COMMENTS FROM THE NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH ON THE OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION PROPOSED RULE ON ERGONOMIC SAFETY AND HEALTH MANAGEMENT

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U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
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NIOSH COMMENTS

The National Institute for Occupational Safety and Health (NIOSH) supports the initiation of rulemaking on ergonomic safety and health management by the Occupational Safety and Health Administration (OSHA). NIOSH recognizes that "ergonomics" is a wide-ranging term with various applications. NIOSH has limited its comments to ergonomic hazards that relate to musculoskeletal problems. The standard should apply to all industries under OSHA jurisdiction, including general industry, agriculture, maritime, and construction.

As OSHA states in its advance notice of proposed rulemaking (ANPR), there is a significant increase in reported cases of ergonomic disorders in the workplace. The ANPR references substantial surveillance data indicatin/g that work-related musculoskeletal disorders are a priority problem for U.S. industry. The importance of work-related musculoskeletal disorders is also reflected in NIOSH experience through its health hazard evaluation program and industrywide studies. NIOSH is conducting ergonomic research and responding to ergonomic concerns of employers and workers across the entire range of U.S. industries and a myriad of occupations, work tasks and operations.

NIOSH offers the following comments to assist OSHA in its development of a proposed rule on ergonomics.

I. INTRODUCTION

A. Definition of "Ergonomic Hazards" and "Ergonomic Disorders"

NIOSH Recommended Revised "Definition of Ergonomic Hazards":

Ergonomic hazards relative to work-related musculoskeletal disorders refer to physical stressors and workplace conditions that pose a risk of injury or illness to the musculoskeletal system of the worker. Ergonomic hazards include repetitive and forceful motions, vibration, temperature extremes, and awkward postures that arise from: improperly designed workstations, tools, and equipment; and improper work methods. The effects of ergonomic hazards may be amplified by extreme environmental conditions. In addition, ergonomic hazards may arise from potentially deleterious job designs and organizational factors such as: excessive work rates; external (versus self) pacing of work; excessive work durations; shiftwork; imbalanced work-to-rest ratios; demanding incentive-pay or work standards; restriction of operator body movement and confinement of the worker to a work station without adequate relief periods; electronic monitoring; and lack of task variety.

NIOSH Recommended Revised "Definition of Ergonomic Disorders":

NIOSH recommends that the term "ergonomic disorders" be replaced with the term "work-related musculoskeletal disorders" to be consistent with the NIOSH recommendation for scope of this standard. Work-related musculoskeletal disorders are those diseases and injuries affecting the musculoskeletal, peripheral nervous, and neurovascular systems that are caused or aggravated by occupational exposure to ergonomic hazards. These disorders are variously referred to as "chronic trauma disorders," "repetitive strain injuries," "repetitive motion injuries," "repetitive trauma disorders," "cumulative trauma disorders," "wear and tear disorders," "overuse syndrome," and "degenerative joint diseases."

Work-related musculoskeletal disorders include damage to tendons, tendon sheaths, synovial lubrication of the tendon sheath, bones, muscles, nerves and ligaments of the hands, wrists, elbows, shoulders, neck, back, hips, knees, and ankles; joint injuries in which some of the fibers of a supporting ligament are ruptured, but the continuity of the ligament remains intact; overstretching or overexertion of some part of the musculature; and a variety of disorders marked by inflammation, degeneration, or metabolic derangement of the connective tissue structures of the body, especially the joints and related structures, including muscles, bursae, tendons and fibrous tissue.

The following diseases in the International Classification of Diseases (ICD) can be caused or aggravated by occupational exposure to ergonomic hazards. However, disorders such as carpal tunnel syndrome can also be caused or aggravated by nonoccupational factors such as carpal tunnel syndrome [Franklin et al. 1991].

ICD Code	Description of Disorder
353	Nerve root and plexus disorders
353.2	Cervical root lesions, not elsewhere classified
353.3	Thoracic root lesions, not elsewhere classified
353.4	Lumbosacral root lesions, not elsewhere classified
354	Mononeuritis of upper limb and mononeuritis multiplex
354.0	Carpal tunnel syndrome
354.1	Other lesion of median nerve
354.2	Lesion of ulnar nerve
354.3	Lesion of radial nerve
355	Mononeuritis of lower limb
355.1	Meralgia paresthetica
355.2	Other lesion of femoral nerve
355.3	Lesion of lateral popliteal nerve
355.5	Tarsal tunnel syndrome
355.7	Other mononeuritis of lower limb
443.0	Raynaud's syndrome (due to vibration)

712	Crystal arthropathies
715	Osteoarthrosis and allied disorders
716.1	Traumatic arthropathy
716.9	Arthropathy, unspecified
719	Other and unspecified disorders of joint
719.0	Effusion of joint
719.4	Pain in joint
719.5	Stiffness of joint, not elsewhere classified
719.7	Difficulty in walking
719.8	Other specified disorders of joint
720.2	Sacroiliitis, not elsewhere classified
722	Intervertebral disc disorders
722.0	Displacement of cervical intervertebral disc without myelopathy
722.1	Displacement of thoracic or lumbar intervertebral disc without myelopathy
722.2	Displacement of intervertebral disc, site unspecified, without myelopathy
722.3	Schmorl's nodes
722.4	Degeneration of cervical intervertebral disc
722.5	Degeneration of thoracic or lumbar intervertebral disc
722.6	Degeneration of intervertebral disc, site unspecified
722.7	Intervertebral disc disorder with myelopathy
722.9	Other and unspecified disc disorder
723.1	Cervicalgia
723.3	Cervicobrachial syndrome (diffuse)
723.4	Brachial neuritis of radiculitis NOS
723.9	Unspecified musculoskeletal disorders and symptoms referable to neck
724.1	Pain in thoracic spine
724.2	Lumbago
724.3	Sciatica
724.4	Thoracic or lumbosacral neuritis or radiculitis, unspecified
724.7	Disorders of coccyx
724.9	Other unspecified back disorders
726	Peripheral enthesopathies and allied syndromes
726.0	Adhesive capsulitis of shoulder
726.1	Rotator cuff syndrome of shoulder and allied disorders

726.10	Disorders of bursae and tendons in shoulder region, unspecified
726.11	Calcifying tendinitis of shoulder
726.12	Bicipital tenosynovitis
726.19	Other specified disorders
726.2	Other affections of shoulder region, not elsewhere classified
726.3	Enthesopathy of elbow region
726.30	Enthesopathy of elbow, unspecified
726.31	Medial epicondylitis
726.32	Lateral epicondylitis
726.33	Olecranon bursitis
726.39	Other
726.4	Enthesopathy of wrist and carpus
726.5	Enthesopathy of hip region
726.6	Enthesopathy of knee
726.60	Enthesopathy of knee, unspecified
726.61	Pes anserinus tendinitis or bursitis
726.62	Tibial collateral ligament bursitis
726.63	Fibular collateral ligament bursitis
726.64	Patellar tendinitis
726.65	Prepatellar bursitis
726.69	Other
726.7	Enthesopathy of ankle and tarsus
726.70	Enthesopathy of ankle and tarsus, unspecified
726.71	Achilles bursitis or tendinitis
726.72	Tibialis tendinitis
726.73	Calcaneal spur
726.79	Other
726.8	Other peripheral enthesopathies
726.9	Unspecified enthesopathy
726.90	Enthesopathy of unspecified site
726.91	Exostosis of unspecified site
727	Other disorders of synovium, tendon, and bursa
727.0	Synovitis and tenosynovitis
727.03	Trigger finger (acquired)
727.04	Radial styloid tenosynovitis
727.2	Specific bursitides often of occupational origin
727.4	Ganglion and cyst of synovium, tendon, and bursa
727.8	Other disorders of synovium, tendon, and bursa
727.9	Unspecified disorder of synovium, tendon, and bursa
728	Disorders of muscle, ligament, and fascia
729	Other disorders of soft tissues
729.1	Myalgia and myositis, unspecified
729.2	Neuralgia, neuritis, and radiculitis, unspecified

729.5	Pain in limb
729.8	Other musculoskeletal symptoms referable to limbs
840	Sprains and strains of shoulder and upper arm
840.0	Acromioclavicular (joint) (ligament)
840.1	Coracoclavicular (ligament)
840.2	Coracohumeral (ligament)
840.3	Infraspinatus (muscle) (tendon)
840.4	Rotator cuff (capsule)
840.5	Subscapularis (muscle)
840.6	Supraspinatus (muscle) (tendon)
840.8	Other specified sites of shoulder and upper arm
840.9	Unspecified site of shoulder and upper arm
841	Sprains and strains of elbow and forearm
841.0	Radial collateral ligament
841.1	Ulnar collateral ligament
841.2	Radiohumeral (joint)
841.3	Ulnohumeral (joint)
841.8	Other specified sites of elbow and forearm
841.9	Unspecified site of elbow and forearm
842	Sprains and strains of wrists and hand
842.0	Wrist
842.00	Unspecified site
842.01	Carpal (joint)
842.02	Radiocarpal (joint) (ligament)
842.09	Other
842.1	Hand
842.10	Unspecified site
842.11	Carpometacarpal (joint)
842.12	Metacarpophalangeal (joint)
842.13	Interphalangeal (joint)
842.19	Other
843	Sprains and strains of hip and thigh
843.0	Iliofemoral (ligament)
843.1	Ischiocapsular (ligament)
843.8	Other specified sites of hip and thigh
843.9	Unspecified site of hip and thigh
844	Sprains and strains of knee and leg
844.0	Lateral collateral ligament of knee
844.1	Medial collateral ligament of knee
844.2	Cruciate ligament of knee
844.3	Tibiofibular (joint) (ligament), superior
844.8	Other specified sites of knee and leg
844.9	Unspecified site of knee and leg

845	Sprains and strains of ankle and foot
845.0	Ankle
845.00	Unspecified site
845.01	Deltoid (ligament), ankle
845.02	Calcaneofibular (ligament)
845.03	Tibiofibular (ligament), distal
845.09	Other
845.1	Foot
845.10	Unspecified site
845.11	Tarsometatarsal (joint) (ligament)
845.12	Metatarsophalangeal (joint)
845.13	Interphalangeal (joint), toe
845.19	Other
846	Sprains and strains of sacroiliac region
846.0	Lumbosacral (joint) (ligament)
846.1	Sacroiliac (ligament)
846.2	Sacrospinatus (ligament)
846.3	Sacrotuberous (ligament)
846.8	Other specified sites of sacroiliac region
846.9	Unspecified site of sacroiliac region
847	Sprains and strains of other and unspecified parts of back
847.0	Neck
847.1	Thoracic
847.2	Lumbar
847.3	Sacrum
847.4	Coccyx
847.9	Unspecified site of back
955	Injury to peripheral nerves of shoulder and upper limb
959	Injury, other and unspecified
959.2	Shoulder and upper arm
959.3	Elbow, forearm and wrist
959.4	Hand

B. Document Problem Using Injury/Morbidity Databases

A number of sources of information exist that can provide documentation of the extent of the ergonomic hazards and work-related musculoskeletal disorders. Definitions and classifications of work-related musculoskeletal disorders, as well as industrial and occupational coverage, differ among these databases. However, while each of these databases are somewhat limited, they are complementary and provide a collective resource to determine high-risk industries and occupations.

These databases may also provide information on trends in incidence of work-related musculoskeletal disorders. Available databases are:

1. **Occupational Injuries and Illnesses in the United States by Industry**

   This is a national sample conducted annually by the Bureau of Labor Statistics that covers all industries except state and local government and farms with fewer than 10 workers. It does not have information on occupation. The disease category that is relevant is "Diseases associated with repeated trauma." This category is defined by examples: conditions due to repeated trauma, vibration, or pressure, such as carpal tunnel syndrome; noise-induced hearing loss; synovitis, tenosynovitis, and bursitis; and Raynaud's phenomena.

2. **Workers' Compensation - Bureau of Labor Statistics (BLS) Supplemental Data System (SDS)**

   This database contains data on workers' compensation that includes industry and occupation. Diseases are coded by a modified American National Standards Institute (ANSI) Z216.2 classification system that is somewhat more specific than the BLS annual survey. The disease categories that are relevant are sprains and strains; inflammation and irritation of joints, tendons, or muscles; and diseases of peripheral nerves and ganglia. This database also identifies the part of body affected. Therefore, any of these disease categories can be sorted by part of body affected, e.g., inflammation of knees. Examples from the BLS-SDS are attached as Exhibit 1 (available from NIOSH on request). Some disadvantages of this database are that it does not cover all states and in the latest year, 1988, only 14 states were involved. Over the years many more states reported, but never all 50. The reporting parameters also varied. Some states reported closed cases, some reported cases occurring during the year, and some reported cases entered into their system during the year. Some of the data were first reports and a portion of these would not be valid claims. Another disadvantage is that the state laws vary with regard to the number of days of disability required, the requirements for coverage that may exclude chronic conditions, etc. A substantial advantage is that it covers all workers in agriculture, and state and local government.

3. **Social Security Disability Data**

   This is a national database administered by the Social Security Administration that covers permanently disabled workers. A disadvantage is that work relatedness of the disability does not have to be established. Advantages are that it covers all employed workers, diseases are coded according to the ICD [DHHS 1989], industries are coded according to the Standard Industrial Classification (SIC) to the 3-digit level, and occupations are coded by the Dictionary of Occupational Titles. NIOSH analyses of the data, as summarized in Exhibit 2 (available from NIOSH on request) for 1969-72 and 1975-76, give some information on disability by industry and occupation. More recent data could be studied. There is an annual summary of disease categories by major industry division that is included in Exhibit 2. The specificity of the disease classification of this database exceeds that of the two databases described in sections

I.B.1. and I.B.2, and will be more useful for chronic diseases because it is more specific for disease and it is restricted to permanent disabilities. Therefore, the Social Security Disability database is useful for studying chronic diseases.

4. National Health Interview Survey (NHIS) - Core Data

The National Health Interview Survey conducted by the National Center for Health Statistics is an ongoing survey of health conditions in the non-institutionalized, civilian population of the United States. Each year about 50,000 households are surveyed, collecting information on about 120,000 persons. Information is collected on chronic conditions, using six condition lists. Each respondent is administered one of the lists. Conditions that are relevant for the surveillance of work-related musculoskeletal disorders are lumbago; sciatica; slipped or ruptured disc; repeated trouble with neck, back, or spine; bursitis; and any disease of the muscles or tendons. Current estimates from the 1988 NHIS reported 17.7 slipped or ruptured discs per 1,000 persons and 18.4 cases of bursitis per 1,000 persons. Frequencies for the other conditions were not reported. Information on the current occupation of those persons in the workforce is available but there is no definite information on the work-relatedness of the conditions.

5. National Health Interview Survey - 1988 Occupational Health Supplement

In 1988, supplementary questionnaires on various occupational health effects were added to the core questionnaire. Sections related to work-related musculoskeletal disorders were on back pain and hand discomfort including carpal tunnel syndrome. Based on stratified sampling of the population, this supplementary database provides statistically defined estimates of the self-reported conditions for various industry/occupation categories. It includes basic demographic information (age, sex, race, region), prevalence and rate of self-reported and medically-diagnosed carpal tunnel syndrome, back pain, and hand discomfort. Repetition, posture, and vibration are self-reported as exposure indicators for carpal tunnel syndrome. A disadvantage of these data is the cases are self-reported without medical validation. Self-reported cases without validation may result in an overestimate or an underestimate.

6. National Occupational Exposure Survey

The National Occupational Exposure Survey conducted by NIOSH in 1982-83 collected data on a number of ergonomic hazards. It can provide information on the number of workers exposed to a specific hazard by occupation and industry sector. A limitation of this database is that it did not cover all industries, or state and local government. Another limitation is the data were observational and were not quantified. It is important to note that this survey excluded finance, insurance, real estate, restaurants, and government agencies, as well as most of the retail and wholesale trade, agricultural, and marine industries. Ergonomic disorders are a recognized occupational health problem in some of these industries.

NIOSH can provide descriptive analyses for 10 "Chronic Trauma" exposures (whole-body vibration, segmental vibration, passive postures, awkward postures, lifting postures, arm-transport movements, shoulder-transport, hand/wrist manipulations, finger manipulations, machine-paced work) plus two forms of vibration (whole body and segmental) defined in the Survey Manual of the 1981-1983 National Occupational Exposure Survey (NOES) [NIOSH 1988]. The following are the analyses that NIOSH can provide:

(1) Estimates of the number of workers (by gender) potentially exposed to each of the cited chronic trauma and vibration hazards.

(2) Stratification of the estimates described in section I.B.6.(1) by Standard Industrial Classification (SIC).

(3) Stratification of the estimates described in section I.B.6.(1) by 1980 census occupational codes and titles across industries.

(4) Estimates of the national number of facilities by Major Industrial Group (i.e., construction and manufacturing) and by 2-digit SIC in which workers are potentially exposed to ergonomic hazards that were included in the survey.

(5) Estimates of the number of facilities or potentially exposed workers as discussed in sections I.B.1. through I.B.4., produced in tabular form by industrial facility employment size ranges.

7. SENSOR Programs

Several state health departments entered into cooperative agreements with NIOSH in 1987 to pilot surveillance strategies for carpal tunnel syndrome based primarily on physician reporting of occupational disease cases. While the programs had varying success in ascertaining cases, the project resulted in two reports by the California Department of Health Services [1990; 1991]. One was a survey of 515 health care providers in Santa Clara County; the respondents estimated caring for 7,214 cases of carpal tunnel syndrome, of which 3,413 cases (45%) were considered to be work-related. The second report summarizes the demographics, occupation, and industry of the 239 work-related Santa Clara County carpal tunnel syndrome cases reported to the surveillance system in 1989-91; patient questionnaire data, that have not been reported to NIOSH and may not yet have been analyzed, include information on symptoms, treatment, and occupational and non-occupational carpal tunnel syndrome risk factors.

Currently two states (Wisconsin and Massachusetts) are conducting SENSOR-sponsored surveillance for carpal tunnel syndrome. These data will include demographic, occupational, and some treatment and risk factor information on carpal tunnel syndrome cases identified through physician reporting, workers' compensation, and hospital reports of carpal tunnel release surgery. Data sources will include patient questionnaires, review of medical records, employer interviews, and, in select cases, workplace visits.

II. SCOPE AND APPLICATION OF ERGONOMICS STANDARD

NIOSH recommends that the standard be limited to ergonomic hazards that cause or aggravate work-related musculoskeletal disorders as defined in Section I.A., and that the standard apply to all industrial divisions under OSHA jurisdiction. Reasons for this are that all employers should be required to conduct a survey of the workplace to determine if workers are exposed to ergonomic hazards as defined in the standard and to conduct a survey of the workers' medical records to determine if there are reports of work-related musculoskeletal disorders. This approach is recommended for the following reasons. The biomechanical stresses on workers preforming repetitive tasks are extremely complex. Very small changes in initial conditions such as the amount of force exerted, the distance over which the force is exerted, the number of repetitions, the lengths of various bones and tendons in individual workers, the temperature, recovery times, and many other factors may result in extreme changes in the biomechanical stress exerted on various anatomical groups.

There are reports of excess work-related musculoskeletal disorders related to a number of specific job tasks such as upper body complaints among meat cutters in the meatpacking industry [OSHA 1990], hand-wrist problems in grocery checkout workers [Morganstern et al. 1991], knee injuries in carpet layers [NIOSH 1990] and dairy farmers [Anderson et al. 1989]. There are also studies reporting statistically significant increases in hand-wrist disorders and tasks involving high force and high repetition compared to tasks involving low force and low repetition in several industrial classifications [Armstrong et al. 1985].

The Bureau of Labor Statistics (BLS) Supplementary Data System (SDS), based on data from 25 states, reported for 1987 (see Exhibit 1):

- 541,000 cases of sprains and strains: 261,000 of those involved the back and 103,000 involved the lower extremities; 326,000 of these sprains and strains were reported as due to overexertion.

- 25,000 cases of dislocations: approximately one-half of the cases involved the back and one-tenth involved the lower limbs; over one-half were due to overexertion.

- 14,500 cases of inflammation or irritation of the joints, tendons, or muscles: 10,600 of these cases involved the upper extremities and 1,000 involved the lower extremities.

- 10,700 cases of diseases of the peripheral nerves: 8,400 of these involved the upper extremities.

Available surveillance data and NIOSH research and health hazard evaluation (HHE) studies suggest that work-related musculoskeletal disorders may exist in all industrial divisions. For example, in the 1988 BLS data from 14 states, 1209 4-digit SIC codes experienced one or more cases that meet the definition of work-related musculoskeletal disorders. The industries that experienced more than 1000 cases were:

BLS WORKERS' COMPENSATION CASES DUE TO WORK-RELATED MUSCULOSKELETAL DISORDERS (1988)

Industry Description	SIC Code	Number of Cases
Oil & gas field services, NEC*	1389	1158
Residential building construction	1520	1647
Nonresidential building construction	1540	2074
Highway & street construction	1611	3097
Water, sewer & utility lines	1623	1074
Heavy construction, NEC	1629	1305
Plumbing, heating, air conditioning	1711	3145
Electrical work	1731	1731
Plastering, drywall & installation	1742	1552
Roofing and sheetmetal work	1761	1272
Concrete work	1771	1035
Special trade contractors, NEC	1799	1175
Meatpacking plants	2011	2372
Bottled & canned soft drinks	2086	1303
Men's & boy's work clothing	2328	1251

*NEC = not elsewhere classified.

Industry Description	SIC Code	Number of Cases
Sawmills & planing mills, general	2421	1902
Miscellaneous plastics products	3079	3996
Machinery, except electrical, NEC	3599	1027
Motor vehicles & car bodies	3711	1554
Motor vehicle parts & accessories	3714	3195
Trucking, local & long distance	4210	5291
Certificated air transportation	4511	1497
Refuse systems	4953	1926
Groceries & related products	5140	1331
Groceries, general line	5141	1612
Lumber & other building materials	5211	1412
Department stores	5310	1662
Department stores	5311	3786
Grocery stores	5410	3445
Grocery stores	5411	7666
New & used car dealers	5511	1469
Auto & home supply stores	5531	1017
Eating & drinking places	5810	3230
Eating places	5812	5255
Real estate operators & lessors	6510	1335
Hotels, motels, & tourist courts	7010	1081
Hotels, motels, & tourist courts	7011	2385
Building maintenance services, NEC	7349	1212
Personnel supply services	7360	1186
Temporary help supply services	7362	2423
Miscellaneous amusement & recreational services	7990	1184
Nursing & personal care facilities	8050	1844

Industry Description	SIC Code	Number of Cases
Skilled nursing care facilities	8051	4844
Nursing & personal care, NEC	8059	4518
Hospitals	8060	4791
General medical & surgical hospital	8062	9777
Psychiatric hospitals	8063	1498
Elementary & secondary schools	8210	3468
Elementary & secondary schools	8211	5614
Colleges & universities	8221	1688
Residential care	8361	1604

There are 422 occupations at the 3-digit coding level that experienced disability from work-related musculoskeletal disorders. Those occupations with more than 1000 cases of musculoskeletal disorders were:

OCCUPATIONS WITH MORE THAN 1000 WORKERS' COMPENSATION CASES, 1988, 14 STATES, MUSCULOSKELETAL DISORDERS

Occupation	1980 Census Code	Number of Cases
Managers, NEC	019	2651
Management related occupations	020	1505
Registered nurses	095	3931
Licensed practical nurses	207	2342
Health technicians, NEC	208	1263
Sales occupations, supervisors	243	2740
Retail sales workers	260	9365
Secretaries	313	1140
Shipping clerks	364	2598
Stock clerks	365	1810
General office clerk	379	1176

Occupation	1980 Census Code	Number of Cases
Firefighters	417	1914
Police & detectives	418	1793
Waiters & waitresses	435	1618
Cooks	436	2871
Kitchen workers, food preparation	439	1475
Miscellaneous food preparation	444	3025
Health aides, except nursing	446	1433
Nursing aides & attendants	447	15131
Maids & housemen	449	4306
Janitors & cleaners	453	9151
Farm workers	479	2860
Groundskeepers	486	2911
Automobile mechanics	505	2758
Truck mechanics	507	1485
Industrial machinery repairers	518	1442
Specified mechanics, NEC	547	1324
Not specified mechanics	549	2073
Construction supervisors	550	1179
Carpenters	567	4537
Electricians	575	1983
Painters	579	1234
Plumbers, pipefitters	585	2073
Construction trades, NEC	599	1311
Precision production supervisors	633	1649
Machinists	637	1159
Butchers & meat cutters	686	1891
Punching & stamping machine operators	706	1325

Occupation	1980 Census Code	Number of Cases
Molding & casting machine operators	719	1271
Textile sewing machine operators	744	1860
Packaging & filling machine operators	754	1980
Miscellaneous machine operators, NEC	777	6115
Machine operators, not specified	779	4432
Welders & cutters	783	3164
Assemblers	785	9021
Miscellaneous hand workers	795	1122
Production inspectors	796	1627
Truck drivers, heavy & light	804	14623
Driver - sales workers	806	3226
Bus drivers	808	1701
Industrial truck & tractor operators	856	1625
Miscellaneous material moving equipment	859	1132
Helpers, construction trades	865	1232
Construction laborers	869	6708
Production helpers	873	2371
Garbage collectors	875	1496
Stock handlers & baggers	877	5343
Machine feeders & offbearers	878	1622
Freight, material handlers, NEC	883	8523
Garage, service station occupations	885	1180
Hand packers & packagers	888	2042
Laborers, except construction	889	21991
Unclassifiable	999	2145

These data show the pervasiveness of work-related musculoskeletal disorders throughout standard industrial and occupational classifications, and also indicate that certain areas in the same industrial and occupational classifications do not exhibit equal risk. For this reason, NIOSH recommends that all industries be covered by the OSHA ergonomic safety and health management standard. However, NIOSH recommends a two-part approach for addressing ergonomic hazards that would first require the employers to review job tasks and medical records, and second, based on the results of this review, proceed to a complete ergonomics management program. The first step would require the employer to conduct a workplace survey using methods described in section III.A. with concentration on simple methods such as checklists. The employer would also be required to review records in order to determine whether any cases of work-related musculoskeletal disorders are occurring using passive surveillance methods as described in section III.C.1. If there are ergonomic hazards and there is no evidence of work-related musculoskeletal disorders, a person trained in ergonomics should evaluate the ergonomic hazards to determine if there is a significant risk of work-related musculoskeletal disorders. If work-related musculoskeletal disorders are identified or a significant risk of work-related musculoskeletal disorders has been determined, the employer should develop a complete ergonomic management program to abate the ergonomic hazards and reduce the risks of injury.

Further analysis of the existing databases noted in I.B. and the results of ongoing research may identify specific industries, occupations, and job tasks where OSHA should require the development of an ergonomics management program regardless of the results of an employer review.

III. ELEMENTS OF AN ERGONOMICS MANAGEMENT PROGRAM

NIOSH presents in this section five elements of an ergonomics management program: 1) worksite analysis, 2) hazard control, 3) health surveillance, 4) medical management, and 5) training and education. An ergonomics management program should be tailored specifically to each location, its workers, and their unique problems.

Management commitment and worker involvement are critical to the success of an ergonomics management program [OSHA 1990]. Management commitment is demonstrated by a written ergonomics management policy, the establishment of an ergonomic task force or committee, and a commitment to regular review and accountability. Worker involvement is manifested by their role as active participants on the ergonomic task force, providing feedback, identifying potential ergonomic problems, developing solutions related to equipment and work procedures, and providing early reports of symptoms.

A. WORKSITE ANALYSIS

The purpose of worksite analysis (ergonomic hazard evaluation) is to identify hazards that cause work-related musculoskeletal disorders. The ergonomic hazard evaluation process can be divided into two parts. The first stage involves an evaluation of job demands to identify the requirements of the task. In the second stage, job demands are compared to known human capacities. If task requirements do, in fact, exceed the capabilities of the workforce, control measures may be indicated.

Evaluation of Job Demands

The demands of most industrial jobs are a function of the work environment. The work environment can be described in terms of three basic components. These are:

- The tools, machines, parts and materials required for the job.
- The workstation and the physical environment.
- The task, including its content and the organizational environment in which it is performed.

A generic definition of tools may include hand tools, powered tools, machines, computer terminals and keyboards, instruments and their component parts. Traditionally, ergonomic evaluations begin with an investigation of the tools and equipment used in the workplace. Tools that require awkward postures and repeated forceful exertions, or transmit vibration to the hand have been implicated in the development of upper extremity musculoskeletal disorders [Putz-Anderson 1988].

The workstation can include tables and benches, stools and chairs, controls and displays, vehicle cabs, checkout stands, and storage bins. The physical environment includes lighting, noise levels, air quality, temperature, and ventilation. Both factors can have significant effects on comfort and functional ability as well as health. Ergonomic deficiencies in the workstation and physical environment may not be as obvious as tool design deficiencies, and special measurements (e.g., sound, illumination) may be required to identify problematic aspects. Correcting these problems may require greater capital expense (e.g., major facility renovations) than changes in tool design [Snyder et al. 1991].

Finally, task and organizational factors are increasingly recognized as important to the health, safety, productivity and satisfaction of workers. Job content (i.e., simple, routine versus complex, varied duties), work scheduling, work pacing, management style and climate, worker autonomy, feedback, worker support, opportunity for advancement, and training, are variables that can contribute to a positive work environment or, alternatively, produce stress. These "psychosocial" factors have been associated with low back pain in industrial workers and neck-shoulder symptoms in office workers [Linton and Kamwendo 1989; NIOSH 1992a; NIOSH 1992b; Wilson and Grey 1984]. Unfortunately, these factors are often the most difficult part of the work environment to evaluate. Although work rate is usually easy to measure, other problems emanating from job/organization factors are usually less evident from a physical inspection of the workplace and are often far more difficult to correct.

Although some studies may be limited to an investigation of tool and workstation factors, a thorough ergonomic hazard evaluation should examine the interaction of the worker with all three components of the work environment. Some hazards result from interactions between tool, workstation and job design characteristics. To accurately characterize the severity of the hazard, an investigation of all three components is necessary. For example, poor workplace design, involving poor chair design or visual display problems, may have only modest consequences for workers with moderate production demands or for professionals able to exercise control over the work regimen. The same design flaws may have far more important implications for workers with more stringent performance demands or little control over their work regimen.

There are no generic procedures for conducting an ergonomic evaluation of the workplace; the specifics of an investigation are dependent on a number of constraints, and procedures must be tailored to the individual workplace. However, the protocol for conducting an ergonomic evaluation usually follows one of two formats [Putz-Anderson 1988]. One approach, referred to as task analysis, involves adaptations of traditional work measurement methods for the purpose of documenting and measuring exposures to ergonomic stressors. A second approach involves use of an ergonomic checklist. A brief description of each approach is provided below.

Task Analysis. Task analysis refers to a broad spectrum of methods used to analyze observable and covert human behavior for the purpose of identifying the performance demands of jobs and job tasks [Drury et al. 1987]. Once task elements and job demands are determined, the analyst can decide whether these demands fall within the capabilities of workers and whether controls and task modifications are needed [Putz-Anderson 1988; Saito 1987]. Task analysis can lead to workplace redesign or tool developments that will eliminate or reduce the hazards of a task. For example, the task of stretching carpets involved the use of knee kicking tools that damaged the knees of carpet layers. A number of mechanical tools have been developed that can eliminate or substantially reduce the use of hazardous knee kickers [NIOSH 1990].

One method, time and motion analysis, determines what the worker is doing and how it is being done over a given time period. Motion analysis is now used by ergonomists to identify excessive manual repetitions and awkward and static postures of jobs that pose a risk of musculoskeletal disorders. Timed activity analysis can also be useful for analyzing complex tasks, with varying levels of detail including irregular activities, and describing simple tasks with very repetitive, short-cycle job elements [Barnes 1983; Drury 1983]. Putz-Anderson et al. [1992] developed an expanded version of a timed activity analysis for application to complex office tasks. Their goal was to develop an objective method to evaluate stressful job designs that posed a risk to clerical workers for developing musculoskeletal disorders.

Checklists. Ergonomic checklists can be used as an alternative or supplement to task analysis methods. Persons with limited formal training can often use checklists to identify common hazard sources in a fairly short period of time, while ensuring that systematic and standardized procedures are followed. Examples of items that might be found on an ergonomic checklist are described by Lifshitz and Armstrong [1986]. Examples of checklists have also been included in Exhibit 3 (see page 37). Users should be cautioned that most checklists are not comprehensive enough to cover the entire spectrum of risk factors that may be present at any specific worksite. Therefore, existing checklists should be customized and evaluated in a walk-through survey to ensure that the questions are appropriate to the worksite of interest [Putz-Anderson 1988].

Evaluation of Human Capacities

For most biomechanical factors, the limits of human capacity have not been defined. The interaction between normal human biomechanical variables and environmental variables may make it difficult to arrive at general principles that can be applied to specific tasks. Thus, in an ergonomic evaluation, it is difficult to determine if job demands exceed acceptable limits of human capacity. Anthropometric tables can help determine if workstation design is compatible with the user. Other studies provide guidance on normal human strength capacities in particular work situations [Kamon et al. 1982; Mathiowetz et al. 1985]. An epidemiological study across several industries and tasks suggests that workers who are subjected to highly repetitive jobs that also involve high manual force exertion are at greater risk for upper extremity musculoskeletal disorders [Armstrong et al. 1985]. The NIOSH Work Practices Guide for Manual Lifting [1981] is based on studies that indicate that a number of variables, including job factors and personal factors, influence the amount of weight a person can lift without back injury. Formulas for calculating load limits for lifting tasks based on analyses of biomechanical stresses on the lower back, data on the lifting strength capabilities of the working population, and psychophysical studies of acceptable exertion levels have been published [Putz-Anderson and Waters 1991].

Where existing data are insufficient to indicate the magnitude of hazards associated with a particular task, additional indicators of task difficulty are task performance, physiological response, and the worker's subjective assessment of the workload [Meister 1985].

<u>Performance measures</u>. Performance measures quantify the productivity and quality of output by the worker. Job demands that exceed workers' capacities may be manifested by decrements in performance measures [Barnes 1983]. Common performance measures include the following [Meister 1985]:

1. Time
    - Reaction time
    - Activity duration time

2. Accuracy
    - Observation errors
    - Response errors

3. Frequency of Occurrence
    - Number of responses per unit or interval
    - Number of errors per unit or interval

4. Amount Achieved or Accomplished
    - Percent of activities accomplished
    - Degree of success

5. Consumption or Quantity Used
    - Units consumed to accomplish activity
    - Units consumed per unit time

Generally, the best performance measures are those that are objective, quantitative, unobtrusive and easy to collect without specialized instrumentation [Meister 1985].

Performance test batteries can also be used to evaluate worker performance and subjective fatigue. Decrements in performance over the course of a work shift may indicate decreased alertness and increased fatigue due to work place conditions. A successful performance test battery was developed by NIOSH researchers to evaluate fatigue effects from shift work and long workdays [Rosa et al. 1985].

Physiological measures. Physiological measures can be used to evaluate an individual's response to controlled working conditions. Non-invasive monitoring techniques that do not interfere significantly with job performance can be used at the worksite to assess the effects of work demands on individual muscle activity or whole body cardiovascular function. Physiological indicators of whole-body stress include heart rate, blood pressure, oxygen consumption, and body temperature. Indicators of localized stress include surface electromyography (EMG), tremor measurements and ratings of perceived exertion [Meister 1985].

Subjective assessment measures. Subjective ratings of perceived exertion or comfort can be used to measure human capacity. An advantage of perceived exertion ratings is that they integrate information from the peripheral muscles and joints, cardiovascular and respiratory functions, and the central nervous system into a single measure. Perceived exertion scales have been found particularly valuable in studies of short-term static work for which valid physiological measures are difficult to obtain [Rosa et al. 1985].

Inherent deficiencies in the use of subjective measurements are: lack of fundamental units for measuring perceived exertion [Rosa et al. 1985]; the worker may be unaware of the extent to which he/she is stressed, he/she may confuse mental and physical effort, and his/her estimates may change over time [Meister 1985]. Nonetheless, psychophysical scales have been used successfully in a number of ergonomic investigations of work tasks, and high correlations have been demonstrated between subjective ratings and physiological variables [Gamberale 1972].

B. HAZARD CONTROL

Background

The goal of "hazard prevention and control" is to eliminate, reduce, or control the presence of ergonomic hazards. Ergonomic hazards may be identified as a result of performing a worksite analysis--the details of which were discussed in the previous section, Part A.

By definition, "ergonomic hazard" is a recent term chosen to refer to a set of work-related risk factors that are associated with the development of musculoskeletal disorders. Risk factors commonly associated with ergonomic hazards include:
(1) repetitiveness, (2) force/mechanical stress, (3) awkward or static posture,
(4) vibration, and (5) work organizational/stress factors [Armstrong et al. 1986; Arndt 1987].[2] In general, ergonomic hazards are present whenever the work demands of a job

[2]This list of risk factors for work-related musculoskeletal disorders is not intended to be all inclusive.

exceed the capacity of those workers performing the jobs. Moreover, excessive work demands can arise from poorly designed work processes, tools, and/or work stations [Putz-Anderson 1988].

There are many potential ergonomic solutions or interventions for each of the risk factors listed. Table 1 provides examples of relatively simple single-fix solutions that have been recommended by various ergonomic experts for each risk factor [Grandjean 1988; Konz 1979]. To be effective, an ergonomic intervention should serve to reduce the source of the physical stress (i.e., reduce the ergonomic hazard) associated with a particular risk factor. The theory is that by reducing hazard levels, there will be similar reductions in illness and injury rates.

In some cases, proposed ergonomic interventions are simple and consistent with common sense. At the majority of worksites, however, where ergonomic hazards have been identified, a more comprehensive approach is required than can be provided by any of the single-fix solutions, some of which are listed in Table 1. Today, with the complexities of the mechanized work environment, ergonomic solutions often serve as the interface between the "person, machine, and work environment," reflecting the importance of a systems approach to hazard prevention [McCormick and Sanders 1982].

NIOSH continues to support a three-tier hierarchy of controls as an intervention strategy for controlling ergonomic hazards. This position was outlined in the "Ergonomics Program Management Guidelines for Meatpacking Plants" [OSHA 1990]. The approaches identified in that document include the following steps in order of preference:

- Engineering or ergonomic design changes to tools, handles, equipment, workstations, work methods, or other aspects of the workplace, often called engineering controls.

- Changes in work practices or organizational and management policies, sometimes called administrative controls.

- Use of personal protective equipment.

A discussion of each of these approaches follows:

1. <u>Engineering/Ergonomic Controls</u>

The preferred method for control and prevention of work-related musculoskeletal disorders is to design the job to match the physiological, anatomical, and psychological characteristics and capabilities of the worker. In other words, safe work is achieved as a natural result of the design of the job, the work station and tools; it is independent of specific worker capabilities or work techniques.

Although the focus of this section is on hazard control, the concept of prevention is best exemplified when the workplace, tools, work station, and work process are designed from the beginning to accommodate the capability and capacities of the workers. Unlike the majority of occupational hazards, however, sources of ergonomic stress are usually hidden or embedded within the job as specialized patterns of movement or tool usage. The result is that ergonomic hazards are often difficult to predict or anticipate during the initial design stage.

Ergonomics is the discipline that strives to develop and assemble information on people's capacities and capabilities for use in designing jobs, products, workplaces and equipment. The goal of ergonomics is to establish through job design, a "best fit" between the human and imposed job conditions to ensure and enhance worker health, safety, comfort, and productivity.

A number of reference works containing ergonomic guidelines for the design of various workplaces have been compiled by Van Cott and Kincaid [1973], Konz [1979], Woodson [1981], Eastman Kodak [1983; 1986], Putz-Anderson [1988], Tichauer [1991], Chaffin and Andersson [1991], and Mital and Kilbom [1992], among others. These strategies apply both to the design of new jobs and the control of hazards in existing jobs. In general, the selection of a design for limiting musculoskeletal stress will depend on existing technology, resources, and employee acceptance; however, numerous studies indicate that designing or redesigning tools, workstations or jobs in accordance with ergonomic guidelines can be effective in limiting worker exposure to ergonomic hazards (Table 2).

Other studies have examined the effectiveness of engineering changes on the incidence rate of musculoskeletal disorders associated with specific job tasks. In a comparison of three approaches to low back injury control, Snook et al. [1978] concluded that worker selection, and training in lifting technique were ineffective, and that designing jobs to fit the capabilities of workers could reduce low back injuries due to lifting by two-thirds. Westgaard and Aaras [1984; 1985] introduced adjustable work stations and fixtures, and counterbalanced tools in a cablemaking company, and found that turnover and absenteeism due to musculoskeletal complaints were reduced by 2/3 over an eight-year period. Companies that have adopted plant- or corporate-wide ergonomics programs consisting of worker training, union-management participative teams, and job analysis and redesign programs, have reported decreases in musculoskeletal injury incidence rates and turnover, and increased productivity [McKenzie et al. 1985; Rigdon 1992; Lutz et al. 1987; Geras et al. (unpublished); LaBar 1992; Echard et al. 1987]. These and other studies describing the effect of various hazard control approaches on musculoskeletal incidence rates are summarized in Table 3.

2. Administrative Controls

Administrative controls can be defined as policies or work practices used to prevent or control exposure to ergonomic stressors that can result in work-related injury or disease. Examples of administrative controls include the following [OSHA 1990]:

- Work Practices
  - -- Providing frequent rest breaks to offset undue fatigue in jobs requiring heavy labor or high performance/production rates
  - -- Limiting overtime work and periodically rotating workers to less stressful jobs.
  - -- Varying work tasks or broadening job responsibilities to offset boredom and sustain worker motivation.
- Training workers to use work methods that improve posture and reduce stress and strain on the extremities
- Worker placement evaluation

a. Work Practices

Although engineering controls are the preferred method of ergonomic hazard control, there are work situations where modification in work practices may be used as a temporary substitute for engineering controls. Such circumstances, however, should continue to be regarded as potentially hazardous, because the source of the ergonomic hazard remains. Any level of protection afforded by "work practices" is a function of human intervention, that is always subject to the weaknesses inherent in human oversight and control activities. The history of such failures is well documented in the occupational safety and health literature.

Work practices refer to modifications in job rules and procedures that are usually under the control of management or administrators. For example, in office settings where the physical environment (lighting, furniture, and VDT equipment) may already be highly refined and state-of-the-art, changes in work organization and attention to psychosocial factors provide more potential for reducing ergonomic stressors [Kilbom 1988]. Furthermore, administrative controls such as worker rotation, additional rest breaks, and slowing of production rates may be the only method of hazard control available in situations where work tasks are highly variable, there are no fixed workstations, or there are no tools involved in the work (e.g., grocery order selectors, workers in certain types of assembly jobs, sign language interpreters).

The effectiveness of work practice controls has been examined by a number of researchers. One investigation of keyboard operators found that operators who were provided short but frequent rest breaks were more productive than operators receiving only the traditional mid-morning, mid-afternoon and lunch breaks [Swanson et al. 1989]. In a series of four studies of 72 workers performing an overhead assembly task, workers were given control over the duration of their work cycles by initiating a one-minute work pause when needed. Such self-pacing served to minimize local shoulder and arm fatigue, resulting in more consistent levels of performance over the course of the study period [Putz-Anderson and Galinsky 1993].

At a plant employing 124 photographic film rollers, decreasing total work time from 353 to 330 minutes per day, and increasing the number of rest breaks from three to six, resulted in a reduction in cervicobrachial disorder and low back complaints [Itani et al. 1979]. An electromyographic study of five jobs where job rotation had been introduced concluded that job rotation may be more useful for reducing stress associated with heavy dynamic tasks than for reducing static muscular load in "light" work situations [Jonsson 1988a].

b. Training: Worker-Employer

Instructional programs aimed at reducing illnesses and injuries are also frequently promoted as readily available and an economical approach to the control of workplace injury. Training programs range from fundamental instruction on the proper use of tools and materials, to instructions on emergency procedures and use of protective devices. More comprehensive training programs are being developed to prepare the worker to participate in a broader range of worksite safety and health activities. These programs are addressed in Section III.E. of this document.

Because the effectiveness of training programs is difficult to evaluate, the success of many of the training programs has been difficult to establish. Some authors have attributed significant reductions in low back disability and lost time injuries to worker training programs [Glover 1976; Bergquist-Ullman and Larsson 1977]. Other studies indicate that well-planned training programs can have small but significant effects on lifting behavior [Chaffin et al. 1986; Varynen and Kononen 1991].

c. Worker Placement Evaluation

Worker placement evaluation has also been promoted as a method for controlling the risk of overexertion injuries and musculoskeletal disorders. The emphasis here is on matching workers to potentially high-risk jobs, i.e., identifying workers with physical characteristics that will enable them to satisfy job demands that may be excessive to other workers. Worker selection or hiring based solely on physical capacities is generally illegal, as a result of the U.S. Federal Rehabilitation Act of 1973 (29 USC[3] §791 et seq.) and the recent Americans with Disabilities Act of 1990 (42 USC §12101 et seq.). However, once a worker is offered a job, he or she can be tested to determine his or her capabilities as a prelude to job placement.

The success of any placement program is dependent on obtaining accurate information on actual job demands as well as with the accuracy of measurements of worker capacities as they relate to the key job demands. A person's capacity for physical work is almost never a single value; it is determined by several factors including the intensity of the effort; the time of continuous effort; the frequency of repeating the effort; the presence of environmental or mental stressors, such as heat, humidity, and time pressure; and individual characteristics such as age, fitness, and skill level [Rodgers 1988].

[3]United States Code

To be valid, work capacity tests must be specific to each job of concern. Furthermore, it must be demonstrated that not only does a worker require the capacity to do the work, but that people without that capacity cannot do the job. For example, it is generally accepted that muscular strength is an appropriate job-related criteria for manual materials handling work. However, it is frequently difficult to measure the strength capacities of the worker that most closely reflect those key strength requirements of the job. Moreover, a worker's maximum strength may have little relationship to his or her ability to exert effort frequently or for long durations. Finally, there are many workplace situations where the job demands change.

In some manufacturing operations, products may frequently change, certain seasons may add environmental stresses, and overtime may change the effort requirements. Thus, the assessment of job demands will not be so accurate that it can be relied upon to predict a worker's success or failure on the job in all situations [Rodgers 1988].

There is some epidemiological support for the idea that strength testing could be a useful means of reducing back injury rates. In studies where the appropriate measurements have been made, a higher incidence of back injuries and back pain was found in those jobs demanding high exertion in relation to the worker's own maximal isometric strength [Keyserling et al. 1978; 1980]. However, to date, there are no valid methods for identifying "high risk people," i.e., accurately predicting whether healthy workers are susceptible to musculoskeletal injury from jobs requiring manual lifting and other forms of exertion. Although the use of X-rays, muscle strength tests, tests of physical fitness or flexibility, or other means have been promoted as screening procedures in the past, thus far none have proved successful [Putz-Anderson 1988].

The American Occupational Medical Association concluded that many of these tests should not be used as screening procedures, but rather as special diagnostic procedures available to the physician on appropriate indications for study [Rothstein 1984].

In summary, an advantage of administrative controls is that they can usually be implemented quickly and easily without the need to purchase or modify equipment. Because administrative controls, however, fail to eliminate the source of the hazard, they should be considered temporary solutions for controlling exposure until more permanent engineering controls can be implemented.

3. <u>Personal Protective Equipment</u>

NIOSH continues to support OSHA in recommending personal protective equipment (PPE) as the least preferred intervention strategy for controlling ergonomic hazards [OSHA 1990]. PPE seldom provides complete protection from exposure to a significant hazard; rather it seeks to reduce the exposure to a level that is acceptable [Moran and Ronk 1987].

Traditionally, PPE has afforded protection to the worker by providing a barrier between the worker and the hazard source. Examples of PPE that operate on this principle include respirators, ear plugs, vibration-attenuating gloves, protective eye wear, chemical aprons, safety shoes and thermal protective clothing. Because braces, wrist splints, back belts, and similar devices do not provide a barrier between the worker and the ergonomic hazard, they cannot be considered PPE. Furthermore, most devices (such as braces and splints) that are purported to reduce biomechanical stress on the musculoskeletal system have questionable value. Indeed, there is little research evidence to demonstrate that these devices limit the risk of injury.

Although other examples may exist, the only obvious example of ergonomic PPE that could be identified is vibration-attenuating gloves. Depending on their composition and construction, gloves have been shown to be effective at absorbing much of the vibration energy that would otherwise be transmitted to the hand [Goel and Rim 1987]. However, potential users should be cautioned that gloves generally interfere with grip strength and manual dexterity, thereby increasing the effort required for manual tasks [Mital and Kilbom 1992].

NIOSH has recently revised the lifting equation to reduce and prevent back injuries [Waters et al. 1991]. This equation is an update of the original equation provided in the *Work Practices Guide for Manual Lifting* [NIOSH 1981]. The new equation addresses jobs that require twisting motions and for which the horizontal and vertical positions of the load and the hand/container coupling can be defined. It re-emphasizes the use of engineering methods in preference to administrative procedures for control lifting hazards.

NIOSH will prepare a position statement on the use of back belts to reduce and prevent low back injuries. This statement will be sent to OSHA in the near future.

Conclusion

Preventing or reducing ergonomic hazards is frequently difficult for a number of reasons. In some cases, several factors combine to create a hazard. Overlapping problems can include high production demands, faulty work methods, awkward work station layouts, and ill-fitting tools [Putz-Anderson 1988]. Therefore, improvements addressing one factor may not eliminate the overall risk. Also, interventions effective in one situation may be ineffective in other settings. Most control plans involve compromise and trade-offs to arrive at the most appropriate solution. The solutions will typically require a series of adjustment or fitting trials to ensure effectiveness and worker adoption. In the final analysis, most ergonomic solutions to work-related musculoskeletal disorders are more often affected through incremental and cumulative improvements in the workplace than from a single, major workplace modification.