the 75 occupations having the highest estimated annual incidence of employer-reported MSDs. Because BLS does not provide incidence estimates by occupation, OSHA calculated the incidence using employment estimates from Bureau of the Census Employment and Earnings (1996). Manufacturing occupations having the highest incidence include:

- Punching and stamping machine operators (30.4 cases/1,000 workers);
- Sawing machine operators (18.9 cases/1,000);
- Furnace, kiln, and oven operators, except food (18.0 cases/1,000);
- Grinding, abrading, polishing machine operators (17.9 cases/1,000); and
- Assemblers (16.2 cases/1,000).

Among manual handling occupations, those with the highest incidence of MSDs include:

- Driver—sales workers (42.4 cases/1,000 workers);
- Machine feeders and offbearers (34.6 cases/1,000);
- Nursing aides, orderlies, and attendants (31.6 cases/1,000);
- Laborers, except construction (29.1 cases/1,000);
- Health aides, except nurses (16.9 cases/1,000);
- Licensed practical nurses (16.5 cases/1,000); and
- Hand packers and packagers (13.7 cases/1,000).

Table VI–6.—Estimated Number of Lost Workday MSDs in 1996 and Annual Incidence per 1,000 Workers, by Occupation Code, Ranked by Incidence

OCCUPATION		ESTIMATED NUMBER OF LWD MSDs	MEDIAN NUMBER OF DAYS AWAY FROM WORK	NUMBER OF EMPLOYEES IN 1996 (000)	INCIDENCE PER 1,000 WORKERS
806	Driver-sales workers (8218)	6,614.0	7	156	42.4
878	Machine feeders and offbearers (8725)	2,420.3	10	70	34.6
463	Public transportation attendants (5257)	3,050.0	9	95	32.1
447	Nursing aides, orderlies, and attendants (5236)	58,421.6	5	1,850	31.6
706	Punching and stamping press machine operators (7314, 7317, 7514, 7517)	2,702.8	6	89	30.4
889	Laborers, except construction (8769)	38,873.3	6	1,334	29.1
866	Helpers, construction trades (8641–8645, 8648)	2,465.7	9	106	23.3
727	Sawing machine operators (7433, 7633)	1,470.4	5	78	18.9
766	Furnace, kiln, and oven operators, except food (7675)	1,171.1	7	65	18.0
709	Grinding, abrading, buffing, and polishing machine operators (7322, 7324, 7522)	2,241.8	7	125	17.9
446	Health aides, except nursing (5233)	5,683.3	4	336	16.9
207	Licensed practical nurses (366)	6,514.1	5	395	16.5
785	Assemblers (772, 774)	20,578.8	9	1,271	16.2
804	Truck drivers (8212–8214)	48,334.2	8	3,019	16.0
719	Molding and casting machine operators (7315, 7342, 7515, 7542)	1,757.8	7	110	16.0
364	Traffic, shipping, and receiving clerks (4753)	9,244.0	6	616	15.0
368	Weighers, measurers, checkers, and samplers (4756, 4757)	820.4	8	55	14.9
756	Mixing and blending machine operators (7664)	1,585.7	5	108	14.7
449	Maids and housemen (5242, 5249)	9,754.8	6	683	14.3
888	Hand packers and packagers (8761)	3,824.0	10	279	13.7
783	Welders and cutters (7332, 7532, 7714)	7,997.2	6	605	13.2
754	Packaging and filling machine operators (7462, 7662)	5,145.1	8	393	13.1
686	Butchers and meat cutters (6871)	3,120.0	8	242	12.9
206	Radiologic technicians (365)	1,732.4	3	135	12.8
757	Separating, filtering, and clarifying machine operators (7476, 7666, 7676)	725.7	8	57	12.7
877	Stock handlers and baggers (8724)	13,447.8	5	1,106	12.2
544	Millwrights (6178)	1,005.9	15	89	11.3
799	Graders and sorters, except agricultural (785)	1,883.8	8	169	11.1
529	Telephone installers and repairers (6158)	1,952.5	9	176	11.1
769	Slicing and cutting machine operators (7478, 7678)	1,972.6	5	179	11.0
365	Stock and inventory clerks (4754)	5,443.4	8	497	11.0
748	Laundering and dry cleaning machine operators (6855, 7658)	2,207.2	5	202	10.9
507	Bus, truck, and stationary engine mechanics (6112)	3,618.0	5	336	10.8
593	Insulation workers (6465)	567.1	12	54	10.5
683	Electrical and electronic equipment assemblers (6867)	3,368.2	7	325	10.4

Table VI–6.—Estimated Number of Lost Workday MSDs in 1996 and Annual Incidence per 1,000 Workers, by Occupation Code, Ranked by Incidence—Continued

	OCCUPATION	ESTIMATED NUMBER OF LWD MSDs	MEDIAN NUMBER OF DAYS AWAY FROM WORK	NUMBER OF EMPLOYEES IN 1996 (000)	INCIDENCE PER 1,000 WORKERS
444	Miscellaneous food preparation occupations (5219)	6,815.0	11	664	10.3
523	Electronic repairers, communications and industrial equipment (6151, 6153, 6155)	1,600.1	8	166	9.6
759	Painting and paint spraying machine operators (7669)	1,901.2	5	200	9.5
318	Transportation ticket and reservation agents (4644)	2,869.8	7	304	9.4
516	Heavy equipment mechanics (6117)	1,433.5	14	156	9.2
566	Carpet installers (part 6462)	923.9	12	103	9.0
885	Garage and service station related occupations (873)	1,510.0	9	169	8.9
577	Electrical power installers and repairers (6433)	1,102.3	9	126	8.7
668	Upholsterers (6853)	511.8	7	59	8.7
585	Plumbers, pipefitters, and steamfitters (part 645)	4,742.4	11	555	8.5
439	Kitchen workers, food preparation (5217)	2,063.2	6	257	8.0
573	Drywall installers (6424)	1,317.0	6	168	7.8
268	Sales workers, hardware and building supplies (4353)	1,814.6	6	254	7.1
689	Inspectors, testers, and graders (6881, 828)	925.2	7	131	7.1
856	Industrial truck and tractor equipment operators (8318)	3,580.6	7	512	7.0
865	Helpers, mechanics, and repairers (863)	801.2	5	115	7.0
453	Janitors and cleaners (5244)	15,278.0	6	2,205	6.9
95	Registered nurses (29)	13,595.2	4	1,986	6.8
344	Billing, posting, and calculating machine operators (4718)	710.1	10	104	6.8
588	Concrete and terrazzo finishers (6463)	543.1	10	80	6.8
653	Sheet metal workers (part 6824)	844.0	5	126	6.7
797	Production testers (783)	380.9	25	57	6.7
744	Textile sewing machine operators (7655)	3,971.1	9	595	6.7
637	Machinists (part 6813)	3,193.3	10	491	6.5
103	Physical therapists (3033)	766.4	5	118	6.5
356	Mail clerks, except postal service (4744)	1,198.4	6	188	6.4
796	Production inspectors, checkers, and examiners (782, 787)	3,404.2	6	538	6.3
518	Industrial machinery repairers (613)	3,407.5	8	540	6.3
738	Winding and twisting machine operators (7451, 7651)	351.3	9	56	6.3
508	Aircraft engine mechanics (6113)	835.4	8	137	6.1
734	Printing press operators (7443, 7643)	1,908.2	9	315	6.1
488	Graders and sorters, agricultural products (5625)	379.1	6	63	6.0
448	Supervisors, cleaning and building service workers (5241)	992.9	5	166	6.0
657	Cabinet makers and bench carpenters (6832)	460.8	9	79	5.8
274	Sales workers, other commodities (4345, 4347, 4354, 4356, 4359, 4362, 4369)	8,616.0	7	1,499	5.7
486	Groundskeepers and gardeners, except farm (5622)	4,981.4	5	875	5.7
505	Automobile mechanics (part 6111)	5,042.1	8	889	5.7
98	Respiratory therapists (3031)	543.7	6	96	5.7
634	Tool and die makers (part 6811)	733.7	17	132	5.6

Source: Estimates of number of work-related disorders provided by BLS for disorders classified by injury types and exposure events shown in Table VII–3. Annual Incidence calculated by OSHA based on 1996 employment data from Employment and Earnings (U.S. Bureau of Census, 1996).

Note: Estimates include sprain, strain, and tear injuries that are not likely to represent MSDs since data on the estimated number of these injuries were not available by occupation; these injuries represent 6.9 percent of the total number of MSDs.

Of the 225 occupations for which BLS provided estimates of the numbers of employer-reported MSDs and total employment, the annual incidence of MSDs was 1 LWD case or more per 1,000 workers per year for 178 (79 percent) of the occupations.

Data provided by the BLS for the years 1992 through 1996 indicate that the annual incidence of employer-reported MSDs has been steadily declining over this period for the majority of 2-digit SIC group industry sectors. These data appear in Figure VI–1. There are a few exceptions to this downward trend where the BLS data indicate that the incidence of employer-reported MSDs is on the rise. These industries include Tobacco (SIC 21) and Air Transportation (SIC 45).

The data described above reflect the annual incidence of MSDs estimated to have occurred in 1996 within general industry sectors and within occupations within this sector. Past risk assessments conducted by OSHA in other health standards rulemakings have typically estimated the lifetime risk to workers based on the assumption that they are exposed to the hazard in question for a full 45-year working lifetime. These past risk assessments dealt primarily with chronic, fatal diseases such as cancer. Unlike the impairments of health caused by many other OSHA-regulated hazards, however, MSDs are not fatal, although they are often debilitating. Moreover, a worker can experience more than one work-related MSD over a working lifetime. As a result, the lifetime risk associated with exposure to risk factors on the job can be expressed in a number of ways. One way of doing this is to define lifetime risk as the probability that a worker will experience at least one work-related musculoskeletal disorder during his or her working lifetime (45 years). This probability is calculated as $1-(p)^{45}$, where p is the probability that a worker will *not* experience a work-related MSD in any given year (*i.e.*, p is one minus the estimated MSD incidence for 1996 in the industry sector of interest).[2] For example, the estimated incidence of MSDs in 1996 for SIC 80, Health Services, is 13.847 lost workday cases per 1,000 workers. The probability that a worker in SIC 80 will not experience an MSD in any given year is calculated as $1-.013847$, or 0.9862 (almost 99 percent). Over 45 years, the probability that a worker will never experience a work-related MSD is $(.9862)^{45}$, or 0.534 (*i.e.*, 53 percent). Therefore, the probability that a worker in SIC 80 will experience at least one work-related MSD is 1–0.534, or 0.466 (*i.e.*, 466 per 1,000 workers).

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[2] OSHA used two simplifying assumptions when calculating the probability of experiencing no work-related MSDs in a working lifetime: (1) Employment in an industry was used as a surrogate for exposure to ergonomic hazards in that industry. (2) The probability of experiencing a work-related MSD in any given industry was treated as if it were identical for workers in that industry who had never previously experienced a work-related MSD and those who had previously experienced a work-related MSD.

Figure VI-1.
Incidence of Lost-Work-Day MSDs, by Year and 2-Digit SIC

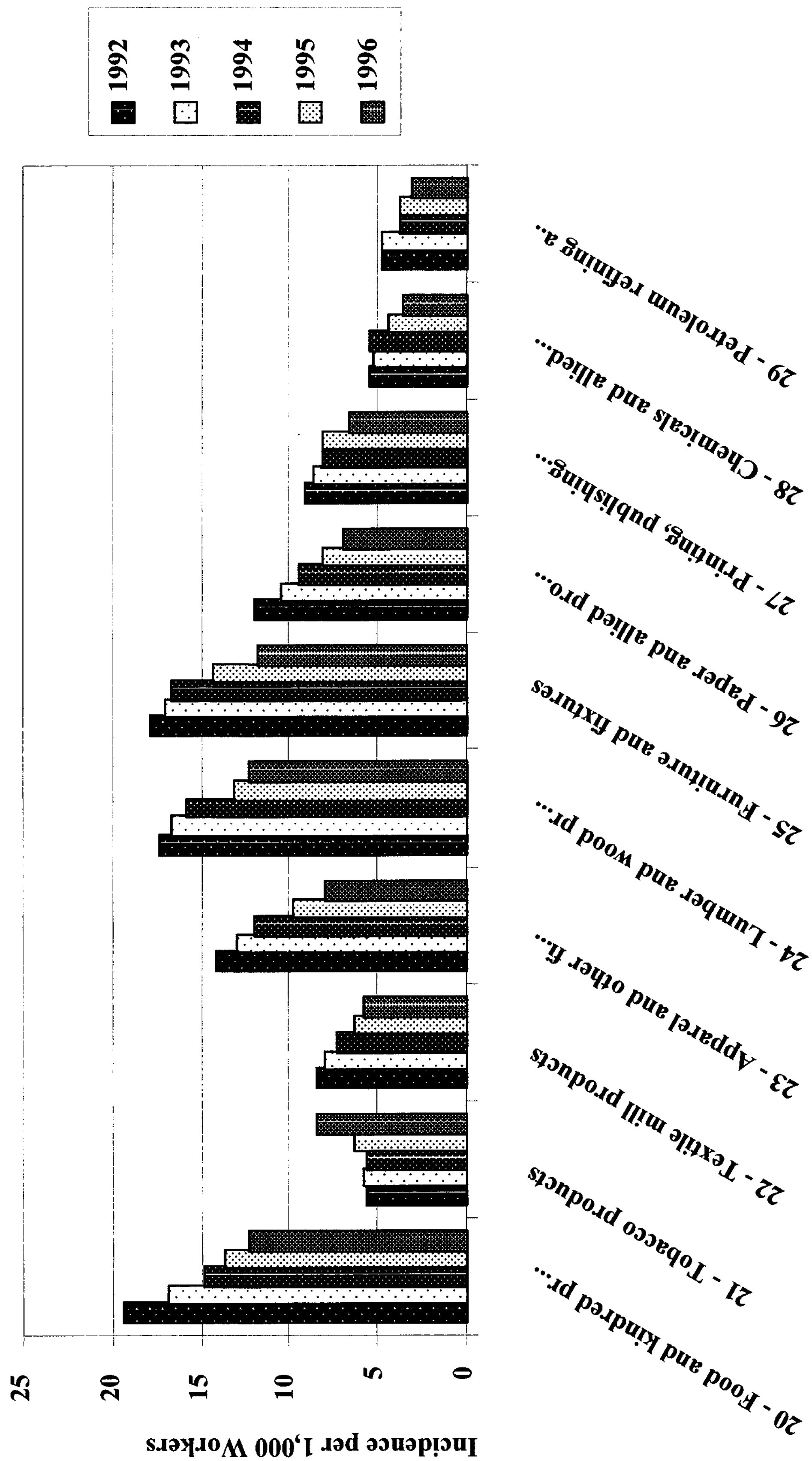


Figure VI-1.
Incidence of Lost-Work-Day MSDs, by Year and 2-Digit SIC (Continued)

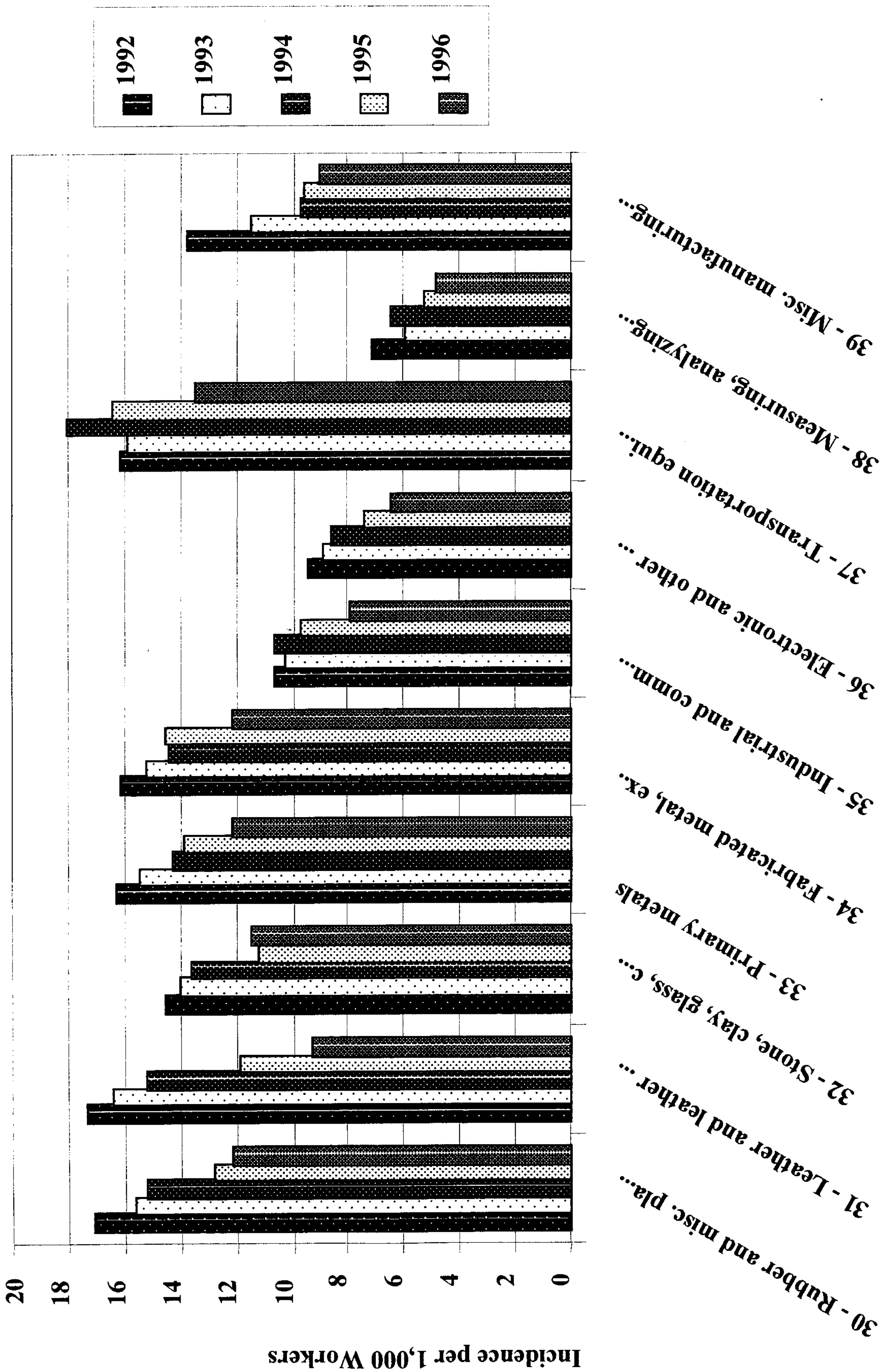


Figure VI-1.
Incidence of Lost-Work-Day MSDs, by Year and 2-Digit SIC (Continued)

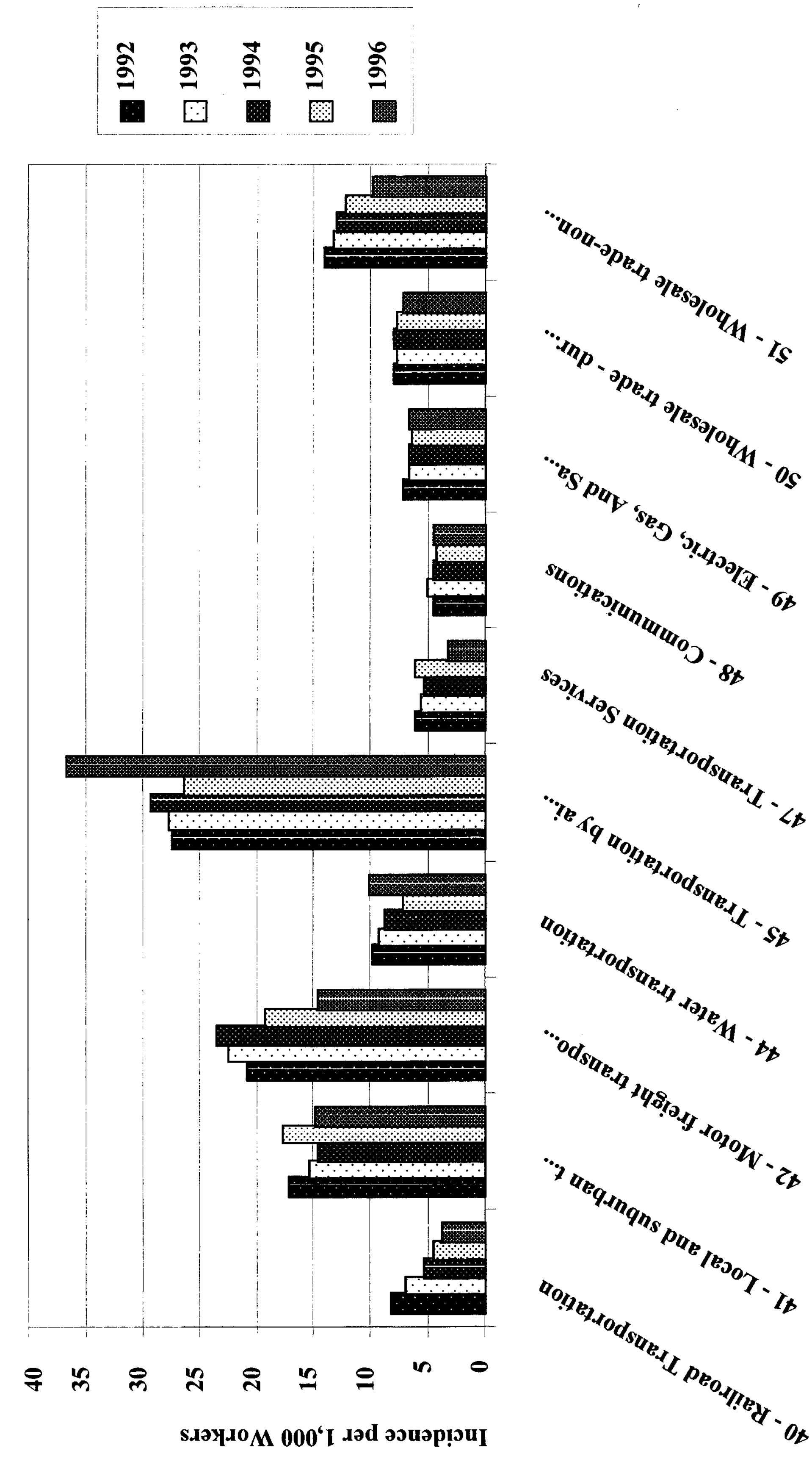


Figure VI-1.
Incidence of Lost-Work-Day MSDs, by Year and 2-Digit SIC (Continued)

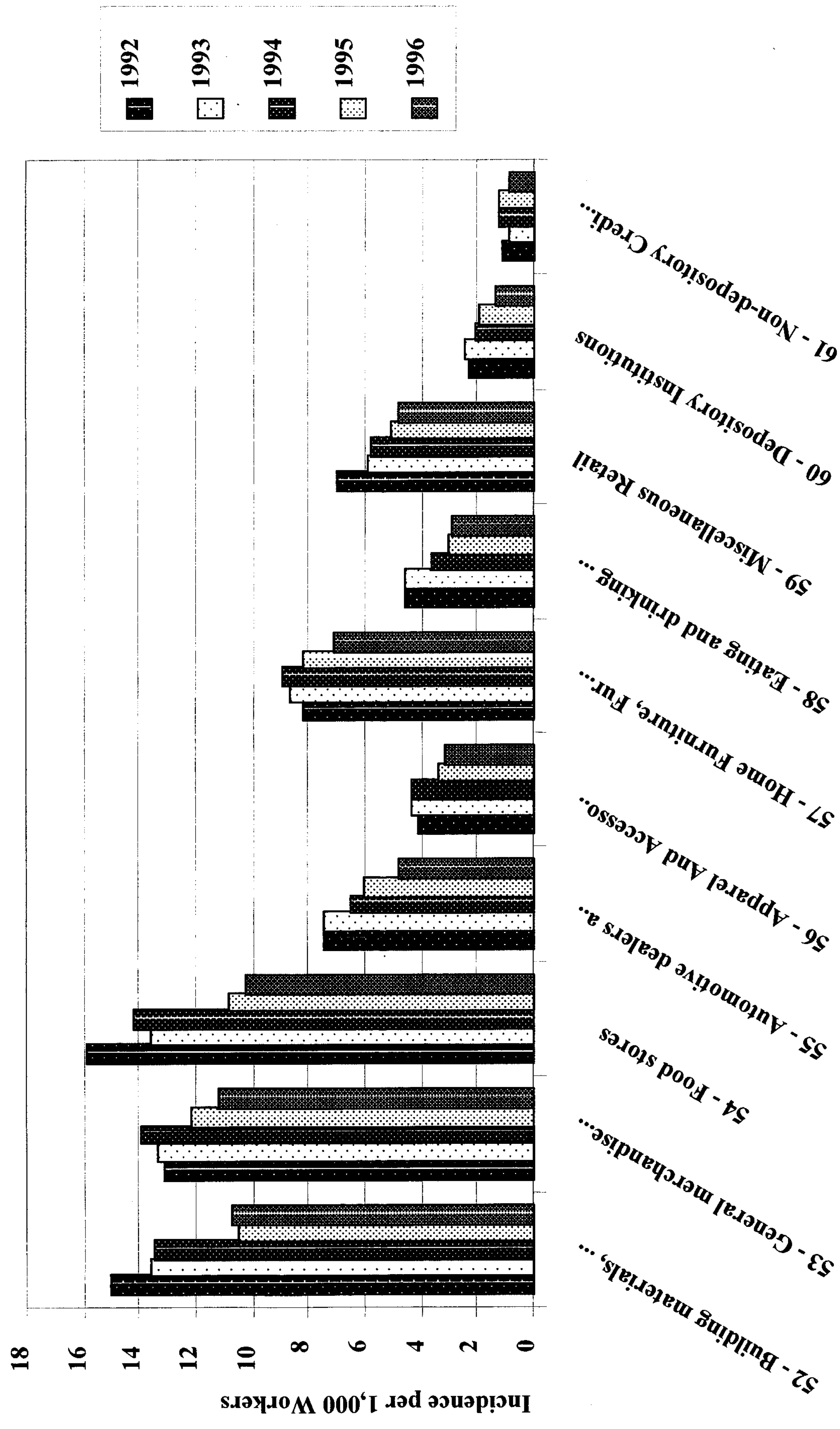


Figure VI-1.
Incidence of Lost-Work-Day MSDs, by Year and 2-Digit SIC (Continued)

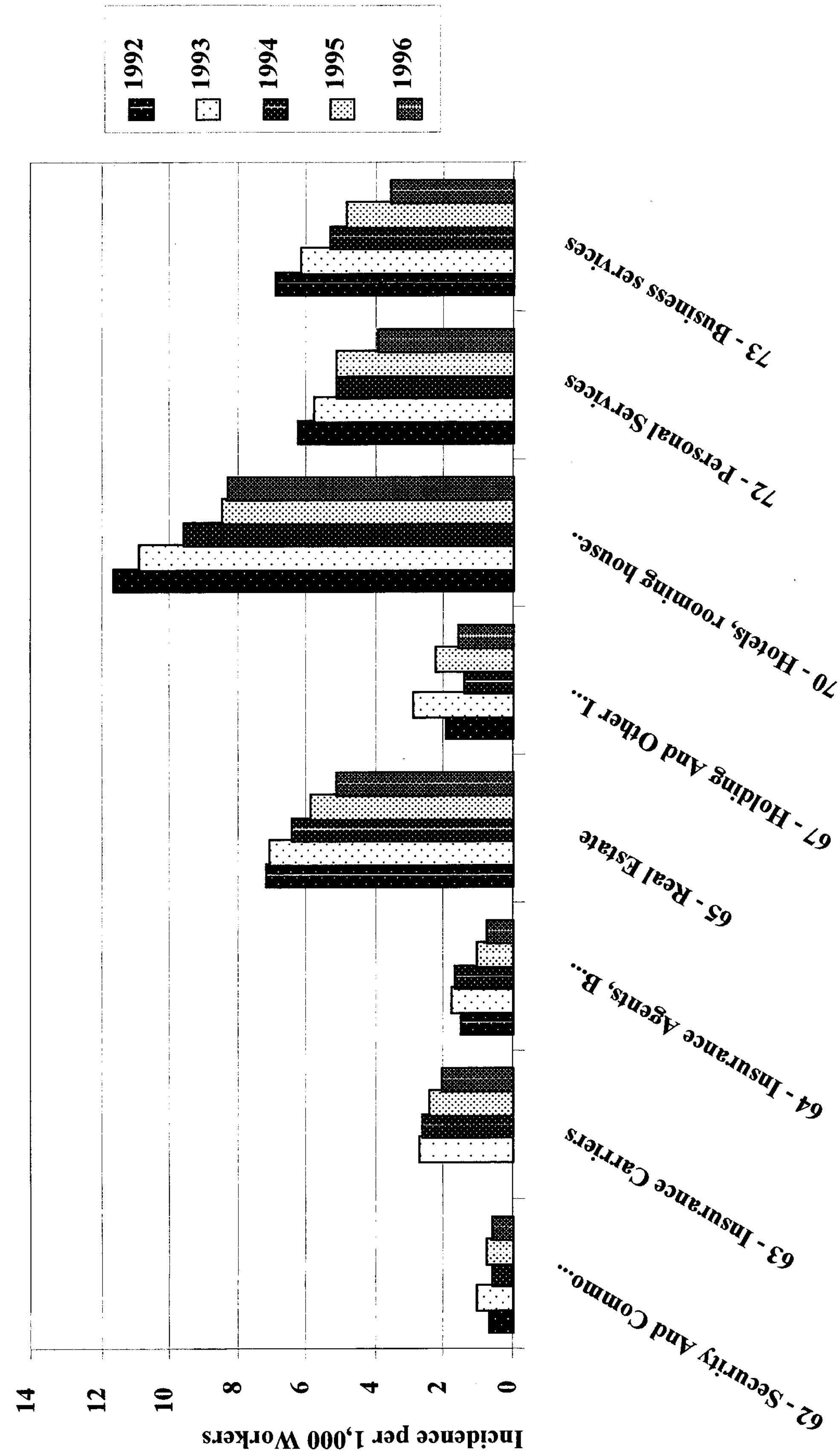
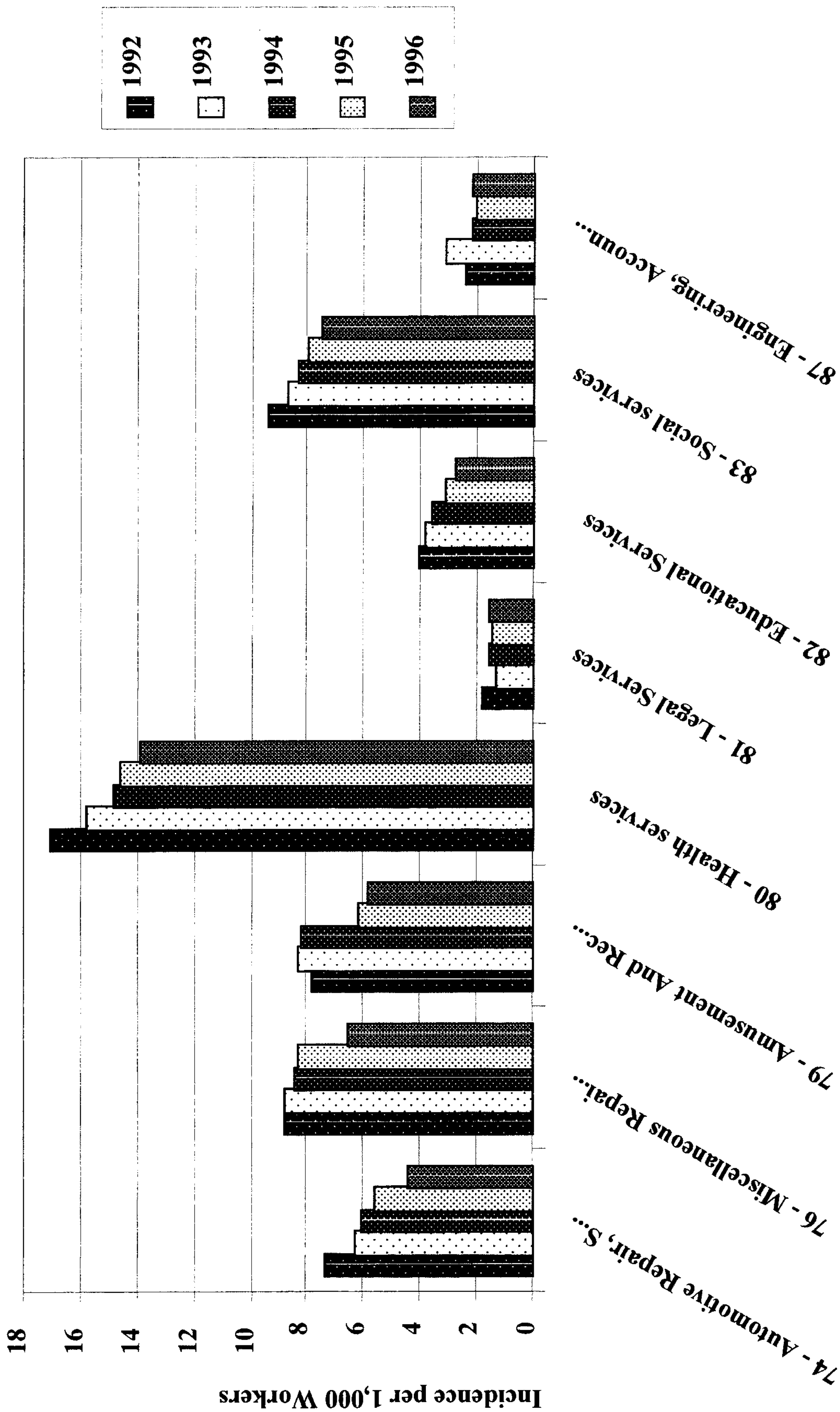


Figure VI-1.
Incidence of Lost-Work-Day MSDs, by Year and 2-Digit SIC (Continued)



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Alternatively, lifetime risk could be defined as the expected number of work-related MSDs an employee entering an industry will experience over a working lifetime in that industry. Unlike a probability, the expected value in such cases can exceed 1. (That is why, in the table below, one industry is identified in which an individual who works for 45 years can expect to experience, on average, more than one work-related MSD during that time.) The expected value represents the experience of the ''average'' individual, a measure that reflects the aggregate experience of many individuals.

Both approaches taken by OSHA to estimate lifetime risk assume that the risk to a worker is independent from one year to the next, *i.e.*, that a worker's injury experience in any one year does not modify his or her risk in any subsequent year. Although this is a reasonable assumption for the purpose of estimating an average lifetime risk, it is likely to be the case that the risk will be higher for workers who have had an MSD and continue to be exposed since musculoskeletal tissue has already been damaged. Among workers who have not experienced symptoms of an MSD, the risk to any individual worker in subsequent years depends on the amount of tissue damage sustained from exposure to risk factors and that worker's individual ability to repair or resist continued injury to the point of experiencing an MSD. In addition, OSHA's approach also assumes that each worker within a given industry sector (defined by 2-digit SIC) has the same risk. For the same reasons as discussed above, a relatively small number of workers will, in fact, experience injury rates far in excess of the average, while a comparatively large number will experience injury rates below the average. At this time, data are not available that would allow OSHA to determine the lifetime MSD risks for subpopulations of workers within each industry sector, *i.e.*, those subpopulations with higher than average or lower than average risks, respectively.

Another meaning or interpretation of expected value may be more intuitive: The expected value is the total number of MSDs that may be expected to occur in a cohort of 1000 workers all of whom enter an industry sector at the same time and all of whom work for 45 years in the industry. The expected value of the number of MSDs occurring among these 1,000 workers over 45 years of employment is calculated as the annual MSD incidence multiplied by 45. For example, the estimated incidence of work-related MSDs in 1996 for SIC 80 (Health Services) is 13.847 cases per 1,000 workers, or a frequency of 0.01387. The expected value of the number of work-related MSDs predicted to occur among those 1,000 workers over 45 years is estimated to be (0.01387*45), or 0.623 (623 per 1,000 workers).

Table VI–7 presents OSHA's estimates of the lifetime risk of experiencing work-related MSDs, by industry sector. Based on the probability approach, the estimated probability of experiencing at least one work-related MSD during a working lifetime ranges from 24 per 1,000 to 813 per 1,000, depending on the industry sector. Based on the expected value approach, the expected number of work-related MSDs that will occur in a cohort of workers all entering an industry at the same time ranges from 24 per 1,000 to 1646 per 1,000, since this approach recognizes that it is possible for a worker to experience more than one work-related MSD in a working lifetime.

D. Analysis of Ergonomic Program Effectiveness

OSHA's evaluation of the effectiveness of ergonomic programs and interventions in reducing MSD risk to employees is derived from three types of data. First, OSHA searched for and evaluated studies that investigated the effect of ergonomic interventions Table VI–7 on reducing exposures to workplace risk factors. These include both field and laboratory studies. Second, OSHA compiled a large database of published and unpublished data from case studies that describe the effect of implementing ergonomic programs on workplace MSD injury rates. Finally, OSHA uses the findings from the epidemiological studies contained in the NIOSH (1997, Ex. 26–1) review to estimate the potential effectiveness of ergonomics programs.

Table VI–7.—Estimated Risk of Developing a Work-Related MSDs Over a 45-Year Working Lifetime, by 2-Digit SIC

TWO DIGIT SIC	INDUSTRY SECTOR	ESTIMATED INCIDENCE PER 1,000 WORKERS	EXPECTED NUMBER OF MSDs PER 1,000 WORKERS DURING A WORKING LIFETIME	NUMBER OF WORKERS PER 1,000 ESTIMATED TO HAVE AT LEAST ONE MSD DURING A WORKING LIFETIME
45	Transportation by air	36.580	1,646	813
41	Local and suburban transit and interurban highway passenger transportation	14.671	660	486
42	Motor freight transportation and warehousing	14.438	650	480
80	Health services	13.847	623	466
37	Transportation equipment	13.420	604	456
20	Food and kindred products	12.242	551	426
24	Lumber and wood products, exc. furniture	12.166	547	424
34	Fabricated metal, exc. machinery & transportation equipment	12.121	545	422
33	Primary metals	12.099	544	422
30	Rubber and misc. plastics	12.069	543	421
25	Furniture and fixtures	11.741	528	412
32	Stone, clay, glass, concrete products	11.444	515	404
53	General merchandise stores	11.152	502	396
52	Building materials, hardware, garden supply, mobile home dealers	10.699	481	384
54	Food stores	10.191	459	369

Table VI–7.—Estimated Risk of Developing a Work-Related MSDs Over a 45-Year Working Lifetime, by 2-Digit SIC—Continued

TWO DIGIT SIC	INDUSTRY SECTOR	ESTIMATED INCIDENCE PER 1,000 WORKERS	EXPECTED NUMBER OF MSDs PER 1,000 WORKERS DURING A WORKING LIFETIME	NUMBER OF WORKERS PER 1,000 ESTIMATED TO HAVE AT LEAST ONE MSD DURING A WORKING LIFETIME
44	Water transportation	9.959	448	363
51	Wholesale trade—nondurable goods	9.792	441	358
31	Leather and leather products	9.226	415	341
39	Misc. manufacturing industries	8.997	405	334
21	Tobacco products	8.308	374	313
70	Hotels, rooming houses, camps, other lodging	8.216	370	310
35	Industrial and commercial machinery & computer equipment	7.946	358	302
23	Apparel and other finished products made from fabric	7.869	354	299
83	Social services	7.483	337	287
50	Wholesale trade—durable goods	7.235	326	279
57	Home Furniture, Furnishings, and Equipment Stores	7.136	321	275
26	Paper and allied products	6.921	311	268
27	Printing, publishing, and allied industries	6.547	295	256
36	Electronic and other electrical, exc. computer equipment	6.506	293	255
76	Miscellaneous Repair Services	6.506	293	255
49	Electric, Gas, and Sanitary Services	6.478	292	254
79	Amusement and Recreation Services	5.857	264	232
22	Textile mill products	5.626	253	224
59	Miscellaneous Retail	4.857	219	197
65	Real Estate	5.113	230	206
55	Automotive dealers and gasoline service stations	4.847	218	196
38	Measuring, analyzing, and controlling instruments; photo, medical, optical; watches, clocks	4.785	215	194
75	Automotive Repair, Services, and Parking	4.422	199	181
48	Communications	4.398	198	180
72	Personal Services	3.865	174	160
40	Railroad Transportation	3.702	167	154
73	Business services	3.564	160	148
28	Chemicals and allied products	3.507	158	146
47	Transportation Services	3.262	147	137
56	Apparel And Accessory Stores	3.132	141	132
29	Petroleum refining and related industries	2.956	133	125
58	Eating and drinking places	2.830	127	120
86	Membership Organizations	2.745	124	116
82	Educational Services	2.681	121	114
87	Engineering, Accounting, Research, Management, And Related Services	2.114	95	91
63	Insurance Carriers	2.068	93	89
67	Holding and Other Investment Offices	1.579	71	69
81	Legal Services	1.524	69	66
60	Depository Institutions	1.355	61	59
61	Non-depository Credit Institutions	0.810	36	36
64	Insurance Agents, Brokers, and Service	0.733	33	32
62	Security And Commodity Brokers, Dealers, Exchanges, And Services	0.533	24	24

ASource: Estimated Incidence of MSDs provided by BLS for disorders classified by injury and exposure events shown in Table VII–3. Lifetime risk estimates calculated by OSHA using methods described in the text.

Many studies were identified that provided quantitative evidence that ergonomic interventions reduce exposures to workplace risk factors. Some of these are summarized in Table VI–8 and include information on the type of study (field vs. laboratory), the nature of the job and exposure being addressed, the kind of intervention(s) examined, and the effect of those interventions on worker exposures to risk factors that could lead, if uncontrolled, to the development of work-related MSDs. These studies show that ergonomic interventions are effective in reducing exposures to workplace risk factors in a wide variety of workplace settings. Interventions represented by these studies include redesigning machines and tools, altering workstation layout or configuration, using lifting devices, and modifying materials to aid in manual handling. These interventions were found to reduce the duration and/or intensity of worker exposures to the risk factors related to MSDs, sometimes by as much as 50 percent. After reviewing some of these same studies, a National Academy of Sciences Panel (NRC 1998, Ex. 26–37) concluded that ''[r]esearch clearly demonstrates that specific interventions can reduce the reported rate of musculoskeletal disorders for workers who perform high-risk tasks. No known single intervention is universally effective. Successful interventions require attention to individual, organizational, and job characteristics, tailoring the corrective action to those characteristics.''

Table VI–8.—Summary of Studies Reporting the Effectiveness of Workplace Interventions on Exposures to Risk Factors Associated With the Development of Work-Related Musculoskeletal Disorders

STUDY	INDUSTRY SECTOR	OPERATION	NATURE OF INTERVENTION	RESULTS
Steele *et al.* (1990, Ex. 26–1254)	Firearms manufacturing	Use of a mechanical test fixture to gauge parts. Work involved intensive hand and wrist motions	Modification of test fixture by using add-on features (*i.e.,* fixture itself was not modified)—change position and angle of parts rack, anchor gauge to bench, use adjustable chair and footrest, install power-grip handle	Reduced the number of damaging wrist motions by 3 to 6 fold. Reduced the number of pinch grips required per cycle. Total cycle time reduced from 5.5 to 3.75 seconds.
Hakkanen *et al.* (1997, Ex. 26–898)	Trailer assembly	Furniture assembly and fixture (female workforce). Work involved driving screws, drilling holes, and lifting	Interventions suggested by ergonomics team and workers. Changes included using modified hand tools, height-adjustable tables, work space redesign, use of hoists, and work enlargement. Workers returning from sick leave were temporarily placed on easier jobs	Driving screws and drilling After intervention, workers selected proper tool for job more frequently (*i.e.,* pistol grip tool for vertical surfaces and an inline tool for horizontal surfaces). Cumulative exposures with deviated wrists (measured in Ns) were reduced for furniture fixers and assemblers. Cumulative exposures were more evenly distributed among workers after intervention due to job enlargement. Low back loading (measured as dose in Nm*s per work cycle) reduced for 3 tasks (reduction ranged from 19–54%), eliminated for 1 task.
Knowlton and Gilbert (1983, Ex. 26–1248)	(Laboratory study)	Driving nails manually	Use of a curve-handled ripping hammer vs. a conventional claw hammer	Use of the curve-handled ripping hammer resulted in a 42-percent lower strength decrement. Ulnar deviation was 2 to 6 times greater when using the conventional hammer.

Table VI–8.—Summary of Studies Reporting the Effectiveness of Workplace Interventions on Exposures to Risk Factors Associated With the Development of Work-Related Musculoskeletal Disorders—Continued

STUDY	INDUSTRY SECTOR	OPERATION	NATURE OF INTERVENTION	RESULTS
Keyserling *et al.* (1993, Ex. 26–1247)	Automotive	Various jobs resulting in prolonged exposure to awkward postures	Administration of checklist by plant personnel after one week of training. Interventions included installing elevated racks and lift tables, and eliminating or reducing horizontal obstructions and overhead reaches	Trunk posture—Decrease in percent of cycle time spent with severe flexion while standing; increase in percent of cycle spent in neutral sitting position. Shoulder posture—Decrease in percent of cycle spent with mild or severe shoulder elevation; increase in percent of cycle time spent in neutral posture. Neck posture—Increase in percent of time spent with mild or severe neck flexion; decrease in time spent with neutral neck posture.
Drury and Wick (1984, Ex. 26–1244) and Wick (1987, Ex. 26–1058)	Shoe manufacturing	Various assembly jobs, clerical, and leather sorting (manual handling)	Install armrests and footrests, elevate and tilt equipment, use better-designed chairs, use pallet leveler to minimize bending while lifting	Reduced number of damaging wrist motions in assembly jobs by at least one-third, and frequently by more than half. Reduced disc compressive forces in clerical jobs by about 17 percent. Reduced disc compressive forces during lifting jobs by more than 50 percent.
Garg and Owen (Undated, Ex. 26–1093)	Health care	Patient transfer	Use of walking belts and mechanical hoists, modifying toilets and shower rooms, modifying patient care techniques	Reduced mean disc compressive forces by 59 percent, reduced mean hand forces by 61 percent, and reduced strength requirements for lifting tasks.
Miller *et al.* (1971, Ex. 26–1250)	Health care	Surgery	Redesign of bayonet forceps	Reduced mean time from grasp to stable hold, reduced workload on thumb and finger flexors (as measured by electromyography).
Hansen *et al.* (1998, Ex. 26–1245)	(Laboratory study)	Prolonged standing or standing/walking	Use of soft shoes and/or mats on hard floors	Standing work for a 2-hour period caused muscle fatigue (measured by electromyography), lower back discomfort, and foot edema. Foot edema was significantly reduced by the use of soft shoes on hard floors. Use of a soft mat had negligible effects. Heel impact forces while walking were reduced by almost half by the use of soft shoes compared to hard shoes. Again, the use of soft mats had little additional effect.

Table VI–8.—Summary of Studies Reporting the Effectiveness of Workplace Interventions on Exposures to Risk Factors Associated With the Development of Work-Related Musculoskeletal Disorders—Continued

STUDY	INDUSTRY SECTOR	OPERATION	NATURE OF INTERVENTION	RESULTS
Johansson *et al.* (1998, Ex. 26–1246)	Retail food stores (laboratory study)	Checkout cashier	Location of scales to the left of the cashier and conveyor vs. in front of the cashier and under the conveyor. Also evaluated standing vs. sitting	There was no effect of the two configurations on work rate. Placing the scales under the conveyor resulted in less external rotation of the left arm, a decrease in the time spent handling articles, an increase in opportunities for resting the left arm, and a reduction in head twisting. A standing position was found to be a more favorable posture for the taller cashier.
Davis *et al.* (1998, Ex. 26–1243)	Various	Palletize/ depalletize (manual handling)	Use of handles on items being manually lifted	Use of handles reduced anterior-posterior shear and compressive forces on the spine and reduced muscle activity for several groups of back muscles.
Peng (1994, Ex. 26–1251)	Heavy vehicle manufacture (laboratory study)	Use of pneumatic percussive rivet hammers and bucking bars	Design modifications of rivet hammers and bucking bars to impart recoilless and vibration dampening properties	Mean vibration levels of recoilless rivet hammers and bucking bars were about half that of conventional tools.
Radwin and Oh (1991, Ex. 26–1253)	Various (laboratory study)	Use of pneumatic hand-held power tools	Varying handle span between 4 and 7 cm. Use of extended trigger (permitting two-finger operation)	Use of a handle span between 5 and 6 cm minimized palm and finger exertion levels. A small but statistically significant reduction in palm and finger forces resulted from use of the extended trigger.
Powers *et al.* (1992, Ex. 26–1252)	Various (office work)	Keyboarding	Use of full-motion forearm supports or negative-slope keyboard support	Wrist extension was significantly less for subjects using the negative-slope keyboard support compared to a traditional keyboard ($-1.2°$ vs. $13.0°$). Use of forearm supports did not affect wrist extension compared to use of a traditional keyboard.

Table VI–8.—Summary of Studies Reporting the Effectiveness of Workplace Interventions on Exposures to Risk Factors Associated With the Development of Work-Related Musculoskeletal Disorders—Continued

STUDY	INDUSTRY SECTOR	OPERATION	NATURE OF INTERVENTION	RESULTS
Luttman and Jäger (1992, Ex. 26–1249)	Weaving mill	Handling and mounting 10-kg bobbins onto the beamer. Transferring bobbins from transfer boxes to push carts prior to mounting	Passageways between arrays in the beamer were widened to accommodate the transfer boxes and eliminate the need to first unload bobbins onto the push cart. Bobbins could then be mounted directly from the transport boxes Bobbins were packed horizontally in boxes rather than vertically to permit them to be unloaded with both hands Used transport boxes with detachable sides along with a hydraulic lift truck to eliminate the need to bend over while unpacking bobbins	Prior to interventions, electromyography showed significantly increased electrical activity reflecting muscle fatigue for the finger flexors of both hands. Intervention eliminated muscle fatigue in both hands. The intervention did not affect work rate.

Furthermore, a large body of literature provides strong evidence that implementation of ergonomic programs and interventions can substantially reduce the prevalence or incidence of work-related MSDs. Appendix VI–B of this section summarizes the published literature and other information that OSHA has identified that include measures of the effectiveness of ergonomics programs in reducing the incidence and severity of MSDs. Generally, the studies that are listed involve case studies of individual companies that instituted programs including some or all of the elements in OSHA's proposed ergonomics program studies were conducted in manufacturing establishments as well as in workplaces where jobs routinely involve manual handling. Overall, OSHA identified 92 case studies that quantified the reduction in MSD incidence following implementation of ergonomic programs and interventions; of these, 21 provided data on the reduction in lost-work-day MSDs and 80 provided data on the reduction in total MSDs, which include both lost-work-day and non-lost-work-day cases. From each of these case studies, OSHA calculated the effectiveness of the standard (*e.g.*, employee involvement and training, implementation of engineering or work practice controls). These case ergonomic interventions as the percent reduction in either lost workday or total number of MSDs prior to and after implementation of the program. That is, effectiveness was calculated as the ratio

$$(N_B - N_A)/N_B$$

where N_B represents the number or incidence of MSD cases prior to implementation of the ergonomic intervention, and N_A represents the number or incidence after the intervention.[3]

OSHA's estimate of the overall effectiveness of ergonomics programs is expressed as the median and mean reduction in MSD injury rates contained in this data set. For all MSDs (*i.e.*, lost workday and non-lost workday MSDs), these case studies reported a median 76 percent reduction in injury rates (mean effectiveness was 73 percent). The median and mean reductions for lost workday MSDs only were somewhat higher, at 82 percent and 79 percent, respectively. Although the effectiveness of individual ergonomics programs varied widely among the establishments described in these case studies, most interventions (about 90 percent of the case studies) achieved at least a 30-percent reduction in MSD injury rates, 70 percent of the case studies reduced MSD rates by half or more, and several achieved the total elimination of lost workday MSDs (see Appendix VI–B).

The effectiveness of ergonomics programs in reducing MSD injury rates is also demonstrated by a group of case studies reported by ergonomists from several countries (including the United States). These studies were compiled

[3] Note that, by this definition, the presence of background MSD cases (non-work-related cases) will decrease the apparent effectiveness of ergonomic interventions since the interventions would presumably not have any effect on the background rate of MSDs in the working population (*i.e.*, both N_B and N_A might contain background MSD cases).

into a volume entitled ''Increasing Productivity and Profit through Health and Safety'' (Commerce Clearing House International, Inc., Book #4703, Chicago, IL) and edited by Oxenburgh (1994, Ex. 26–1041). From these case studies, Oxenburgh concluded that engineering controls can, in general, reduce work-related musculoskeletal disorders by 70 to 90 percent (Oxenburgh 1994, Ex. 26–1041). The large number of case studies summarized by this author in his book support this effectiveness rate.

The companies reflected in the case studies may have policies protecting the reporting of or paying for all lost-time caused by job-related injuries. Companies do not consider their benefits policies noteworthy and do not discuss them in any detail when reporting on successful ergonomics interventions. There is no information on their benefits policies in these materials.

OSHA also reviewed the epidemiological literature to identify evidence of the effectiveness of ergonomic approaches. Although many articles recommend the use of engineering and administrative controls to control workplace risk factors, few articles present quantitative evidence of their effectiveness. However, several articles provide assessments of the extent to which particular types of jobs or particular types of risk factors contribute to work-related musculoskeletal disorders. Because the proposed standard will reduce or eliminate risk factors in problem jobs, these articles are relevant to an assessment of the potential effectiveness of the standard. In a recent meta-analysis, Hagberg and Wegman (1987, Ex. 26–32) reviewed the epidemiological literature and selected 21 studies in which diagnoses of neck and shoulder disorders were made from physical or laboratory examinations. Odds ratio measures from studies describing similar disorders were pooled across studies for common occupations that involved exposures to workplace risk factors, and the authors computed the overall odds ratio for each type of occupation and disorder. In addition, the authors assessed the effect of the exposure to workplace risk factors on MSD risk by computing the etiological fraction in the exposed population; this statistic describes the proportion of MSD cases among the exposed workers that is, in fact, attributable to their exposures (and thus is the fraction of MSDs that is potentially avoidable by reducing or eliminating the exposure to workplace risk factors). The etiologic fraction was computed only from those odds ratios that were statistically significantly higher than 1. Hagberg and Wegman (1987, Ex. 26–32) found the etiological fraction to range from 40 to 99 percent, depending on the specific type of upper extremity disorder. Thus, this study provides evidence that most work-related MSDs could be eliminated by implementing ergonomic interventions that serve to reduce worker exposures to risk factors.

Several other epidemiological studies described in the Health Effects section of this preamble (Liles *et al.*, 1994, Ex. 26–33; Snook *et al.*, 1978, Ex. 26–35; Silverstein *et al.*, 1987, Ex. 26–34; Holmstrom *et al.*, 1992, Ex. 26–36; Punnett *et al.*, 1991, Ex. 26–39; Punnett, 1998, Ex. 26–38) demonstrated that the magnitude of the risk of work-related MSDs is related to the intensity of exposure to workplace risk factors (*e.g.*, amount of force applied, number of repetitive motions per unit of time) and to the duration of exposure.

OSHA believes that these studies also demonstrate that reductions in intensity and/or duration of exposure to workplace risk factors will reduce the risk of work-related MSDs among employees who are so exposed. For example, Liles *et al.* (1994, Ex. 26–33) examined the relationship between a numerical measure of work-related exposure to back stress (called the Job Severity Index) and the number of OSHA-recordable back injuries reported to have occurred among workers in jobs that were rated on this numerical scale. The data from this study show that reducing the stress scores of manual handling jobs rated above 1.5 (the job severity threshold identified in this study for back injuries caused by manual handling) to an average score below 1.5 would reduce the number of back injuries by 79 percent. Another well-known quantitative study conducted by Snook, Campanelli, and Hart (1978, Ex. 26–35) found a statistically significantly higher number of back injuries than would be expected in manual handling jobs that required a level of exertion beyond the physical capabilities of more than 25 percent of the working population. Their findings suggest that back injuries could be reduced by 66.6 percent in jobs where the level of physical exertion associated with the job could be reduced sufficiently by ergonomic controls to enable 75 percent or more of the working population to perform it without overexertion.

In another example, the National Institute for Occupational Safety and Health (NIOSH) analyzed a survey of 27,804 currently employed workers and developed estimates of the relationship between the number of workers reporting one week or more of severe back pain during the previous year and the number of hours these employees were exposed to strenuous physical activity (lifting, pushing or pulling heavy objects) (Wild, 1995, Exs. 26–1104, 26–1105, 26–1106, 26–1107). The workers surveyed were between 18 and 64 years of age. Using these data, NIOSH found statistically significant positive exposure-response relationships between prevalence of back pain and number of hours per week spent performing strenuous physical activity or repeated bending, twisting, and reaching. Thus, these data show that decreasing the duration of exposure to physical exertion can decrease the risk of back pain (for a complete presentation of these results, see the Health Effects section of this preamble). For example, workers exposed to strenuous activity for fewer than 2 hours per day have a prevalence of back pain that is 65 percent less than the prevalence among workers exposed to these stresses for more than 2 hours per day.

For jobs that involve exposure to multiple risk factors, other epidemiological studies provide evidence that the risk of work-related MSDs can be reduced either by reducing or eliminating exposure to one of those risk factors, or by reducing duration of exposure to the risk factors. Silverstein *et al.* (1987, Ex. 26–34) and Armstrong *et al.* (1987, Ex. 26–48) examined the prevalence of carpal tunnel syndrome and tendinitis, respectively, among populations exposed to various combinations of risk factors, including those involving low-force-and-low-repetition, high-force-and-low-repetition, low-force-and-high-repetition, and high-force-and-high-repetition. The high-force-and-high-repetition population in this study is exposed to two or more risk factors (*i.e.*, repetition and force). Silverstein *et al.* (1987, Ex. 26–34) found that the prevalence of carpal tunnel syndrome was statistically significantly elevated among workers exposed to high repetition alone or to both risk factors together; the prevalence of carpal tunnel syndrome was elevated, but not statistically significant, among workers exposed to high force alone. Odds ratios for hand/wrist tendinitis were elevated for all three groups of exposed workers, but was statistically significant only among workers exposed to both high force and high repetition (Armstrong *et al.* 1987, Ex. 26–48). Based on these data, implementing ergonomic interventions that reduce employee exposures from two risk factors to one could be expected to lead to a reduction in injuries of 83 percent for carpal tunnel syndrome and a between 79 and 89 percent for tendinitis. Punnett *et al.* (1998, Ex. 26–38) conducted a cross-sectional study in an automobile stamping plant and in an engine plant, and assessed exposures to workplace risk factors by using an exposure scoring procedure that reflected the intensity and duration of exposure to any of several risk factors and found a positive, statistically significant relationship between risk factor exposure score and prevalence of upper-extremity disorders. Data from her study indicate that the prevalence of employee-reported symptoms of upper extremity disorders, and the prevalence of physician-confirmed MSD cases, could be reduced by more than 50 percent if the exposure score was reduced by at least half, which could be accomplished by eliminating exposures to some risk factors or by reducing exposure durations. These data also show that about one-fourth to one-third of MSD cases could be eliminated from more modest reductions in the exposure score. Thus, the Silverstein *et al.* (1987, Ex. 26–34), Armstrong *et al.* (1987, Ex. 26–48), and Punnett *et al.* (1998, Ex. 26–38) studies show that exposures to workplace risk factors do not need to be entirely eliminated to achieve substantial reductions in MSD injury rates.

Finally, OSHA turned to the large body of scientific epidemiology studies reviewed by NIOSH (1997, Ex. 26–1), which compiled the measured excess MSD risk reported in these studies, to make an overall estimate of the effectiveness of ergonomic programs and interventions from data sources independent of the case studies described earlier in this section. The risk measures contained in the epidemiological studies include odds ratios, prevalence rate ratios, and (for a few studies) incidence ratios, and approximate the relative risk of musculoskeletal disorders in an exposed worker population compared to a referent group. These studies reported a total of 83 risk ratios for neck and/or shoulder disorders, 91 risk ratios for upper extremity disorders, and 56 risk ratios for musculoskeletal disorders of the lower back. (The NIOSH study did not review studies of lower extremity disorders.) To determine the extent to which risk could be reduced, as predicted by the risk ratios reported in these studies, OSHA calculated the median and mean values of the risk ratios from each of the studies included in the NIOSH report, by body part affected. From these values, OSHA estimated the mean and median etiological fraction for each type of disorder; this measure describes the proportion of MSD injuries among exposed workers that is attributable to their exposure and thus potentially avoidable by reducing those exposures. OSHA then estimated the effectiveness of ergonomics programs (defined the same as for the case studies described above, which recognizes that some MSDs represent background and are not work-related), assuming either that half of the work-related MSD injuries would be avoided or that all of the work-related risk would be eliminated. OSHA does not believe that the latter assumption is unreasonable since, as discussed above, epidemiological evidence indicates that it is not necessary to eliminate all exposures to workplace risk factors to achieve substantial reductions in MSD incidence. The results of OSHA's analysis appear in Table VI–9. Under the assumption that the risk attributed to exposure at work is reduced by half, the median estimated effectiveness of ergonomic programs and interventions ranges from about 28 to 43 percent (the mean effectiveness estimate ranges from about 38 to 47 percent). If all of the work-related risk were to be eliminated, the median effectiveness estimate would range from 56 to 86 percent, with a mean estimate of from 75 to 95 percent.[4] The estimates of effectiveness based on the latter assumption are similar to the estimates drawn from the intervention case studies described above, which OSHA believes corroborates the general finding from the case studies that ergonomic interventions will result in substantial declines in MSD case rates.

Table VI–9.—Estimated Effectiveness of Ergonomic Interventions Based on Risk Ratios Contained in the NIOSH (1997) Review of the Epidemiological Literature for MSDs

	BODY PART AFFECTED/DISORDER							RANGE IN MEDIAN OR MEAN EFFECTIVENESS (PERCENT) [a]
	NECK OR NECK/SHOULDER	ONLY SHOULDER	ELBOW	CARPAL TUNNEL SYNDROME	HAND/WRIST TENDINITIS	HAND/ARM VIBRATION	BACK	
Number of Studies Included	57	26	19	38	21	13	56	
Risk Ratios [b]								
Median	3.30	3.30	2.70	2.75	3.70	7.10	2.25	
Average	17.78	4.76	5.03	4.15	6.96	18.71	4.01	
Estimated Etiologic Factor [c]								
Median	0.697	0.697	0.630	0.636	0.730	0.859	0.556	
Average	0.944	0.790	0.801	0.759	0.856	0.947	0.751	

[4] Note that even if all of the work-related risk is eliminated, the effectiveness of the ergonomic interventions is still less than 100 percent because of the presence of background illnesses.

Table VI–9.—Estimated Effectiveness of Ergonomic Interventions Based on Risk Ratios Contained in the NIOSH (1997) Review of the Epidemiological Literature for MSDs—Continued

	BODY PART AFFECTED/DISORDER							RANGE IN MEDIAN OR MEAN EFFECTIVENESS (PERCENT) [a]
	NECK OR NECK/SHOULDER	ONLY SHOULDER	ELBOW	CARPAL TUNNEL SYNDROME	HAND/WRIST TENDINITIS	HAND/ARM VIBRATION	BACK	
Estimated Percent Effectiveness Assuming Exposure-Related Risk Is Reduced by Half [d]								
Median	34.9	34.9	31.5	31.8	36.5	43.0	27.8	27.8–43.0
Average	47.2	39.5	40.5	37.9	42.8	47.4	37.6	37.6–47.4
Estimated Percent Effectiveness Assuming Exposure-Related Risk Is Eliminated [e]								
Median	69.7	69.7	63.0	63.6	73.0	85.9	55.6	55.6–85.9
Average	94.4	79.0	80.1	75.9	85.6	94.7	75.1	75.1–94.7

[a] Effectiveness is the estimated percent reduction in MSD incidence after implementation of ergonomic interventions.
[b] Risk ratios include odds ratios, prevalence rate ratios, and incidence ratios.
[c] Etiologic factor is the proportion of disorders among exposed workers that is attributable to their exposure at work, and is calculated as (RR–1)/RR, where RR is the median or average risk ratio derived from each group of epidemiological studies.
[d] Calculated as half of the etiologic factor, expressed as a percentage. Alternatively, using the formula to calculate effectiveness, $(N_B - N_A)/N_B$, where N_B is the fraction of cases existing before ergonomic intervention=1, and N_A is the fraction of cases remaining after intervention=[1 − (0.5*etiologic fraction)].
[e] Equals the etiologic factor expressed as a percentage. Alternatively, using the formula to calculate effectiveness, $(N_B - N_A)/N_B$, where N_B is the fraction of cases existing before ergonomic intervention=1, and N_A is the fraction of cases remaining after intervention=[1 − etiologic fraction)].

Source: Derived from NIOSH (1997).

Based on this review of an extensive body of case studies, epidemiological studies, and other articles from the trade and scientific literature, OSHA believes that it is reasonable to assume that the proposed standard will reduce work-related musculoskeletal disorders in the high risk population by at least 30 percent and by as much as 100 percent, as has been documented in a number of case studies of ergonomics programs. Overall, OSHA believes that MSD incidence will be reduced by about half or two-thirds as a result of implementing ergonomics programs.

E. Preliminary Conclusions

In this section, OSHA estimated the risk of experiencing a lost workday MSD to workers exposed to workplace conditions such as forceful lifting, pushing, or pulling; repeated bending and twisting; repetitive hand or arm motions; static and awkward postures; contact stress; and whole-body and localized vibration. The basis for these estimates is drawn from BLS data that describe the incidence of employer-reported MSDs from 1992 through 1996. For the latest year for which data are available, the estimated industry-specific annual incidence of MSDs ranges from 0.5 to 36.6 lost workday cases per 1,000 workers (by 2-digit SIC); OSHA believes that, because these figures represent the incidence across the entire production workforce in each industry sector, the true incidence among the subset of workers exposed to workplace risk factors is much higher. This is supported by the vast array of epidemiological evidence showing that the risk among exposed workers is up to 10 or 20 times higher than the risk to workers that are not so exposed. The BLS data also demonstrate a significant risk of experiencing MSDs among workers in specific occupations, with the annual incidence estimated to range between 5.6 and 42.4 lost workday cases per 1,000 workers for the 75 occupations having the highest incidence. From these data, OSHA estimated the lifetime risk to workers exposed to risk factors in the workplace, assuming exposure over a 45-year period. The estimated probability of a worker experiencing at least one lost workday MSD over 45 years ranges from 24 to 813 per 1,000 workers, depending on the industry sector.

OSHA also provided evidence that implementation of ergonomic programs and interventions are effective in reducing the risk of MSDs to exposed workers. This evidence consists of 92 case studies that document reductions in MSD injury rates that have resulted after ergonomic programs and interventions have been implemented by employers; field and laboratory studies that show ergonomic interventions are successful in reducing the magnitude of the forces imposed on the body that can damage musculoskeletal tissues; and several epidemiological studies that have shown quantitative relationships between the intensity and duration of exposure to workplace risk factors and the risk of MSDs, which provides direct evidence that reducing exposures will reduce MSD incidence. From the case studies, OSHA estimates that ergonomic programs and interventions will reduce the incidence of total MSDs (*i.e.*, both lost workday and non-lost workday) by a median value of 76 percent (mean value of 73 percent). Case studies suggest that the effectiveness of ergonomic programs and interventions will be somewhat higher in reducing lost workday MSDs, with median and mean estimates of 82 and 79 percent, respectively. These estimates are consistent with those inferred from the body of epidemiological data, which show that more than one-half of the MSDs that occur among exposed employees is attributable to exposure, and therefore potentially preventable under an ergonomics program. OSHA requests additional information and data describing the effectiveness, or lack thereof, of ergonomics programs on reducing MSD rates

Appendix VI–A.—BLS Injury Categories Likely To Include Employer-Reported Musculoskeletal Disorders

BLS CODE	NATURE OF INJURY	DESCRIPTION
00	Traumatic injuries and disorders, unspecified	This major group classifies traumatic injuries and disorders when the only information available describes the incident as traumatic. For example, employee was hurt in car accident.
01	Traumatic injuries to bones, nerves, spinal cord	This major group classifies traumatic injuries to the bones, nerves, or spinal cord which include breaking and dislocating bones and cartilage and traumatic injury to the brain, spinal cord, and nerves.
011	Dislocations	Subluxations; slipped, ruptured, or herniated disc; partial displacement; and fractured or broken cartilage.
012	Fractures	Closed fractures for which no open wound exists; open fractures for which there is an accompanying open wound; comminuted, compound, depressed, elevated, fissured, greenstick, impacted, linear, march, simple, and spiral fracture; and slipped epiphysis.
013	Traumatic injuries to spinal cord	Severed spinal cord, nonfatal severed spinal cord resulting from a gunshot wound, traumatic transient paralysis, anterior cord syndrome, lesion of spinal cord, and central cord syndrome.
014	Traumatic injuries to nerves, except the spinal cord	This nature group classifies traumatic injuries to nerves other than the spinal cord. Cranial nerves, peripheral nerve of the shoulder or pelvic girdle, and nerves of the limb are possible locations for injuries in this nature group. Diseases or disorders of the nervous system that occur over time as a result of repetitive activity, such as carpal tunnel syndrome, are classified in major group 12. Includes division of nerve, lesion in continuity, traumatic neuroma.
018	Multiple traumatic injuries to bones, nerves, spinal cord	This nature group classifies multiple injuries and disorders of equal severity within Traumatic injuries to bones, nerves, spinal cord, major group 01.
019	Traumatic injuries to bones, nerves, spinal cord, n.e.c.	
020	Traumatic injuries to muscles, tendons, ligaments, joints, etc., unspecified	Traumatic injuries that affect the muscles, tendons, ligaments or joints; exact nature of disorder not specified in employer's report.
021**	Sprains, strains, tears	This nature group classifies cases of sprains and strains of muscles, joints tendons, and ligaments. Diseases or disorders affecting the musculoskeletal system, including tendonitis and bursitis, which generally occur over time as a result of repetitive activity should be coded in Musculoskeletal system and connective tissue diseases and disorders, major group 17. Includes avulsion, hemarthrosis, rupture, strain, sprain, or tear of joint capsule, ligament, muscle, or tendon. Excludes hernia (153), lacerations of tendons in open wounds (034), torn cartilage (011).
029	Injuries to muscles, tendons, ligaments, joints, etc., n.e.c	This nature group classifies injuries to muscles, tendons, ligaments, etc. that are not classified elsewhere in this major group.
0972** 0973** 0978 0979	Back pain, hurt back Soreness, pain, hurt, except the back Multiple nonspecified injuries and disorders Nonspecified injuries and disorders, n.e.c	Subcategories under nature group 097, Nonspecified injuries and disorders, which includes traumatic injuries and disorders where some description of the manifestation of the trauma is provided and generally where the part of body has been identified. Subcategory 0972 includes hurt back, backache, low back pain.
099	Other traumatic injuries and disorders, n.e.c.	

Appendix VI–A.—BLS Injury Categories Likely To Include Employer-Reported Musculoskeletal Disorders—Continued

BLS CODE	NATURE OF INJURY	DESCRIPTION
1240	Disorders of the peripheral nervous system, unspecified	Subcategories under nature group 124, Disorders of the peripheral nervous system, which includes the nerves and ganglia located outside the brain and spinal cord. Subcategory 1249 includes Bell's palsy, tarsal tunnel syndrome, other mononeuritis of the extremities, nontraumatic lesion of the median, ulnar and radial nerves, muscular dystrophies.
1241**	Carpal tunnel syndrome	
1249	Other disorders of the peripheral nervous system, n.e.c.	
1371	Raynaud's syndrome or phenomenon	Subcategory under nature group 137, Diseases of arteries, arterioles, capillaries.
153**	Hernia	This nature group classifies hernias of the abdominal cavity. Includes: femoral (1539), esophageal (1539), hiatal (1532), inguinal (1531), paraesophageal (1539) scrotal (1531), umbilical (1539), and ventral (1533) hernias. Excludes: herniated disc (011), herniated brain (1231), and strangulations (091).
17**	Musculoskeletal system and connective tissue diseases and disorders	This major group classifies diseases of the musculoskeletal system and connective tissue.
170	Musculoskeletal system and connective tissue diseases and disorders, unspecified.	
171	Arthropathies and related disorders (arthritis)	This nature group classifies joint diseases and related disorders with or without association with infections. Includes: ankylosis of the joint, arthritis, arthropathy, and polyarthritis. Excludes: disorders of the spine (172), gouty arthropathy (1919), rheumatic fever with heart involvement (131).
172	Dorsopathies	This nature group classifies conditions affecting the back and spine. Includes: spondylitis and spondylosis of the spine (1729); intevertebral disc disorders, except dislocation (1723); sciatica (1721); lumbago (1722); and other nontraumatic backaches (1729). Excludes: dislocated disc (011), curvature of the spine (1741), fractured spine (012), herniated disc (011), ruptured disc (011), traumatic sprains and strains involving the back (021), and other traumatic injuries to muscles, tendons, ligaments, or joints of the back (02), and traumatic back pain or backache (0972).
173	Rheumatism, except the back	This nature group classifies disorders marked by inflammation, degeneration, or metabolic derangement of the connective tissue structure of the body, especially the joints and related structures of muscles, bursae, tendons and fibrous tissue. Generally, these codes should be used when the condition occurred over time as a result of repetitive activity. Includes: rotator cuff syndrome (1739), rupture of synovium (1739), and trigger finger (1739). Excludes: rheumatism affecting the back is included in code (172), traumatic injuries and disorders affecting the muscles, tendons, ligaments and joints (02).
174	Osteopathies, chondropathies, acquired deformities	This group is comprised of diseases of bones, diseases of cartilage, and acquired musculoskeletal deformities. Includes: osteomyelitis, periostitis and other infections involving bone; and acquired curvature of the spine.
179	Musculoskeletal system and connective tissue diseases and disorders, n.e.c.	This nature group classifies musculoskeletal system and connective tissue diseases and disorders that are not classified elsewhere.
4120	Symptoms involving nervous and musculoskeletal systems, unspecified	Subcategories under nature group 412, Symptoms involving nervous and musculoskeletal systems, which includes symptoms specific to either the nervous or musculoskeletal systems. Subcategory 4129 includes abnormality of gait, lack of coordination, tetany, and meningismus.
4128	Multiple symptoms involving nervous and musculoskeletal systems.	
4129	Symptoms involving nervous and musculoskeletal systems, n.e.c.	

Appendix VI–A.—BLS Injury Categories Likely To Include Employer-Reported Musculoskeletal Disorders—Continued

BLS CODE	NATURE OF INJURY	DESCRIPTION
414	Symptoms involving head and neck	This nature group classifies symptoms which are specific to either the head or neck. Includes: throat pain (4149), aphasia (4149), and epistaxis/nosebleed (4149).

** Categories included in OSHA's preliminary risk assessment.

Source: Occupational Injury and Illness Classification Manual, Bureau of Labor Statistics, December 1992 (Ex. 26–1272).

Appendix VI–B.—Summary of Case Studies Demonstrating Effectiveness of Ergonomic Programs/Interventions

JOB TITLE OR ACTIVITY	SIC CODE	ERGONOMIC SOLUTIONS	REPORTED REDUCTION IN INJURY RATES		SOURCES
			LOST WORK-DAY MSDs	TOTAL MSDs	
Food Packing	20	Implemented full program on packing line, including job task analysis, employee involvement in identifying problems and solutions, worker training, and medical management. Job analysis resulted in 56 proposals for changes in equipment and work environment, half of which were implemented in six months.		In 1976, prior to implementing the program, there were 51 hand MSDs identified among 200 packing workers. Hand MSDs were eliminated by 1980, four years after program implementation. Other upper extremity illnesses declined by about 47% in this same time period.	Luopajarvi *et al.* (1982) (Ex. 26–1042); Luopajarvi *et al.* (Undated) (Ex. 26–1090).
Meatpacker	2011	Training efforts included awareness training of corporate and plant managers and technical training of safety and medical personnel. Ergonomic task forces were established at individual plants to identify problem jobs and implement exposure controls. Controls included use of anti-fatigue mats and manual handling assists such as conveyors and trucks. Job rotation and cross-training of rotated workers was also employed.	Not Reported.	Cumulative trauma injuries reduced from four in one month to none reported during a 6-month period.	McCasland (1992) (Ex. 26–1043).
Meatpacker-pork deboning	2011	Introduction of automated system for deboning/skinning and a pneumatic lifter to automate hanging of large sausage casings onto processing racks.	Lost time due to injury dropped from 30% of total work hours to less than 2%.	CTDs have declined from 84 cases to 9 cases over a 6-year period.	Murphy (1992) (Ex. 26–1103).

Appendix VI–B.—Summary of Case Studies Demonstrating Effectiveness of Ergonomic Programs/Interventions—Continued

JOB TITLE OR ACTIVITY	SIC CODE	ERGONOMIC SOLUTIONS	REPORTED REDUCTION IN INJURY RATES		SOURCES
			LOST WORK-DAY MSDs	TOTAL MSDs	
Meatpacker	2011	Implementation of an ergonomics program, including engineering controls, work hardening program, training, and medical management.	Not Reported.	CTDs decreased from 47.8 per 100 workers (1987) to 17.2/100 workers (1990) and 17.7/100 workers (1991).	OSHA Site Visit, Case Study No. 2 (26–1175).
Meat preparation	2011	Introduction of engineering controls: redesigned workstation by sloping the work surface toward the meatcutter; introduced rotary cutter and single hooks.	Not Reported.	80% reduction in musculoskeletal injuries in the first year.	Oxenburgh (1994) (Ex. 26–1041), Case 45.
Poultry processing	2015	Implementation of an ergonomics program, including redesign of processing lines, use of rubber-matted stools and platforms of varying heights to eliminate awkward reaches, worker training, and job reassignment for injured workers.	Not Reported.	Decline in upper-extremity and neck/shoulder injuries from about 32 per month to 0.	Farr (1991) (Ex. 26–1044).
Poultry processing	2015	Introduction of workstation analysis and redesign, including altering heights of products, providing workstands, and installing tank tilters to reduce manual handling. Program also included worker training and development of an integrated medical management/surveillance-analysis system.	Not Reported.	Carpal tunnel incidence rates decreased from 7.8 per 200,000 hours to between 2.4 and 3.7 per 200,000 hours. Back injury rates declined from 4.4 per 200,000 hours to 3.0 per 200,000 hours.	Stuart-Buttle (1994) (Ex. 26–1045).
Poultry processing	2015	Introduction of engineering controls: tool/handle redesign; work practice controls; administrative controls.	Not Reported.	Recordable injuries and illnesses decreased from 10–14/100 workers (1988–89) to 7/100 workers (1991).	OSHA Site Visit, Case Study No. 1 (Ex. 26–1174).

Appendix VI–B.—Summary of Case Studies Demonstrating Effectiveness of Ergonomic Programs/Interventions—Continued

JOB TITLE OR ACTIVITY	SIC CODE	ERGONOMIC SOLUTIONS	REPORTED REDUCTION IN INJURY RATES		SOURCES
			LOST WORK-DAY MSDs	TOTAL MSDs	
Ice cream manufacture, various jobs	2024	Performed job hazard analysis, implemented several controls including use of non-skid elevating platforms for shorter workers; modified workspace layout to permit workers to move without being hindered; replaced sharp edges of equipment with sloping angles or padding; replace hygienic thin-filmed gloves with warm, flexible gloves; modified way employees performed lifting and carrying tasks.	In 1985, before implementing the program, there were 4 compensation claims and absenteeism equalled 10% of the number of shifts worked. In 1897, there were no compensation claims and absenteeism was reduced to 4% of shifts worked.		Elie (OH&S Canada, Vol. 4, No. 7) (Ex. 26–1100).
Cattle feed processing operation	2048	Provided a forklift and a bobcat to eliminate manual lifting and relocated the feed mixer in order to install chutes and augers to permit mechanical loading of feed. Installed bulk storage containers so that additives could be gravity-fed to the mixer. Constructed a platform under the auger equal in height to the truck platform, which allowed feed bags to be filled without manual lifting. Program also included providing lifting and handling training to workers.	Not Reported.	The company eliminated manual handling injuries.	Teleki (1995) (Ex. 26–1046).
Bakery	205	Engineering controls: workstation redesign, tool modifications; improved work practices; formation of labor-management CTD committee.	Absenteeism related to carpal tunnel syndrome decreased from 731 lost work days (1987) to 8 lost work days (Jan.–Aug., 1991).	Carpal tunnel cases decreased from 34 (1987) to 13 (1990).	Robinson (1993) (Ex. 26–1102).
Packaging sugar cubes	206	Cubes were packed tightly using a hand tool that required worker to exert considerable pressure on a sharp corner edge. Company changes marketing strategy that permitted cubes to be packed loosely, avoiding use of excessive hand force.	Considerable reduction in sickness absence and workers compensation claims.	Serious strain injuries to hands was ‘‘virtually’’ eliminated.	Oxenburgh (1994) (Ex. 26–1041), Case 41.

Appendix VI–B.—Summary of Case Studies Demonstrating Effectiveness of Ergonomic Programs/Interventions—Continued

JOB TITLE OR ACTIVITY	SIC CODE	ERGONOMIC SOLUTIONS	REPORTED REDUCTION IN INJURY RATES		SOURCES
			LOST WORK-DAY MSDs	TOTAL MSDs	
Mattress manufacturer, material handling	2515	Introduction of hand trucks and lift systems to aid in manual handling. Job hazard analysis involving the employees in identification of problem areas and solutions to problems.	53.5% reduction in workers compensation reports in one year (1991).	Not Reported.	Bedtimes (1992) (Ex. 26–1047).
Mattress manufacturer, material handling	2515	Job hazard analysis of all job functions to resolve ergonomic problems. Modified workstations, tools, and manufacturing procedures. Modified equipment to reduce need to lift items above shoulder height or below knee level.	Lost time reduced ¼ to ⅓ in 3 years.	Not Reported.	Bedtimes (1992) (Ex. 26–1047).
Mattress manufacturer, warehousing	2515	Added conveyor, increased fork truck use, reduced stacking heights, and revised handling procedures. Production process changed to eliminate material handling and loading onto truck.	Not Reported.	Decreased injuries from 9 to 1 in one year.	Marcotte (undated) (Ex. 26–1048).
Office furniture manufacturing, various jobs	252	Introduction of a plant ergonomics program employing engineering controls, work practice controls, administrative controls, medical management, and education and training.	Restricted workdays decreased from 301/100 employees to 221/100 employees.	Decreased rate of MSDs from 21/100 employees (1989) to 19/100 employees (1991–1992).	Robinson (1993) (Ex. 26–1102).
Office furniture manufacturing, various jobs	252	Installed scissor lifts to aid in packaging file cabinets of different sizes. Small-assembly workstations were altered to eliminate twisting and bending during lifting.	Not Reported.	Back injuries have been cut by 50 percent.	LaBar (1991) (Ex. 26–1078).
Pulp and paper mill workers	2611 & 2621	Conducted training sessions covering CTD issues and hazardous postures at the workplace. Job analysis included interviews of employees. Program included strengthening exercises and fitness initiatives. The following engineering controls were implemented: • Reduced the number of wires per bale to reduce weight, • Use of padded bolt cutter handles, • Provided better lifting devices.	Not Reported.	In a six-month follow-up to the interventions, the CTD rate had been diminished to zero and there were no wrist and elbow problems.	''Avenor's fitness a warm-up to ergonomics.'' CTD News (1996) (Ex. 26–1050).

Appendix VI–B.—Summary of Case Studies Demonstrating Effectiveness of Ergonomic Programs/Interventions—Continued

JOB TITLE OR ACTIVITY	SIC CODE	ERGONOMIC SOLUTIONS	REPORTED REDUCTION IN INJURY RATES		SOURCES
			LOST WORK-DAY MSDs	TOTAL MSDs	
Printing, glue machine operators	27	Installed partial mechanical aid for off loading of cartons.	Not Reported.	No injuries reported in 2 yrs since changes.	Shinnick (1985) (Ex. 26–1049).
Book binding operator	278	Introduced industrial load leveler (a spring loaded table) for loading/unloading pockets, binders, stitchers, and off-line mailers.	Lost workdays fell from 413 to 112.	Not Reported.	Ferris (1992) (Ex. 26–1051).
Organic chemical manufacture, manual handling	283	Analysis of injury data, observation of material handling tasks. Installed materials handling equipment, automated container-packaging and inspection equipment. Reduced weight of bags and drums. Worker training program.	Severe back injuries resulting in lost workdays were eliminated (1979–1989).	62% reduction in the incidence of total overexertion back injuries.	Ridyard (1990) (Ex. 26–1052).
Paint manufacturing, manual handling	2851	Installation of material handling equipment. Medical management of injuries.	From 1990–1993, lost time injury rate decreased by approximately 63%.	Total OSHA recordables reduced by 40% from 1990–1993.	Akzo Coatings, Inc., Louisville, KY. correspondence with OSHA (1994) (Ex. 26–1054).
Oil refinery, handling hoses and valves, manual handling	2911	Added platforms that make valve access easier, added extensions to valve stems to eliminate bending to turn valves, installed hoists over work tables to eliminate lifting and bending, purchased adjustable height carts, upgraded lighting, and conducted back injury training.	Not Reported.	Injury rates dropped by 90%.	Bone (1993) (Ex. 26–1055).
Rubber hose manufacturing	3052	A new hand tool was designed (an air gun) that is counterbalanced to reduce the amount of weight supported. This tool also has better handles.	No lost time incidents from repetitive trauma since the new tool was introduced.	Not Reported.	Oxenburgh (1994) (Ex. 26–1041), Case 7.

Appendix VI–B.—Summary of Case Studies Demonstrating Effectiveness of Ergonomic Programs/Interventions—Continued

JOB TITLE OR ACTIVITY	SIC CODE	ERGONOMIC SOLUTIONS	REPORTED REDUCTION IN INJURY RATES		SOURCES
			LOST WORK-DAY MSDs	TOTAL MSDs	
Shoe/luggage manufacturing, various jobs	31	Instituted a comprehensive ergonomics program as part of a total quality management initiative. Program included elements of worker participation, medical management, job analysis and control of exposures to risk factors, and employee education and training. Exposure controls included installation of adjustable workstations; new jig fixtures to hold work pieces at proper angles; partial automation of processes; and use of anti-skid surfaces on tools, fixtures, and handles.	Reduced lost time upper extremity and back disorders by 79%.		Rooney and Morency (1992) (Ex. 26–1056).
Shoe manufacturer, various jobs	314	Several programs implemented that included exercise and conditioning, stretching, and ergonomics awareness training. Conducted special training on ergonomics for industrial engineers and maintenance workers. Continuous flow manufacturing including group working, cross training, and job rotation was instituted. Engineering controls implemented included: • Purchase of new adjustable chairs; • Use of anti-fatigue mats for all employees whose jobs involved prolonged standing; • The cast iron base on heavy equipment was cut off and refitted with an adjustable base; • Electric or pneumatic foot pedals were used instead of non-adjustable mechanical ones; • Prepackaged shoe laces were purchased to eliminate hand-tying repetition; and • Sewing machines were tilted toward the worker to eliminate awkward posture.	Not Reported.	Repetitive motion injuries in two problem areas were reduced from 70 percent to between 25 and 30 percent of the total OSHA recordable incidents in three years.	''Red Wing Shoes' early warning system.'' CTD News (1995) (Ex. 26–1057).

Appendix VI–B.—Summary of Case Studies Demonstrating Effectiveness of Ergonomic Programs/Interventions—Continued

JOB TITLE OR ACTIVITY	SIC CODE	ERGONOMIC SOLUTIONS	REPORTED REDUCTION IN INJURY RATES		SOURCES
			LOST WORK-DAY MSDs	TOTAL MSDs	
Shoe manufacture, pneumatic press operator	314	Workstation design improvements included use of adjustable chairs and footrests, providing armrests, changing angle of the presses, providing parts bins to reduce extreme wrist flexion, and redesigning shoe ornaments so prongs were angled for easier insertion and pressing.		No injuries reported for 2 years since changes were implemented.	Wick (1987) (Ex. 26–1058).
Footwear assembly and fabrication	3149	Extensive ergonomic training program.	Lost-time injuries dropped 67% in 2 years.	Total number of CTDs dropped by 62% in 2 years.	Holland (1991) (Ex. 26–1059).
Sewing and cutting operations	3199	Introduction of ergonomics program, including medical program to detect and treat CTDs early. Workplace modifications included use of adjustable workstations, footrests, and anti-fatigue mats; installing larger handles on hot irons to improve grip; installing proximity switches on presses; adjusting glue stations to prevent awkward upper-extremity postures; and automating some processes.	Not Reported.	CTD incidence fell from 14.6% in 1990 to 11% in 1992.	Nickasch (1994) (Ex. 26–1060).
Encapsulating automotive glass windows	3229	Ergonomics program and control measures, including installation of adjustable workstations, job rotation, and anti-fatigue matting; medical management program and an employee training program.	Incidence of lost-work-day injuries declined from 8.6% to 0.2% in 2 years. Rate of lost workdays declined from 1,615/100 workers (1990) to 0.9/100 workers (1992).	Not Reported.	OSHA Site Visit, Case Study No. 12 (Ex. 26–1182).
Packagers	3231	Workplace improvements included: Reduced all material handling to less than 50 pounds; Purchased different sizes of gloves, cuffs, and sleeves to reduce additional stress and energy expenditure; Designed a device that allows employees to roll the glass onto the line instead of lifting it;	Not Reported.	Injury incidence rate dropped from 14 per 100 workers in 1987 to 3.3 in 1996. Reduced severity and frequency of injuries.	‘‘PPG learned to overcome ergo innocence.’’ CTD News (1996) (Ex. 26–1061).

Appendix VI–B.—Summary of Case Studies Demonstrating Effectiveness of Ergonomic Programs/Interventions—Continued

JOB TITLE OR ACTIVITY	SIC CODE	ERGONOMIC SOLUTIONS	REPORTED REDUCTION IN INJURY RATES		SOURCES
			LOST WORK-DAY MSDs	TOTAL MSDs	
		Raised the racks to knuckle height to avoid bending while lifting the windshields; and Altered the racks to allow workers to step into them and load them from back to front in order to eliminate stressful forward reaches.			
Ceramic tile manufacturing, various jobs	3253	Implementation of an ergonomics program including engineering controls (workstation redesign), job rotation, changes in work practices, and an ergonomic training program for employees.	Lost-time injury rate for repetitive motion injuries decreased from 1.6 in 1988/1989 to 0 in 1993.	Not Reported.	Stuart-Buttle (1994) (Ex. 26–1045).
Fiber-cement board manufacture, manual handling	3272	Install on-loader at from of conveyor to permit workers to load boards at their own pace. Automate process for separating boards and transferring them to the on-loader. Automate stacking of final product.	Eliminated lost-time MSDs in 2 years after improvements were made.	Not Reported.	Oxenburgh (1994) (Ex. 26–1041), Case 11.
Metal castings, unpacking operation	33	Frequent, excessive reach was required to unpack 15- to 18-pound casting from crates. Crates were modified by adding drop gates at each end of the crates and installing a scissor lift to lift crates. In addition, changes were made in the way the castings were stacked in the crates to permit the workers' arms to remain close to the body while unpacking.	Not Reported.	Eliminated back injuries associated with this operation.	Oxenburgh (1994) (Ex. 26–1041), Case 34.
Palletizing operation	33	Scissor lift tables with turntable tops were installed alongside each packing station.	Not Reported.	Five out of six back injuries were eliminated.	Benson, (1987) (Ex. 26–1062).
Aluminum manufacturer, materials handling	3350	Establishment of an ergonomics program, including of introduction lift tables, cranes, and mechanical assists in overhead lifting, rearrangement of work to allow use of cranes in lifting.	Not Reported.	Reduced overexertion injuries of the back by 40% to 60%.	Mandelker (1993) (Ex. 26–1063).
De-burring and finishing cast metal parts	34	Parts were held still by hand during finishing operations. Work bench was replaced by a potter's wheel to hold the part and rotate it as necessary. Finishing tools were redesigned.	Not Reported.	Upper-extremity disorders were eliminated.	Oxenburgh (1994) (Ex. 26–1041), Case 43.

Appendix VI–B.—Summary of Case Studies Demonstrating Effectiveness of Ergonomic Programs/Interventions—Continued

JOB TITLE OR ACTIVITY	SIC CODE	ERGONOMIC SOLUTIONS	REPORTED REDUCTION IN INJURY RATES		SOURCES
			LOST WORK-DAY MSDs	TOTAL MSDs	
Welding	34	Manual welding of a 5-meter weld required welder to work in a prolonged static posture. This process was replaced by a semi-automatic powder welding process, permitting welder to work from a standing position.	Not Reported.	All knee, neck, and shoulder injuries from this operation have been eliminated.	Oxenburgh (1994) (Ex. 26–1041), Case 33.
Materials handling, hardware manufacture	3411	Use of adjustable lift tables/transporters completely eliminated manual lifting from the job.	Not Reported.	Back injuries reduced by 90%.	''Put ergonomics to practical use.'' Material Handling Engineering (1988) (Ex. 26–1064).
Packager	3452	Packaging area was redesigned; raised the level at which boxes are lifted, installed semi-automatic sealing machines and adjustable chairs, and eliminated loading of pallets; training introduced.	Nearly a five-fold decrease in musculo-skeletal injuries based on days lost. (equivalent to 5% of the department's total wage costs).	Not Reported.	Oxenburgh (1994) (Ex. 26–1041), Case 10.
Manufacturing automotive cables	3496	Introduction of ergonomics program utilizing engineering controls, work practice training, and medical management.	Lost workday cases decreased from 48 (1991) to 27 (1993). Number of lost workdays decreased from 1,287 days (1991) to 275 days (1993).	Decreased illnesses from 47 (1991) to 17 (1993).	OSHA Site Visit, Case Study No. 11 (Ex. 26–1181).
Steel furniture manufacturing, various jobs	3499	Employee involvement in identifying hazards and developing interventions. Engineering approaches included the following: • An enclosed shotblaster machine has been used to automate polishing of the steel. • An automatic washing system has been provided. • Lighting placement and brightness have been improved to reduce the awkward posture required to inspect and brush the products. • Many of the jigs were improved to be adjustable.	Lost days from carpal tunnel syndrome, back strain and other CTDs dropped to zero in 1996, down from 176 lost workdays in 1991.	Not Reported.	''Charleston Forge welds homemade approach.'' CTD News (1996) (Ex. 26–1065).

Appendix VI–B.—Summary of Case Studies Demonstrating Effectiveness of Ergonomic Programs/Interventions—Continued

JOB TITLE OR ACTIVITY	SIC CODE	ERGONOMIC SOLUTIONS	REPORTED REDUCTION IN INJURY RATES — LOST WORK-DAY MSDs	REPORTED REDUCTION IN INJURY RATES — TOTAL MSDs	SOURCES
		• And other engineering controls.			
Farm equipment manufacture, assembly and materials handling	3523	Initiated an eight-hour engineer ergonomics training program. Appointed ergonomics coordinators in all U.S. and Canadian factories, foundries and distribution centers chosen from the industrial engineering and safety departments. Conducted training through attending professional courses and conferences, memberships in professional organizations, subscriptions to ergonomics publications and tracking the latest ergonomics research. Conducted ergonomic review of new office furniture purchases. Conducted VDT ergonomics awareness training for video display operators. Engineering Controls included: • Limiting manual lifting to 40 pounds or less; • Redesigning the assembling operations so that assemblers worked in an upright position; • Altered hand tools for better fit; and • Installed hoists and lift tables.	83 percent reduction of back injuries that resulted in lost time.	Not Reported.	‘‘An ergo process that runs like a Deere.’’ CTD News (1995) (Ex. 26–1101).
Welding, vehicle manufacture	3531	Ergonomic training program implemented, seat height adjustments installed, and work station height adjusted.	Not Reported.	Back injury rate went down by 27%.	‘‘Caterpilar, Inc.’’ Welding Journal (1992) (Ex. 26–1066).
Chain saw assembly	3546	Introduction of new tools and modified production methods, and employee training.	The sick-leave rate decreased from 17.0 to 13.7 on an average annual basis.	Not Reported.	Parenmark *et al.* (1993) (Ex. 26–1067).

Appendix VI–B.—Summary of Case Studies Demonstrating Effectiveness of Ergonomic Programs/Interventions—Continued

JOB TITLE OR ACTIVITY	SIC CODE	ERGONOMIC SOLUTIONS	REPORTED REDUCTION IN INJURY RATES: LOST WORK-DAY MSDs	REPORTED REDUCTION IN INJURY RATES: TOTAL MSDs	SOURCES
Computer manufacturer	3571	The company engaged in several training and education initiatives, including: • Mandated ergonomics training classes for high risk groups; • Created and distributed a 16-page ergonomics brochure; and • Created an ''ERGO Hotline'' to schedule ergonomics evaluations, report problems, and seek information; Exposure control approaches included: • Limiting manual lifting to 40 pounds or less; educated the employees via a brief program on the basic ergonomics fundamentals; • Purchased new office sit-stand workstations; • Adjusted the workstation surface height to accommodate each worker; and • Attached a wider, adjustable keyboard and mouse platform to the standard desk.	Not Reported.	• 41 percent drop in reportable upper limb disorders from 1994 to 1995 which addressed about 70 percent of the company's upper-limb reportable injuries. • Further 50 percent decrease in reportable CTD cases from 1995 to 1996. • Reportable cases of CTDs decreased to 25 through November of 1996 compared to 70 cases in 1994.	''Silicon Graphics melds high- and low-tech.'' CTD News (1997) (Ex. 26–1068).
Computer mainframe assembly	3571	Training had been provided for proper lifting techniques, general safety and use of special tools. Extensive office workstation ergonomics training was provided. Engineering controls included: • Providing new workbenches to accommodate workers' shorter reaches; • Adding roller-ball conveyor belts and lifting devices were added to raise the units onto the conveyor belt; • Replacing pneumatic drivers with lighter electric units which had much less vibration and weighed about one pound; • Installing lift platforms that would raise the cabinets and 3 feet off the floor; • Providing seated and standing workstations so one employee could build the entire cabinet instead of working on an assembly line in order to reduce the static fatigue; and	There are no lost days due to CTDs in the office workplace.	CTD related injuries were eliminated in production.	''AT&T uses cost-conscious program to fight CTDs.'' CTD News (1995) (Ex. 26–1069).

Appendix VI–B.—Summary of Case Studies Demonstrating Effectiveness of Ergonomic Programs/Interventions—Continued

JOB TITLE OR ACTIVITY	SIC CODE	ERGONOMIC SOLUTIONS	REPORTED REDUCTION IN INJURY RATES		SOURCES
			LOST WORK-DAY MSDs	TOTAL MSDs	
		• Modifying scissor lifts to rise up to 4 feet off the floor.			
Copying machine control system assembly	3579	Assembly of the systems was performed on a workbench and required frequent lifting and turning of the part. The bench was replaced by an adjustable stand designed to take the weight of the part being assembled.	Not Reported.	MSD rate declined by 50% in the first year. In the second year, the MSD rate declined to one-third.	Oxenburgh (1994) (Ex. 26–1041), Case 37.
Hand tool operation, telecommunications manufacturing	36	Safety and health committee implemented program that included creation of task force, worker training, improvements in workstation design and tooling, and medical management of workers on restricted duty.		Plant-wide incidence of repetitive trauma disorders was 2.2 cases per 200,000 work hours, reduced to 0.53 cases per 200,000 workhours in 1 year after program implementation.	McKenzie *et al.* (1985) (Ex. 26–1070).
Electronics manufacture	36	Controls: workstation redesign and job rotation.	Not Reported.	CTDs reduced by 46% in one year.	Robinson (1993) (Ex. 26–1102).
Electrical equipment manufacture, press operator	36	Automated handling and grinding of resistance elements. Eliminated possibility for hazardous exposures.	Not Reported.	Eliminated MSDs.	Oxenburgh (1994) (Ex. 26–1041), Case 16.
Press operator, small electronic parts manufacture	36	Press operation caused excessive wrist flexion and palm compression. The press was modified by adding switches that either eliminated hand contact or only involved contact with parts of the hand that do not have nerves close to the skin surface.	Not Reported.	29% reduction in musculoskeletal injury incidence.	Oxenburgh (1994) (Ex. 26–1041), Case 42.
Lamp manufacturing, materials handling	3641	Added a vacuum hoist, reduced equipment height, reduced box size and weight, and introduced a back awareness program for employees.	Not Reported.	Eliminated back and upper extremity disorders in the last four years.	Carreau and Bessett (1991) (Ex. 26–1071).

Appendix VI–B.—Summary of Case Studies Demonstrating Effectiveness of Ergonomic Programs/Interventions—Continued

JOB TITLE OR ACTIVITY	SIC CODE	ERGONOMIC SOLUTIONS	REPORTED REDUCTION IN INJURY RATES		SOURCES
			LOST WORK-DAY MSDs	TOTAL MSDs	
Telephone systems assembly	3661	Implemented an ergonomics program for the assembly line. Elements included an employee awareness program, disorder treatment protocols, job task analyses, job redesign, and cost savings analysis.	Lost-time repetitive strain injuries dropped from 20 to 4 over 1.5 years.		Darcangelo (1989) (Ex. 26–1072).
Telecommunications equipment assembly	3661	Introduced a training program, job hazard analysis, and an engineering program to abate ergonomic hazards. Medical management of injured employees on restricted jobs.		Rate of repetitive trauma disorders dropped from 1.1 per 100,000 hours to 0.26 per 100,000 hours in 1 year.	Pope (1987) (Ex. 26–1073).
Telecommunications equipment assembly	3661	Workstation redesign (adjustable tables, illumination), ergonomically designed chairs, and tool redesign.	Musculoskeletal injury sick leave in 1978=5.0, in 1982=2.9.	Not Reported.	Westgaard and Aaras (1984) (Ex. 26–1026).
Electronics assembly	367	Job rotation, new assembly line procedures, and ergonomic line balancing.	Not Reported.	No new cases of cumulative trauma were reported.	Townes and Imrhan (1991) (Ex. 26–1074).
Electronics manufacturing, various jobs	3674	Redesigned workstations; introduced powered-screwdrivers; job rotation.	Not Reported.	Reduced injuries (not quantified).	Burri and Helander (undated) (Ex. 26–1075).
Vehicle seat assembly	371	Ergonomics training was provided. Engineering controls included: • Redesigning seat covers in order to decrease the number of fasteners by more than 50 percent; • Provided a compression tool to clamp the foam padding to the seat; • Installed adjustable workstations; • Provide electric torque guns. • In addition, a program of job rotation was introduced.		Tendinitis cases fell by 93% and carpal tunnel cases fell by 96 percent in the year following program implementation.	‘‘Problem-solving by committee at General Seating.’’ CTD News (1995) (Ex. 26–1076).
Unpacking auto parts	371	A plywood sheet end board had to be removed to unpack crates, requiring excessive force and awkward postures. Plywood sheets were modified to reduce their weight and permit them to slide more easily in the grooves.	Not Reported.	Back and shoulder injuries associated with this operation were eliminated.	Oxenburgh (1994) (Ex. 26–1041), Case 38.