EPIDEMIOLOGY OF WORK-RELATED MUSCULOSKELETAL DISORDERS

Thomas R. Hales, MD, and Bruce P. Bernard, MD, MPH

Musculoskeletal disorders (MSDs) are disorders of the soft tissues and their surrounding structures not resulting from an acute or instantaneous event (e.g., slips or falls). In the epidemiologic literature, MSD can be grouped as

- Clinically well-defined disorders (such as tendinitis, carpal tunnel syndrome, and hand-arm vibration syndrome)
- Less clinically well-defined conditions (such as tension neck syndrome)
- Nonspecific (such as repetitive strain injury [RSI], cumulative trauma disorders [CTDs], overuse syndrome, and cervicobrachial disorders

Clinicians typically can easily relate to the "clinically well-defined" disorders in which the criteria for the epidemiologist's "case definition" are similar to the clinician's "diagnostic criteria." Unfortunately, most clinicians are not familiar with the more inclusive "surveillance" case definitions used by epidemiologists to identify risk factors and to institute preventive measures rather than to diagnose and treat individual patients. Vender et al[122] recently exhorted that the issue of work-related MSD fails to incorporate sound medical diagnostic criteria in defining and identifying these conditions. Given clinicians' difficulty with these broad, less well-defined terms, it is somewhat ironic that the term *overuse syndrome* seems to have originated in the orthopedic literature to describe athletic injuries.[20] Another term that has crossed over from the orthopedic literature is RSI, used to describe injuries in distance runners.[142] Riihimäki[79] recently stated, in an editorial concerning MSD, that the wide use of the standardized Nordic questionnaire has perhaps prohibited progress in the field of MSD research because of its over simplicity and lack of specific criteria. Armstrong, on the other hand, pointed out that "while an exact diagnosis is desirable for affected workers," in most cases, it is desirable to intervene in the work place before explicit signs of disease develop. This confusion over terminology and case definitions has had a dramatic impact on the recognition, reporting, surveillance, and individual diagnoses of these disorders.[63, 70, 73]

MSDs are considered to be work-related when the work environment and the performance of work contribute significantly to their development.[243] Work-related MSDs are, therefore, distinguishable from occupational diseases in that occupational diseases have a direct cause–effect relationship between a single hazard and a specific disease (e.g., asbestos and asbestosis, silica and silicosis), whereas MSDs do not. Epidemiologic studies have identified several work-place risk factors

From the Medical Section, Hazard Evaluations and Technical Assistance Branch, National Institute for Occupational Safety and Health, Cincinnati, Ohio

associated with these disorders in workers. This article critically examines this literature to describe (1) the magnitude of the problem; (2) the risks associated with various occupations and industries; and (3) specific personal, physical, and psychosocial risk factors associated with these disorders.

EPIDEMIOLOGY

Before focusing on the evidence, the following section lays a foundation for health professionals without epidemiologic training to interpret the results of MSD epidemiologic studies.

Definition

Epidemiology is the study of the distribution and determinants of health problems in specified populations and the application of the study to the control of the problems.[123] It is important to note that this definition recognizes the role of the epidemiologist to describe both the distribution (e.g., person, place, and time) and determinants (e.g., risk factors) of disease and to link those findings to prevention programs. Studies in epidemiology seek to find associations between exposure and disease (cause and effect). The need to identify and interpret associations is greatest for conditions accounting for a large share of society's health problems. Given the magnitude of the work-related MSD problem in the United States (elaborated upon later in this article), musculoskeletal conditions fulfill this criterion.

Epidemiologic Study Design Issues

Epidemiologic studies seek to identify factors associated, positively or negatively, with the development of adverse health outcomes. These factors can be demographic, genetic, lifestyle-related occupational, behavioral, or environmental, and a variety of study designs are available to identify them:

- Descriptive
  - Case reports
  - Case series
- Analytic
  - Case-control
  - Cohort (prospective or retrospective)
  - Cross-sectional

A brief synopsis of the types of studies conducted for occupational MSD follows.

Case reports and case series are reports of disorders identified during the clinical evaluation of individual employees or several members of a work force. The author typically describes some interesting or intriguing observations among the employees. Case reports and case series typically generate hypotheses that can then be investigated in analytic epidemiologic studies, such as cross-sectional, case-control, and cohort studies. These reports or series should not be viewed as providing evidence for causal association between a particular exposures and MSDs. In addition, because case reports and case series do not involve hypothesis testing or have comparison groups, many epidemiologists do not consider them to be "epidemiologic studies."

Case-control studies select subjects based on their "disease" status. Differences in exposures are compared between employees who are MSD "cases" and those who are "noncases" ("controls" or "referents"). A ratio is generated between the proportion of cases exposed to the risk factor versus the proportion of noncases exposed. This ratio is known as the *odds ratio* (OR). The OR informs the reader regarding the strength of the association between the exposure and the work-related MSD. An OR of 3 for a particular exposure factor, for example, suggests that factor will increase your risk of getting that disease threefold. Two statistical measures are used to ensure that associations are not attributable to chance—the P value and the confidence interval (CI). By convention, scientists often use a P value < 0.05 to conclude that the results observed were unlikely to have arisen by chance (the results 95 times out of 100 would not be attributable to chance). The CI indicates the probable range in which the OR actually falls. Again, by convention, scientist typically use a 95% CI. If the CI includes 1, the association between the exposure and the MSD may have occurred by chance alone, and the OR is not considered statistically significant. Case-control studies are good for evaluating rarely occurring conditions or those that include a small number of cases. The main limitation of case-control studies is the inability to determine the temporal relationship between exposure and disease condition. Another important consideration with case-control studies is how the control population was selected, and whether it represents an appropriate comparison group.

Cohort studies involve the identification of an exposed worker population (cohort), follow-up over time, and a determination of disease frequency in relation to the exposure type and level. When MSDs have not yet occurred at the time the exposure status is being ascertained, the study is considered a prospective cohort study. If MSDs have already occurred when the exposure status is being ascertained, the study is considered a retrospective cohort study. The incidence (defined subsequently) of MSD cases among the exposed employees is compared with the incidence of MSD among the nonexposed employees. This comparison establishes a relative risk (RR), which assesses the relationship between exposures and MSD. A RR of greater than 1 implies that the incidence of MSD was greater in the exposed than the nonexposed group, thereby suggesting an association between that exposure factor and MSDs. A CI is used to indicate the probable range in which the RR actually falls.

Cross-sectional studies represent the most common study designs investigating work-related MSDs. Employees are usually selected for study based on their exposure to a particular factor in their employment within a particular industry, occupation, plant, or department. Exposure is usually stratified into at least two categories, and MSD prevalences (defined subsequently) are determined among exposed and nonexposed workers. The prevalences of a MSD among the exposed and nonexposed are usually evaluated by a prevalence ratio; an OR can also be derived. Interpretation of the OR, CI, and *P* value were discussed earlier. It is important to note that both the MSD and exposure status are determined more or less at the same time. This inability to establish a temporal relationship or to track exposure status over time is a major limitation of cross-sectional studies. An employee who acquires a work-related shoulder tendinitis attributable to factors from one job may be assigned to another job, for example. This situation would both obscure the association of shoulder tendinitis with the original job and may erroneously associate the tendinitis with the second job.

Using Epidemiologic Studies to Infer Causality

A number of criteria have been developed for the interpretation of epidemiologic data.[illegible] The criteria relevant to the study of work-related MSDs can be summarized as

- Strength of the association
- Dose–response relationship
- Consistency of the association
- Coherence
- Reversibility
- Statistical significance
- Specificity
- Temporal relationship

The size of the RR or OR is a measure of the strength of association. In general, strong associations (RR or OR greater than 3) are unlikely to be attributable to chance or unidentified confounding associations and, therefore, support a potential causal association.[149] If the risk of disease increases as exposure to a risk factor increases, a dose–response relationship is said to exist. A dose-response relationship is relatively strong evidence for a causal association, but its absence does not rule out a causal association because of a potential threshold effect or inability to quantify the exposure adequately. Consistency refers to whether the association has been reported in other studies. Diverse study designs conducted by a variety of researchers in several countries that yield similar associations support a causal association. Review of the literature in a more formal approach, known as meta-analysis, can synthesize data from many studies and derive a single best estimate of the strength of association. Coherence implies the cause–effect interpretation for an association does not conflict with the known natural history and biology of the disease. In other words, it is the biologic plausibility, or believability of the potential association. Reversibility refers to whether the disease risk is lower with the elimination or reduction of the exposure to the risk factor. Obviously, this criterion is only applicable to intervention studies. Given the inability to control many of the potentially confounding factors for MSD, intervention studies are difficult to perform and therefore uncommon. Statistical significance refers to the process by which an association is estimated to be attributable to chance. Too often, statistical significance has been equated with clinical or public health significance. Taken out of context, the *P* value or CI has little meaning.[45, 150] Specificity assumes that a cause leads to a single effect, not multiple effects. Given the multifactorial nature of most MSDs, this criterion may not always be appropriate for interpreting MSD epidemiologic studies. Temporal relationship refers to the condition required for causal associations—the exposure precedes the disease.

Incidence

The incidence is defined as the number of new cases of disease in a population within a certain period of time. The basic characteristic of incidence data is that time is part of the units (i.e., cases/population/time). Incident rates are usually measured in experimental and cohort studies.

Prevalence

Prevalence measures the number of cases that are present at, or during, a specified period of time. The prevalence equals the incidence multiplied by the average duration of the disease. The two types of prevalence used by investigators are point prevalence and period prevalence. Point prevalence refers to the number of cases present at a specified moment of time. Period prevalence refers to the number of cases present during any part of a specified period of time—for example, 1 year. Prevalences are usually measured in cross-sectional studies.

MAGNITUDE OF THE WORK-RELATED MUSCULOSKELETAL DISORDER PROBLEM

During the past 10 years, there have been increased interest, improved reporting, and targeted surveillance of work-related MSDs. Despite widespread documentation, however, there remains some controversy as to the extent of the problem in the United States. This is because of many reasons, including: (1) difficulty establishing a specific diagnosis for many of these disorders, (2) difficulty establishing whether an individual MSD case is work-related, and (3) differing eligibility criteria for compensation among states.

Upper Extremity Disorders

Incidence

The Bureau of Labor Statistics (BLS) estimates over 332,000 cases of disorders caused by repeated trauma occurred in 1994.[38] From 1984 to 1994, the incidence rate of these disorders increased from 5.1 to 39 cases per 10,000 full-time workers (ftw) (Fig. 1). This increase probably is explained by two factors: (1) increased awareness among employees, employers, and health care providers that these disorders may be work related, thereby resulting in more complete recording; and (2) a true increase in the number of cases. Because of underreporting problems in this database, these numbers should not be used to estimate the actual number of disorders.[126] Rather, the data are most useful for interpreting trends and identifying high-risk industries (discussed in next section).

In 1988, Stevens et al[205] reported 11 cases of carpal-tunnel syndrome (CTS) per 10,000 person-years in the community surrounding Rochester, Minnesota, for the years 1960 to

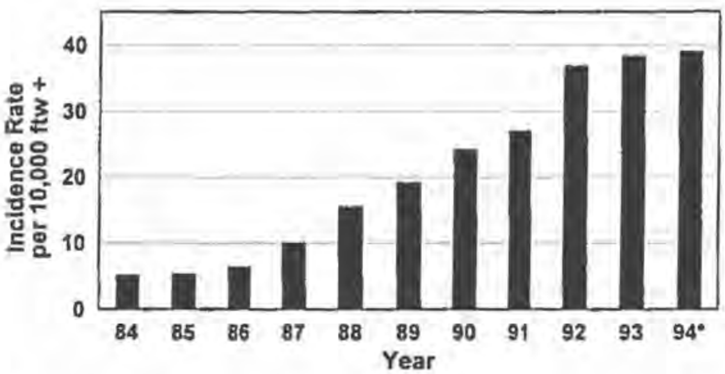

Figure 1. Disorders due to repeated trauma, 1984–1994. +, Full-time worker; *, projected. (*Data from* Bureau of Labor Statistics: Workplace Injuries and Illnesses, 1994. Washington, DC, U.S. Department of Labor [publication no. 95-508], December 1995.)

1980. Unfortunately, that study did not address the component of these cases that was work-related. A survey of health care providers in the San Francisco Bay area suggested approximately 47% of all CTS cases were work-related.[39] Data from the Washington State Workers Compensation program reported the overall incidence of work-related CTS for the 5-year period of 1984 through 1988 to be 17.4 cases per 10,000 ftw.[64] There was no consistent trend during that time regarding an increase or a decrease in the number of claims filed for work-related CTS.

In 1974, Allander[3] reported incidence rates of "painful shoulder" and "tennis elbow" among residents of Stockholm, Sweden for the years 1965 to 1968. Rates were reported by age groups and stratified by gender; 42 to 46 year olds reported the highest rates—approximately two cases per 100 people per year for painful shoulders, and approximately one case per 100 people per year for epicondylitis. Like the Stevens et al study already mentioned, Allander did not address the proportion of cases that was considered work related.

Prevalence

The prevalence of upper-extremity MSD depends upon the occupation studied, the risk factors present, and the specific body part studied. In 1988, the National Health Interview Survey (NHIS)[214] found that 8% of the 127 million active workers reported prolonged hand discomfort (20 days or more in the past year, or seven or more consecutive days in the past month). Approximately 0.5% (675,000 current workers) reported both prolonged hand discomfort and "medically called" CTS, of whom approximately 50% (356,000) of respondents reported that the medical person said the CTS was work-related. Hagberg[75] reviewed the literature on work-related CTS and found a prevalence ranging widely, from 0.6% to 61%, depending on the occupational group studied. Allander[3] reported prevalences of painful shoulder ranging from less than 10% to more than 20%, depending on the age group studied, and epicondylitis ranged from less than 1% to more than 5% depending on the age group studied.

Cost

In 1989, the total US workers' compensation costs for upper-extremity CTDs was estimated to be $563 million.[232] This figure did not include the indirect costs, such as administrative costs for claims processing, lost production time if disability occurred, or costs to train new workers hired to replace the disabled worker. Although few data exist to estimate indirect costs, it has been estimated that total costs are two to three times direct compensation costs.[78]

Low Back Disorders

Low back pain is a common ailment. Most studies report a lifetime prevalence of 60% to 80% and a yearly prevalence of 6% to 20% (Table 1). Fortunately, most episodes are relatively mild and self-limited. Approximately 90% spontaneously recover and regain activity tolerance within a month.[24, 37] Approxi-

Table 1. PREVALENCE OF BACK PAIN IN THE GENERAL POPULATION AND WORKERS

Investigator (Year)	Population Studied	Condition	Prevalence (%)
Cunningham (1984)	General population United States	Back pain	14–16
Anderson (1986)	Workers United Kingdom	Back pain	20
Deyo (1987)	General population United States	Lower back pain lasting at least 2 weeks	10
Svane (1987)	Workers Denmark	Low back pain	8
Leigh (1989)	Workers United States	Back/spine trouble	20
Guo (1995)	Workers United States	Back pain lasting over 1 week	18
Papageorgiou (1995)	General population United Kingdom	Low back pain in past month	35–37

mately 20% of individuals with back pain seek health care. Only about 10% of workers with work-related back pain seek compensation.[44] The incidence rate of compensation for back injury ranges from 0.3 to 3.3 cases per 100 workers per year.[2, 37, 39, 116] The small proportion of cases that become chronic account for a high proportion of the compensation costs.[202]

Costs

The direct workers' compensation costs for low back disorders in 1989 was estimated to be $11.4 billion.[233] This figure, again, does not include the indirect costs already mentioned. Including those indirect costs with the direct compensation costs results in a $30-billion-per-year estimate of the total cost of compensable work-related low back disorders.[173] Adding the cost of uncompensated low back pain to that figure (recall, only about 10% of workers with work-related low back pain seek compensation),[44] the total cost to society reaches between $50 billion and $100 billion.[65]

INDUSTRIES AND OCCUPATIONS WITH RISK FOR WORK-RELATED MUSCULOSKELETAL DISORDERS

Industries

According to the BLS annual survey, red-meat-packing plants have had the highest MSD rate since the BLS began collecting industry-specific data in 1984. In 1994, the rate was 1257 cases per 10,000 ftw in red meat packing plants (Table 2). The automobile manufacturing industry and poultry processing industry also have the dubious distinction of being in the top five since 1988, ranking second and fourth, respectively, in 1994 (see list). Data on CTS from individual state workers' compensation programs and NHIS data have identified the same high-risk industries.[64, 82, 214]

Table 2. TOP FIVE INDUSTRIES WITH DISORDERS DUE TO REPEATED TRAUMA, 1994

SIC	Industry Description	Rate per 1000 ftw
2011	Meat packing	126
2254	Knit underwear manufacture	101
3711	Motor vehicles manufacture	96
2015	Poultry processer	83
3142	House slippers manufacture	73

SIC = Standard industry code; ftw = full-time worker
Data from Bureau of Labor Statistics: Workplace Injuries and Illnesses in 1994. Washington, DC, US Department of Labor [publication no. 95-508], December 1995.

Occupations

Case studies have given rise to a number of disorders named for the occupation for which it was identified.

- Bricklayer's shoulder
- Carpenter's elbow
- Janitor's elbow
- Stitcher's wrist
- Cotton twister's hand
- Telegraphist's cramp
- Writer's cramp
- Bowler's thumb
- Jeweler's thumb
- Cherry pitter's thumb
- Gamekeeper's thumb
- Carpet-layer's knee

This does not mean, however, that the disorders are unique to those occupations. The NHIS described cases of self-reported CTS to be highest among mail and message distributors (prevalence = 3.2%), health assessment and treating occupations (2.7%), and construction trades (2.5%).[214] The Wisconsin workers' compensation program reported wrist injury to be highest among dental hygienists (OR = 17), data entry keyers (OR = 11), and hand grinding and polishing occupations (OR = 7) compared with all Wisconsin employees.[82] Occupations with the highest prevalence of low back pain are construction laborers (prevalence = 23%), carpenters (22%), and industrial truck and tractor equipment operators (22%) for men. For women, the occupations with the highest prevalence of low back pain are nursing aides (19%), nurses (16%), and maids (15%).[77]

PERSONAL RISK FACTORS FOR WORK-RELATED MUSCULOSKELETAL DISORDERS

The main purpose of this article is to review the contribution of work factors to MSD. Because of the multifactorial nature of MSD, it is necessary to include a discussion of personal factors that can influence the occurrence of this disorder. The following is a brief discussion of some of these factors.

Upper Extremities

Age

The relationships between age and some specific MSDs are well established. For example, osteoarthritis is clearly associated with advancing age.[50, 108] For others, such as CTS, the findings are mixed. Stevens et al[205] found an increasing rate of CTS with advancing age in men, but the rate in women seemed to peak in the 45 to 54 age group and then decline with increasing age. Hagberg et al,[75] in their literature review of occupational studies of CTS, found no studies showing age to be a risk factor once the duration of occupational exposure was controlled. Age as a risk factor for shoulder tendinitis has been reported in some studies,[59, 165] but not others.[86, 176] One explanation for the lack of an observed relationship between advancing age and increased risk for work-related disorders is that many of the older workers left the work force due to MSD, causing a "survivor bias." Also, advancing age and increasing number of years on the job are highly correlated, so years employed is a true confounder with age and must be adjusted for when examining the relationship to work.

Gender

Many studies report a higher prevalence of MSD in women compared with men.[12, 23, 47, 81, 124, 197, 205] Women, however, traditionally have been assigned to jobs requiring less physical strength, but requiring more stereotypic repetitive movements. When these occupational exposure factors are accounted for, some studies report no association with gender.[79, 197] Other potential explanations for this association include the fact that work stations were built for the height and reach capabilities of men, thereby placing female workers at suboptimal working postures[9]; women may be more likely to report pain and seek medical treatment than men; and women have more exposure to risk factors off the job.[9, 81]

Sports

When participation in sports activities is considered in the exposure assessment, either in case series or epidemiologic studies, results are mixed. Some studies report an increased risk of MSDs associated with playing sports, especially at the professional level, whereas others seem to indicate a protective effect of sports. Epicondylitis in professional athletes has been well documented, and many of the biomechanical and physiologic studies of epicondylitis have been conducted in professional tennis players and baseball pitchers.[114, 181] One prospective study found slowing of suprascapular nerve conduction among healthy baseball pitchers as the season progressed.[181]

Weight

Weight, height, body mass index (BMI, a ratio of weight to height squared), and obesity have all been reported to be potential risk factors for CTS. Most studies examining anthropometric risk factors in relationship to CTS have been hospital-based populations; whether these results are applicable to working populations, therefore, is unclear. Several investigators have reported that their industrial study subjects with CTS were shorter and heavier than the general population.[42, 60, 156, 234, 237] Werner et al[237] estimated obese individuals (BMI > 29) were 2.5 times more likely than slender individuals (BMI < 20) to be diagnosed with CTS. Studies using multiple linear regression models (Werner[237] and Nathan[157]) found that BMI accounted for only 5% and 8.6% of the variance of the nerve conduction tests. Researchers[69, 237] have questioned the methods and conclusions reached the Nathan paper, however. The relationship of CTS and BMI has been suggested to relate to increased fatty tissue within the carpal canal or to increased hydrostatic pressure throughout the carpal canal in obese individuals compared with slender individuals.[237]

Low Back Disorders

Age

Low back pain (LBP) is uncommon in childhood and the teen years. The prevalence increases as people enter their working years. By the age of 35, most people have had their first episode of back pain.[44, 72] During their working years (ages 25–65), however, the prevalence is relatively consistent.[26, 72] Age groups having the highest rates of compensable back pain and strains were the 20 to 24 age group for men and the 30 to 34 age group for women.[116] Given this information, it would be incorrect to conclude that LBP is a health problem confined to older workers. On the other hand, osteoporosis, which may be a specific cause of LBP, is clearly associated with advancing age.[93, 179]

Gender

The prevalence of LBP is equal among men and women.[72, 125] Compensable LBP cases, however, are more common in men.[116] Whether this difference is attributable to differing occupations and job tasks or differing severity of back pain is unknown.

Socioeconomic Status

Lower socioeconomic status (SES) employees reported LBP more frequently than workers with upper SES, but that finding is probably because of the physically demanding occupations often held by people with lower SES.[155]

Weight/Height

Weight, BMI, and obesity have been identified in several studies as potential risk factors for low back disorders, specifically lumbar disc conditions.[83, 94] Others, however, have found no association with weight factors.[11, 53, 90, 106, 107] Height has also been reported to be associated with LBD; the awkward positions taller people would have to assume while working have been postulated as an explanation.[53, 94, 107] Others, however, have not found this association.[30, 53, 106]

Medical History

There is general consensus that a previous history of back or sciatic pain is one of the most reliable predictive factors for subsequent work-related back problems. Two studies have found associations between the number of births or pregnancies and sciatica or LBP.[67, 223] The reasons postulated for this association are the mechanical stress placed on the pelvic ligaments during the final stages of pregnancy.

Smoking

Many studies have reported on the relationship between of low back disorders and tobacco smoking. Authors who have reviewed this literature report that most of these studies support the association.[68, 108, 109] The postulated mechanisms for this association are the nicotine-induced diminished blood flow to vulnerable tissues and smoke-induced coughing causing mechanical strain.

Physical Fitness and Training

A few investigators have reported that physical fitness and conditioning had a significant preventive effect on back injuries,[41] but most studies suggest otherwise.[17, 66, 107] Most clinicians accept the premise that improving physical fitness reduces musculoskeletal injuries, but the epidemiologic literature at present does not support the efficacy of physical fitness and training as a primary intervention for preventing musculoskeletal and back injuries.[68]

Strength

Many studies have documented less strength in trunk flexors and extensors among patients with LBP compared with asymptomatic subjects. The logical explanation for this finding, however, is that the reduced strength is a result of the LBP, not a cause of it. These tests are not predictive of future LBP, and most researchers consider the strength of the spinal and abdominal muscles to be of insignificant importance in the prevention of work-related LBP.[17, 93]

PHYSICAL FACTORS

This section examines the evidence linking work factors to MSD. The ensuing discussion will focus on studies using clinically well-defined diagnoses (shoulder tendinitis, epicondylitis, CTS, hand–arm vibration syndrome); when appropriate, studies of symptoms also are mentioned (Tables 3–9). The epidemiologic studies listed in these tables have used (1) case definitions based on standardized physical examinations and questionnaires or (2) case definitions based solely on questionnaire data. Generally, the physical examination maneuvers used to define specific upper-extremity MSD cases have been uniform across studies.[16, 23, 35, 79, 80, 81, 178, 197, 230] The exception is CTS for which studies based their diagnoses on various combinations of symptoms, physical examination findings, and electrodiagnostic testing.

The studies have also used a variety of methods to assess workplace exposure—job title, job title assessed by an ergonomics expert, use of ergonomic checklists, and video and electromyographic recordings of representative workers. Interestingly, studies with the most accurate method of assessment of work load, in general, have stronger associations between MSD and physical factors. These physical factors include frequent or prolonged repetitive movements, forceful exertions, awkward postures, static muscle loads, cold temperatures, local or segmental vibration, and contact stresses. Exposure to these risk factors typically occurs in some combination (e.g., exposure to both force and repetition) in occupations in which the risk of MSDs is elevated.

Neck Disorders

An association between work involving repetitive movements (usually defined as such on job categorization or observation, not measurement) and the development of neck MSDs has been found in 11 studies, with odds ratios ranging from 1.5 to 5.7; five studies had ORs over 4[5, 40, 102, 119, 128, 134, 165, 166, 169, 182, 236] (see Table 3). Only one study reviewed did not find a statistically significant relationship between repetition and neck MSDs.[167] Kiken et al[111] found that 12% of 294 poultry workers in the high-exposure group (based on repetition and force) had neck symptoms and physical examination findings, compared with none in the low-exposure group. Berg et al,[19] Linton,[130] Wells,[236] and Kuorinka and Koskinen[129] all studied workers in forceful, repetitive hand-intensive jobs requiring static neck muscle contraction (in order to secure positioning of the hand-intensive work). These authors found workers in those jobs to have a higher prevalence of neck MSDs than workers in less forceful, repetitive jobs, again with ORs over 2. In these studies, force was estimated by questionnaire, biomechanical models, or electromyographic activity. Several of the studies concerning neck MSDs involved video display terminal (VDT) operators and did not characterize forceful exposure. Most of the VDT studies used symptom questionnaires to ascertain cases of neck disorders. Prevalence rates based on symptom reporting alone tend to be about twice the rates when compared with prevalence rates based on both symptom reporting *and* physical examination results.[22, 23, 40, 50, 102, 182]

Three studies found an association between the wearing of bifocals and awkward postures of the head and neck, and neck MSDs (OR = 3.8).[22, 41, 149] Sakakibara and coworkers' study of orchard workers[190] found a relationship between flexion and extension of the neck and MSDs, but data presented in the paper did not allow for calculation of ORs.

Kuorinka and Koskinen[129] did not find that work pace and productivity were associated with neck disorders among blue collare assembly workers; Bernard et al[23] and Burt et al,[40] in their studies of newspaper employees, however, found that working under a deadline (potentially a form of work pace) was statistically associated with neck symptoms. These mixed results may be attributable to the fact that the same or similar risk factors may have been estimated in different ways, or different aspects of the risk factor may have been measured, or the relationship is dependent upon other aspects of the occupation (that is, different occupations may have different risk modifiers).

Following changes in workplace organization and equipment in a work place using VDTs, Aaras[1] reported a reduction in (1) the number of sick-leave days and (2) the prevalence of neck pain. After these changes, there was also a significant reduction in trapezius load measured by EMG. This study illustrates both the potential causal relationship between static loading and MSDs but, more globally, that an identification of a risk factor (statis loading) in the work place and subsequent reduction in that risk factor can result in less worker disability (sick leave).

The study by Ohara,[164] contrary to the assertion in the review by Winkel and Westgaard,[242] both portrayed the multifactorial nature of neck and shoulder MSDs and illustrated that the increase in repetitiveness and awkward and static postures by cash register operators using new electronic cash registers placed on unsuitable counter heights increased symptoms in neck MSDs.

Several studies have suggested an exposure–response relationship between increased level or time of exposure and an increased prevalence of neck MSDs. Burt et al[40] (1990), in their investigation at a major urban newspaper, found that an increase in the percent of time typing at VDT keyboards was associated with a moderately increased prevalence of neck symptoms. Keyboard time was consid-

Text continued on page 696

Table 3. EPIDEMIOLOGIC STUDIES ADDRESSING RISK FACTORS FOR NECK DISORDERS

Investigator (year)	Design	Exposure Ascertainment	Disease Ascertainment	Risk Factor	OR/RR
Onishi (1976)	Cross-sectional	Observation and job category	Examination with pressure measurement	Static load and repetition	3.8
Maeda (1977)	Cross-sectional	Job category	Questionnaire and physical examination	Repetition	5.7*
Luopajarvi (1979)	Cross-sectional	Observation, video analysis, interview	Questionnaire and physical examination	Force and repetition	1.6
Kuorinka (1979)	Cross-sectional	Observation and job analysis	Questionnaire and physical examination	Higher workload	4.1*
Wells (1983)	Cross-sectional	Job category	Telephone interview	Shoulder load	2.6*
Kukkonen (1983)	Cross-sectional	Job category	Physical examination	Repetition, static postures	2.3*
Silverstein (1986)	Cross-sectional	Job analysis, video analysis	Questionnaire and physical examination	Repetition force	5.9*
Sakakibara (1987)	Cross-sectional	Job category, and posture measurements	Questionnaire	Posture	P<05
Berg (1988)	Cross-sectional			Physical load	2.6
Jonsson (1988)	Prospective cohort		Three separate physical examinations and questionnaires	Thirty-eight subjects reallocated to more varied tasks improved; those with unchanged working conditions deteriorated further	
Hales/Cargill (1989a)	Cross-sectional	Observation	Questionnaire and physical examination	Force and repetition; symptoms Symptoms and physical findings = Indeterminate	0.7
Ohlsson (1989)	Cross-sectional	Job category	Questionnaire	Force and repetition	1.9
Hayer (1990)	Cross-sectional	Observation and interviews	Questionnaire	Repetition	1.5
Milerad (1990)	Cross-sectional	Telephone questionnaire	Telephone questionnaire	Posture	2–2.6*
Kiken (1990)	Cross-sectional	Observation	Questionnaire and physical examination	Force and repetition; symptoms Symptoms and physical findings = Indeterminate	2.9

Baron (1991)	Cross-sectional	Job category, video analysis	Symptom and physical examination	Repetition and posture	2
Kamwendo (1991)	Cross-sectional	Questionnaire	Questionnaire	Repetition >5 hours and static posture	1.7*
Andersen (1993)	Cross-sectional	Observation	Questionnaire (interview) and physical examination	Years of employment as sewing operators; exposure response relationship	$P < 0.05$
Viikari-Juntura (1994)	Prospective cohort	Job category	Questionnaire	Whole-body vibration and static dynamic works	4.2* 3*
Hales (1994)	Cross-sectional	Observation and questionnaire	Questionnaire and physical examination	Posture (use of bifocals)	3.8*
				Psychosocial factors	2.4–3.8
Bernard (1994)	Cross-sectional	Observation, questionnaire, job analysis	Questionnaire	Psychosocial factors; posture (hours on telephone)	
Bergqvist (1995)	Cross-sectional	Questionnaire	Symptoms and physical examination	Repetition (VDT >20 hours/ week) and eye glasses	6.9*
Liss (1995)	Cross-sectional	Postal questionnaire	Postal questionnaire	Static postures	1.7*
Ohlsson (1995)	Cross-sectional	Observation and videotaping	Questionnaire and physical examination	Repetition	4.6*
Welch (1995)	Cross-sectional	Questionnaire	Questionnaire	Awkward posture (time spent hanging ductwork overhead)	7.5
Marcus (1996)	Cross-sectional	Questionnaire	Questionnaire	Psychosocial factors	2.2*
				Duration of VDT use	
				<3	4.1*
				4–6	5.6*
				>6	4.3*

OR = odds ratio; RR = relative risk; * = statistically significant ($P \leq 0.05$); VDT = video display terminal.

Table 4. EPIDEMIOLOGIC STUDIES ADDRESSING RISK FACTORS FOR SHOULDER TENDINITIS

Investigator (year)	Design	Exposure Ascertainment	Disease Ascertainment	Risk Factor	OR/RR
Ohara (1976b)	Cross-sectional	Questionnaire and observation	Questionnaire and physical examination	Repetition	1.7*
Bjelle (1979)	Case-referent	Interview and observation	Clinical evaluation	Posture (work above shoulders)	11*
Luopajarvi (1979)	Cross-sectional	Questionnaire and videotape	Clinical evaluation	Repetition and posture	3.4
Herberts (1981)	Cross-sectional	Observation and electromyelograph	Clinical evaluation	Posture (work above shoulders)	13*
Wells (1983)	Cross-sectional	Weight	Questionnaire	Load (force)	4*
Herberts (1984)	Cross-sectional	Observation	Clinical evaluation	Posture and force	9
Punnett (1985)	Cross-sectional	Observation and questionnaire	Questionnaire and physical examination	Repetition and static load	2.2
Silverstein (1986)	Cross-sectional	Interview, observation, videotape, electromyograph	Clinical evaluation	High force/high repetition	4.5
				High force/low repetition	7.3
Hagberg (1987)	Cross-sectional	Observation	Questionnaire and physical examination	Posture (work above shoulders)	11.0*
Hales/Cargill (1989a)	Cross-sectional	Observation	Questionnaire and physical examination	Symptoms	3.8
				Symptoms and physical findings	0.9
Kiken (1990)	Cross-sectional	Observation	Questionnaire and physical examination	High force/high repetition	4
				Symptoms and physical findings = indeterminate	
Burt (1990)	Cross-sectional	Observation and videotape	Questionnaire and physical examination	Lack of sufficient rest	4*
Heyer (1990)	Cross-sectional	Observation	Clinical evaluation, "shoulder symptoms"	Intensive keying	1.4
McCormack (1990)	Cross-sectional	Observation and job category	Clinical evaluation	Force and repetition	2.4
Kamwendo (1991)	Cross-sectional	Questionnaire	Questionnaire	>5 Hours/day keyboard work	1.9
Baron (1991)	Cross-sectional	Questionnaire and observation, videotaping	Questionnaire and physical examination	Repetition	3.9
Stenlund (1992)	Cross-sectional	Questionnaire and records of employment	Questionnaire and physical examination	Vibration	1.7
				Heavy lifting	3.3
Holstrom (1992)	Cross-sectional	Questionnaire	Questionnaire	Overhead	2
Hales (1994)	Cross-sectional	Questionnaire and observation	Questionnaire and physical examination	Psychosocial variables	1.4–1.9
Bernard (1994)	Cross-sectional	Questionnaire and observation	Questionnaire	Psychosocial	1.4–1.6*
				Years of employment	1.4*
Ohlsson (1995)	Cross-sectional	Questionnaire and observation, job category	Questionnaire and physical examination	Repetition and posture	3.4*
English (1995)	Cross-sectional	Questionnaire	Clinical evaluation	Posture (repeated shoulder and elevated arm)	2.3

OR = odds ratio, RR = relative risk, * = statistically significant ($P < 0.05$).

Table 5. EPIDEMIOLOGIC STUDIES ADDRESSING RISK FACTORS FOR ELBOW TENDINITIS

Investigator (year)	Design	Exposure Ascertainment	Disease Ascertainment	Risk Factor	OR/RR
Roto (1984)	Cross-sectional	Observation	Clinical evaluation	High force and posture	7
Dimberg (1987)	Case referent	Job title/classification	Physical examination	Blue- versus white-collar jobs	0.7
Kopf (1988)	Cross-sectional	Job category	Questionnaire	Repetition, force	2.7
Ohlsson (1989)	Cross-sectional	Job category	Questionnaire	Repetition	1.9
McCormack (1990)	Cross-sectional	Job category	Clinical evaluation	Repetition	1.5
Burt (1990)	Cross-sectional	Questionnaire and observational job analysis	Questionnaire	Repetition	2.8*
Kurppa (1991)	Prospective cohort	Observation	Clinical evaluation	High force	6
Viikari-Juntura (1991a)	Cross-sectional	Observation	Clinical evaluation	High force	1
Moore (1994)	Cross-sectional	Observation, video analysis	Records review	Repetition, force	5.5*
Baron (1991)	Cross-sectional	Observation and videotape	Questionnaire and physical examination	Repetition	2.3
Chiang (1993)	Cross-sectional	Observation and videotape	Physical examination	Low force/low repetition	1
				High force or high repetition	1.7
				High force and high repetiton	5.3*
Anderson (1993)	Cross-sectional	Observation and job category	Questionnaire	Repetition	1.7
Hoekstra (1994)	Cross-sectional	Observation, measurements of workstation	Questionnaire	Posture (nonoptimally adjusted chair)	4*
Olafsdottir (1995)	Prospective cohort	Production figures	Questionnaire	Repetitive movements	2.1

OR = odds ratio; RR = relative risk; * = statistically significant ($P = 0.05$).

Table 6. EPIDEMIOLOGIC STUDIES ADDRESSING RISK FACTORS FOR HAND-WRIST TENDINITIS

Investigator (year)	Design	Exposure Ascertainment	Disease Ascertainment	Risk Factor		OR/RR
Kuorinka (1979)	Cross-sectional	Job analysis	Clinical evaluation	Repetition and posture		1
Luopajarvi (1979)	Cross-sectional	Questionnaire and videotape	Clinical evaluation	Repetition and posture		8*
Silverstein (1986)	Cross-sectional	Observation; video analysis; electromyography of shoulder	Interview and physical examination	Low force/low repetition		1
				High force/low repetition		6.3
				Low force/high repetition		3
				High force/high repetition		31.7
Armstrong (1987)	Cross-sectional	Electromyelograph and videotape	Questionnaire and physical examination	Low force/low repetition		1
				High force/low repetition		2
				Low force/high repetition		2
				High force/high repetition		29*
Hales (1989b)	Cross-sectional	Observation	Questionnaire and physical examination	High force and repetition; symptoms		2.4
				Symptoms and physical findings		7.5*
McCormack (1990)	Cross-sectional	Job category	Clinical evaluation	Repetition		4*
Kiken (1990)	Cross-sectional	Observation	Questionnaire and physical examination	Repetition and force; symptoms		4.4*
				Symptoms and physical findings		3
Baron (1991)	Cross-sectional	Questionnaire and observation	Questionnaire and physical examination	Repetition *OR*		1.6
				Years of grocery employment		
				0–5		
				5–10		
				10+		
Burt (1990)	Cross-sectional	Questionnaire and observation	Questionnaire	Typing speed		
				Slow		0.9
				Moderate		1.3
				Fast		2.5
				Being a reporter		2.4*
Punnett (1990)	Cross-sectional	Questionnaire and observation	Questionnaire	Posture	Men	2.2*
					Women	0.9
				Force repetition		
Kurppa (1991)	Cohort	Observation	Clinical evaluation	Force (typing)		24*
Bernard (1994)	Cross-sectional	Questionnaire and observation	Questionnaire and physical examination	20–40%		0.6
				40–60%		1.5
				60–80%		7.6
				80–100%		2.3
Hales (1994)	Cross-sectional	Questionnaire and observation	Questionnaire and physical examination	Psychosocial factors		2
				Job title		0.1–1.9
Hoekstra (1994)	Cross-sectional	Presence of equipment; questionnaire and observation	Questionnaire	Nonadjustable equipment versus superior ergonomic office equipment		2.2
Moore (1994)	Retrospective cohort	Observation	OSHA illness and injury logs and medical records	Force/little recovery		6.9
English (1995)	Cross-sectional	Questionnaire	Clinical evaluation	Repetitive pinching		4
				Posture		1.4–30
				Repetitive grip		3

OR = odds ratio; RR = relative risk; * = statistically significant ($P \le 0.05$).

Table 7. EPIDEMIOLOGIC STUDIES ADDRESSING RISK FACTORS FOR CARPAL TUNNEL SYNDROME

Investigator (year)	Design	Exposure Ascertainment	Disease Ascertainment	Risk Factor	OR/RR
Armstrong (1979)	Case control	Observation, video analysis, electromyelograph	Medical record assessment	Pinch grip	2*
				Hand force	1.1*
Cannon (1981)	Case referent	Job category	Clinical assessment	Vibration	7*
				Repetition	2.1*
Punnett (1985)	Cross-sectional	Questionnaire and videotape	Questionnaire and physical examination	Repetition	3*
Silverstein (1987)	Cross-sectional	Electromyelograph and videotape	Questionnaire and physical examination	Low force/low repetition	1
				High force/low repetition	1.8
				Low force/high repetition	1.9
				High force/high repetition	15.5*
Nathan (1988)	Cross-sectional	Observation	Nerve conduction	Low repetition/very light	1
				Resist	1
				Very heavy repetition/light resistance	1.6*
				Moderate repetition/heavy resistance	
				Moderate high repetition/moderate resistance	2.3
				High repetition/very heavy resistance	4*
Wieslander (1989)	Case referent	Questionnaire	Clinical assessment and nerve conduction	Vibration	6.1*
				Repetition	4.5*
				Force	2.7*
				Obesity	3.4*
deKrom (1990)	Case referent	Questionnaire	Clinical assessment and nerve conduction	Flexed wrist (hours)	
				1–7	1.5
				8–19	3
				20–40	8.7
				Extended wrist (hours)	
				1–7	1.4
				8–19	2.3
				20–40	5.4
Chiang (1990)	Cross-sectional	Observation	Clinical assessment and nerve conduction	Low repetition/not cold	1.0
				High repetition/not cold	2.2
				High repetition/very cold	9.4*
Barnhart (1991)	Cross-sectional	Observation	Physical examination and nerve conduction	Repetition/pinch	1.9*
Schottland (1991)	Cross-sectional	Current versus pre-employment	Nerve conduction	Repetition in women	2.86*

Table continued on following page

Table 7. EPIDEMIOLOGIC STUDIES ADDRESSING RISK FACTORS FOR CARPAL TUNNEL SYNDROME *(Continued)*

Investigator (year)	Design	Exposure Ascertainment	Disease Ascertainment	Risk Factor	OR/RR
Baron (1991)	Cross-sectional	Job category, observation, and videotaping	Clinical assessment	Repetition	3.7
Bovenzi (1991)	Case referent	Observation, vibration measurements	Clinical assessment	Vibration	21.3*
Morgenstern (1991)	Cross-sectional	Survey	Symptoms	Repetition/posture	1.9*
				(hours worked/week)	34
Nathan (1992)	Prospective cohort	Observation	Nerve conduction	Body mass index	0.6%*
				Age	3.3%*
				Wrist dimension	2.1%*
				Hand dominance	1.0%*
				Exercise level	0.6%*
				Weight	0.4%*
Chiang (1993)	Cross-sectional	Observation	Questionnaire and physical examination and nerve conduction	Low force/low repetition	1
				Men	
				High force or high repetition	2.2
				High force and high repetition = indeterminate	
				Women	
				High force or high repetition	1.3
				High force and high repetition	2.6*
Stetson (1993)	Cross-sectional	Observation and video analysis	Questionnaire and physical examination and nerve conduction	Industrial workers with smaller amplitudes and longer latencies than asymptomatic controls	
Bovenzi (1994)	Cross-sectional	Interview, vibration measurement	Clinical assessment	Vibration	3.4*
Nilsson (1994)	Cross-sectional	Observation and vibration measurements	Clinical assessment and nerve conduction	Force/vibration	2.0
Moore & Garg (1994)	Retrospective cohort	Observation and vibration measurements	OSHA illness and injury logs and medical records	"Hazardous jobs" based on repetition, force, posture	2.8
Osorio (1994)	Cross-sectional	Job category and observation	Clinical assessment and nerve conduction	Repetitive forceful wrist motions	8.3*
English (1995)	Case control	Self-reported exposure to accepted risk factors. No actual measurements or observations	Based on agreed criteria for clinical assessment by orthopedic surgeons	Awkward shoulder and arm posture	1.8*
Tanaka (1995)	Retrospective cohort	Telephone interview	Self-reported by examination by a MD	Repetitive bending/twisting	5.2
				Vibrating tools	1.8

OR = odds ratio; RR = relative risk; * = statistically significant at ($P \leq 0.05$).

Table 8. EPIDEMIOLOGIC STUDIES ADDRESSING RISK FACTORS FOR HAND–ARM VIBRATION SYNDROME

Investigator (year)	Design	Exposure Ascertainment	Disease Ascertainment	Risk Factor	OR/RR
Letz (1992)	Cross-sectional	Vibration measurements	Questionnaire	Part-time vibration exposure	8.23*
				Full-time vibration exposure	40.6*
Miyashita (1992)	Cross-sectional	Job category	Questionnaire	Vibration	0.49
McKenna (1993)	Cross-sectional	Questionnaire	Cold provocation testing	Vibration	24
Nagata (1993)	Cross-sectional	Questionnaire	Dermatologic tests and physical examination	Vibration exposure >20 years	7.1*
Bovenzi (1994)	Cross-sectional	Interview; vibration movements in tool sample	Physician-administered interview	Vibration	9.33*
Kivekas (1994)	Prospective cohort	Questionnaire	Clinical assessment, radiographs	Vibration	3.4*
				Cumulative incidence HAVS	4.4*
Mirbod (1994)	Cross-sectional	Questionnaire, interview, sample vibration measurements	Questionnaire; interview field visits or annual health examinations	Vibration	3.77*
Virokannas (1995)	Cross-sectional	Interview	Vibration perception threshold testing and electroneuromyography	Vibration	1.5

OR = odds ratio; RR = relative risk; * = statistically significant ($P \leq 0.05$); HAVS = hand–arm vibration syndrome.

Table 9. OCCUPATIONAL FACTORS ASSOCIATED WITH LOW BACK PAIN

Factor	All or Unspecified Low Back Pain	Radiographic Herniated Intervertebral Disc	Lumbar Degeneration
Frequent lifting over 25 pounds	1.5–3	1	1.8
Non-neutral postures (twisting, flexion, lateral bending)	1.4–5.9	1	
Frequent lifting in non-neutral postures		2.5–6.1	
Static postures, especially prolonged sitting	1.6	1.6	
Whole-body vibration	1.8	2.4†	
Motor-vehicle driving	2.8	2.8‡	
Truck driving	1.7–4.7	4.7‡	

*Risk ratios published or calculable from published data.
†Age over 35.
‡Men only.
From Castorina J, Deyo RA: Back and lower extremity disorders. *In* Rosenstorck L, Cullen M (eds): Textbook of Clinical Occupational and Environmental Medicine. Philadelphia, WB Saunders, 1994, p 365.

ered as a surrogate for time spent in static postures with arms unsupported. Rossignol et al[182] (1987) found, among 1545 clerical workers, that the prevalence of neck symptoms increased with the number of hours per day using VDTs. These studies showing a dose–response effect provide strong evidence for a causal association between work exposure and neck disorders.

The large number of studies listed in Table 3 illustrate the consistent association between neck disorders and physical risk factors. Overall, the physical factors of repetition, forceful exertions, and constrained or static postures, usually found in combination, have been shown to be risk factors associated with the development of neck MSDs across numerous occupations exposed to these factors.

Shoulder Musculoskeletal Disorders

Consistently high ORs for shoulder tendinitis have been found for exposed worker populations compared with unexposed occupationally based referent groups (see Table 4). Hagberg and Wegman,[74] (1987) in their review article, attributed a majority of shoulder problems occurring in a variety of occupations to workplace exposure. Risk factors most strongly associated with shoulder tendinitis include working at or above shoulder height, heavy lifting and carrying loads supported by the shoulder, static postures, and hand–arm vibration. Strong associations (ORs = 10–13) were found in four studies.[31, 56, 67, 166] Strong associations (OR = 2.3–7.3) between repetitive movements and the development of shoulder MSDs were found in 10 studies, although not all were statistically significant.[16, 59, 79, 111, 133, 143, 167, 169, 197] Studies of heavy lifting and repeated loading of the shoulder, such as those with letter carriers and construction workers reported ORs ranging from 2.2 to 10.[203, 236] Shoulder disorders assessed by clinical examination in worker populations with similar exposures ranged from 1% in sign language interpreters for the deaf[212] to 31% in workers employed as sewing machine operators.[5] Prevalences of other shoulder conditions ranged from 8% among female electronic assemblers doing overhead work[113] to 48% for muscle tenderness in female farmers bagging peas.[191]

Several studies have found associations that can be interpreted as exposure–response effects for shoulder MSDs using duration of employment in a job as a surrogate for exposure. Duration of employment as an assembler, telephone operator, newspaper worker using VDTs, or rockblasters has been associated with an increasing prevalence of shoulder disorders.[23, 96, 113, 182, 203] Wells et al[236] (1983) found that the prevalence of shoulder pain in male letter carriers, adjusted for age, number of years on the job, height/weight ratio, and prior work experience, clearly demonstrated an exposure–response effect of direct weight bearing. Westgaard,[239] (1985) in his study of three groups of workers with different work loads on the shoulder muscles, showed that the risk of developing MSDs increased according to the level of static load on the trapezius muscles. In a study of grocery store checkers, Baron et al[16] (1991) demonstrated a clear relationship between 25 or more hours of checking per week and prevalence of shoulder MSDs. Rossignol et al[182] (1987) found among 1545 clerical workers that the risk of shoulder MSDs doubled after 7 hours per day of VDT use (time spent typing was used as a surrogate for time spent in static postures with arms unsupported). Associations with employment are not often uniform, however, even among studies of seemingly similar study populations. Prevalences of shoulder disorders in Danish sewing machine operators studied by Andersen and Gaardboe[5] (1993) were related to duration of employment, but that relationship was not observed among US garment workers.[176]

Most telling may be the 2-year prospective cohort study (the "best" type of epidemiologic study) by Kilbom and Persson,[112] (1987) in which there was a significant increase (from 8 to 21%) of shoulder tendinitis at the 2-year follow-up among 68 female assembly workers. The strong predictors for workers developing severe disorders of the neck and shoulder at the 2-year follow-up included the rate of shoulder elevations and neck flexions per hour, and duration of neck flexion, shoulder extension, and fixed arm posture (0–30 degrees shoulder abduction). Thirty-eight workers who had been reallocated to more varied work tasks had improved (16% initially had severe symptoms), whereas those with unchanging working tasks deteriorated further (26%).

Elbow

Relatively few studies have addressed the occurrence of risk factors associated with work-related epicondylitis (see Table 5). This may be because of its long acceptance in the surgical and sports medicine literature as work-related in occupations and sports requiring overexertion of the finger and wrist extensors while the elbow is in extension.[161, 162] Several occupational studies reviewed show a significant association,[40, 46, 47, 117, 121, 150, 176] with ORs greater than 2.5. Others studies have shown associations but are not statistically significant (OR > 1)[5, 16, 133, 143, 185]; two studies found no association.[56, 225] The one prospective study[121] found a strong relationship between strenuous work (based on repetition, forceful exertion, and awkward postures) and epicondylitis (OR = 6.4). This study also found the annual incidence of epicondylitis in nonstrenuous jobs to be similar to that found by Allander[3] (1974) in the general population (1%). In another recent prospective cohort study of elbow MSDs, Olafsdóttir and Rafnsson[168] found the prevalence of epicondylar symptoms increased among women in fish-fillet assembly-line work after the institution of a new automated flow-line system that increased the number of repetitive movements.

Several studies have found that a number of specific risk factors, usually identified by observation in high-risk jobs, are associated with elbow MSDs: Punnett's[176] (1985) study of garment workers; Moore and Garg's[150] (1991) study of pork processors; Kopf's[117] (1988) studies of construction workers; Hales'[79] (1989) study of meatprocessors; and Baron's[16] (1991) study of grocery checkers. In other studies, however, there was no significant difference in prevalence between groups observed to have higher exposure and groups thought to have lower exposure: In Viikari-Juntura's[225] (1991) study, meat processors had no higher prevalence of epicondylitis than office workers and maintenance men; Dimberg's[56] (1987) meat packers had a prevalence similar to construction foremen, and Luopajarvi's[133] (1979) assembly-line packers and shop assistants showed no substantial difference. Chiang[47] (1993) showed an apparent association between epicondylitis and increasing force and repetition but, in the multivariate analysis, this finding was not statistically significant.

Studies of professional athletes have reported that changes in postures (e.g., less shoulder abduction, hitting the ball during wrist extension) or a decreased applied force when playing (e.g., tennis) result in decreased symptom severity among affected individuals.[105, 174, 175]

In view of these criteria, overall, the evidence for workrelatedness of epicondylitis has not clearly shown consistency across all occupations studied, but the two cohort studies, which provide stronger evidence than cross-sectional studies, and the sports literature, suggest a relationship.

Hand–Wrist Tendinitis and Carpal Tunnel Syndrome

In recent years, the literature relating occupational factors to the development of hand–wrist tendinitis, CTS, and hand–arm vibration syndrome has been extensively reviewed by numerous authors.[9, 70, 75, 76, 151, 206, 224] Overall, almost all of these reviews reached a similar conclusion—that work factors were one of the important causes of hand–wrist tendinitis (see Table 6) and CTS (see Table 7). One review by Moore[157] (1992) found the evidence equivocal. He stated, however, that the epidemiologic studies revealed a fairly consistent pattern of observations regarding the spectrum and relative frequency of CTS (among other MSDs) among jobs believed to be hazardous.

The strength of the association between work place factors and CTS varies greatly among studies. Of the 22 studies listed in Table 7, 16 report statistically significant ORs, ranging in magnitude from 1.7 to 34, for exposure to various job-related factors. The degree of association reported by different investigators appears influenced by three factors: (1) the precision of diagnostic criteria used for the health outcome, (2) the degree of sophistication of exposure measures, and (3) the specific work factors examined in the study. In two of 22 studies listed in Table 10, CTS was assessed based on symptoms alone; in another six, the case definition was based on a combination of symptoms and physical findings. Electrophysiologic tests of nerve function were used in 11 studies. In two studies, CTS cases were identified from records only, so the diagnostic criteria may have differed substantially among cases. In general, the stronger associations were found in studies with more precisely defined and more severe cases (in terms of intensity, duration, and frequency of symptoms), and in which exposures were assessed in greater detail and more objectively.

One explanation for the variability in the degree of association among the reviewed studies is the differences in the exposure variables examined. Although the causes of CTS and tendinitis are believed to be multifactorial, it is highly probable that some workplace factors are more directly related to these outcomes than others. Despite this variability in the strength of the association, there is consistent evidence to support the association of repetitive hand motions,[46, 120, 157, 197, 198, 234] forceful manual exertions,[8, 197, 198, 234] and hand–arm vibration[34, 35, 42, 234] with CTS or hand–wrist tendinitis.

Activities in non-neutral wrist postures were associated with CTS in studies by Armstrong and Chaffin[8] (1979), deKrom et al,[54] (1990) and Barnhart et al,[15] (1991) but they were not associated with hand–wrist tendinitis in the study by Kuorinka and Koskinen[120] (1979). Repetitive work that involved high force and precision of the hands resulted in higher static loading of the arms in a study by Milerad and Ekenwall[145] (1990). Although there was a strong relationship between cold temperatures and an increased risk of CTS in the study by Chiang et al,[46] (1990) the authors indicated that workers who were most exposed to low temperatures also exerted more force with their hands, a factor that was not considered in the analysis. Among risk factors for which evidence of a relationship is strongest, repetitive work appears to be more strongly related to hand–wrist musculoskeletal disorders than other factors[46, 197, 198]

There is evidence that the presence of two or more risk factors can have highly synergistic effects—i.e., workers who perform repetitive and forceful activities have far higher rates of hand–wrist disorders than workers who perform either repetitive or forceful activities alone.[46, 157, 197, 198] The combined effects of exertional force and other risk factors were found to be multiplicative for hand–wrist tendinitis and CTS in several studies. Silverstein et al[197, 198] (1986, 1987) found a fivefold increased risk of CTS for highly repetitive jobs compared with low-repetition jobs. When high force was combined with high repetition, the OR for CTS increased to 15, whereas the odds of hand–wrist tendinitis increased 29-fold compared with low force, low repetition.[10] In a study of meat packers, Moore and Garg[152] (1994) found force (defined as estimated percent maximum voluntary contraction) combined with duration of recovery time within a cycle to be significantly associated with distal upper-extremity disorders, which were primarily tendon-related (OR = 6.9–39.4).

Morgenstern et al[153] (1991) and Baron et al[16] (1991) demonstrated that the risk of CTS increased with increasing hours at work among grocery cashiers, and DeKrom et al[54] (1990) reported an increased risk of CTS with increasing weekly exposure to wrist flexion. The Silverstein[197] (1986) study also suggests an exposure–response relationship, in that workers in high-force, high-repetition jobs had a higher prevalence of CTS and wrist tendinitis than those in low-force, high-repetition jobs. These workers, in turn, had a higher prevalence of disease than those in low-force, low-repetition jobs (see Table 7). Similar findings, correlating CTS with increasingly forceful and repetitive work, were reported by Stock[206] (1991) and Hales[78] (1991) in their reanalysis of the Nathan et al[157] (1988) data. At the present time, however, there is insufficient evidence to describe precisely the shape of the exposure–effect relationship or to determine the relative contribution of several simultaneous exposures.

Hand–Arm Vibration Syndrome

The hazardous effects of occupational exposure to hand–arm vibration have been discussed in literally hundreds of studies dating to the work of Loriga in 1911. In general, studies support a strong association between exposure to hand–arm vibration and vascular symptoms of hand–arm vibration syndrome (HAVS). Compared with one estimate that placed the prevalence of Raynaud's phenomenon at 4.6% (females) and 2.5% (males) in the general population, only 7 of 17 studies conducted between 1987 and 1994 found prevalence rates less than 20% among workers exposed to hand–arm vibration. Of the seven studies, four examined forestry workers in Japan and Finland, where significant improvements in working conditions were implemented in the 1970s. In the remaining three studies, hand–arm vibration exposure was not actually measured and there is reason to suspect that the study population was not heavily exposed. Likewise, according to the 1989 National Institute for Occupational Safety and Health review, only 9 of 52 cross-sectional studies reported a prevalence rate less than 20% among workers exposed to hand–arm vibration.[159] In studies in which exposed workers were compared with a control group, ORs greater than 5 were frequently reported.[159]

Table 11 lists studies conducted since 1992, including one prospective cohort study among Finnish lumberjacks.[115] In that study, Kivekäs et al[115] (1994) found a HAVS cumulative incidence of 14.7% among the lumberjacks over a 7-year period compared with a cumulative incidence of only 2.3% among referents.[115] The cumulative incidence rate of lumberjacks who had more than 25 years' exposure at the end of the follow-up period was 30.6%. Other studies of Finnish forest workers also show marked decreases in HAVS prevalence following the introduction of improved chain saws with reduced-vibration designs.[118, 177]

Two studies provide evidence for a dose–response relationship between vibration and HAVS prevalence,[15] and vibration and symptom severity.[156] Bovenzi's[15] (1988) study of stone cutters using rock drills and chisel hammers reported that HAVS prevalence increased almost linearly with the total number of working hours, from about 18% for persons with 6000 hours of exposure, to more than 50% among persons with more than 26,000 hours of exposure. Mirbod's[146] study (1992) of 447 chain-saw workers reported that the prevalence of HAVS increased from 2.5% among workers with fewer than 14 years of exposure, to 11.7% among workers with 20 to 24 years exposure, and to 20.9% among workers exposed 30 years or more. Thus, both studies found a statistically significant dose–response relationship between symptom severity (graded according to the Taylor-Pelmear scale) with vibration exposure over time.

Overall, there is substantial evidence linking the intensity and duration of exposure to vibrating tools and the risk of developing HAVS. As the intensity and duration of exposure are increased, the onset of HAVS is hastened, although the precise shape of the dose–response relationship is unknown.

Low Back Disorders

Heavy Manual Labor

Several reviews of LBP in workers support the association of heavy manual labor and LBP.[96, 98, 108, 201] In addition, workers' compensation data show that workers with heavy manual jobs are more likely to develop compensable back injuries.[21, 97, 98, 211] An increased load on the already afflicted back produces more pain, and LPB will probably interfere with work requiring heavy manual labor.[65] Workers with LBP in heavy physical jobs therefore are less likely to be able to perform their job duties than workers with LBP in less physically demanding jobs. Among the specific motions associated with heavy physical activity, lifting, twisting, and bending have been studied the most.

Acute LBP can be triggered by a single lift. The risk of acute LBP increases with increasing weight of the object and unexpected maximal effort.[96, 115] The relationship between repetitive lifting and LBP is less clear, but most studies and reviews support the association.[43, 68, 108, 109, 173, 201] Increasing object weight increases the risk, with 25 lb reported as the "threshold."[7, 110] Reviewing the literature, Castorina[41] summarized the strength of this association across studies, reporting RR from 1.5 to 3. Other factors encountered during manual material handling such as distance the object is held away from the body (horizontal distance), distance to raise or lower the object (vertical distance), and twisting, by themselves, are associated with LBP. Castorina[41] reports RR ranging from 1.4 to 5.9 for these factors (see Table 9). The occurrence of all these factors together (lifting, heavy objects, bending, twisting, and high frequency) markedly increases the risk of LBP. Assigning a relative value for each of these factors is the basis for the National Institute for Occupational Safety and Health revised lifting equation.[231] Pending validation in field studies, this equation provides recommended weight limits to prevent or reduce the occurrence of lifting-related LBP among workers.

Prolonged Sitting and Standing

Several investigations have shown that jobs that involve nearly all standing or nearly all sitting postures increase an individual's risk of LBP compared with jobs with frequent changes in posture. Some studies report reduced postural fatigue and less sick days when changes in posture are required during work[136] (see Table 9).

Vibration and Driving

Driving motor vehicles is clearly associated with low back disorders (see Table 9). Whether this is caused by the prolonged sitting or the whole-body vibrations experienced while driving is not completely clear.

PSYCHOSOCIAL FACTORS

For most clinicians, the term *psychosocial factors* is ill defined and difficult to grasp. As a result, considerable confusion and misunderstanding exist regarding the contribution of psychosocial factors or stressors to MSD. Work-place psychosocial factors can be placed into three broad categories: (1) job or task demands, (2) organizational structure, and (3) physical work environment (Table 10). In addition, individual characteristics (such as personality traits, coping ability, attitude toward one's own health) and factors outside of work can be independent contributors, moderators, or buffers:

- Individual
  - Personality traits
  - Psychological dysfunction (depression)
  - Coping ability
  - Job dissatisfaction
  - Attitude toward life
  - Attitude toward one's own health
  - Overall poor health
  - Lower socioeconomic status
  - Lower intelligence
- Nonwork
  - Marital problems
  - Living alone
  - Financial problems
  - Coping ability
  - Child-rearing problems
  - Interpersonal conflicts

These latter factors may influence the reason individuals perceive or react differently to the same workplace situation. Hurrell et al[95] (1992) developed an excellent model to describe the complexity by which these factors can interact (Fig. 2).

Three mechanisms have been suggest to account for associations between psychosocial factors and musculoskeletal disorders.[34, 52, 192, 220] First, psychosocial demands may overwhelm the individual's coping mechanism and produce a stress response. This stress response may increase muscle tension or static loading of muscles.[229, 240] Second, psychosocial demands may affect MSD awareness and reporting, or increase its attribution to the work environment. Finally, in some work situations, psychosocial demands may be highly correlated with increased physical demands. Any association between psychosocial factors and MSD therefore may actually reflect the association between physical factors and MSD, not the association between psychosocial factors and MSD.

Upper Extremities

Workplace Factors

The majority of cross-sectional studies support the association of job or task demands and work-place psychosocial factors and upper-extremity MSD. Factors that have the most consistent association include high work loads, perceived time pressure, work pressure, high work-load variability, poor work

Table 10. EXAMPLES OF WORKPLACE PSYCHOSOCIAL FACTORS AND STRESSORS

Job–Task Demands*	Organizational*	Physical
Heavy workload	Job insecurity	Too hot or cold
High workload variability	Lack of participation in decision making	Noisy
Increasing work pressure	Poor communication	Noxious odors
Unrealistic deadlines	No opportunity for career advancement	Poor ventilation
Unrealistic production standards	Inadequate compensation	Poor lighting
No control over amount and quality of work	Performance evaluation done poorly	Crowding
No control over job-related matters	Computer monitoring	Isolation
Lack of autonomy	Long hours or required overtime	
Lack of meaningful work	Shiftwork	
Underutilization of skills	Little interaction with coworkers	
Ambiguous job expections	Lack of social support from supervisors or coworkers	
Monotonous tasks	Poor labor–management relationship	
Inadequate resources to accomplish job	Low priority for health and well-being	
Customer hostility	Racial or gender discrimination	
No opportunity for learning	Sexual harassment	
	No spirit of partnership or teamwork	

*Factors within these categories overlap

content, and monotonous work. Most of these studies based their case definitions of MSD on self-reports of neck and shoulder symptoms.* Several studies used physical examination in addition to symptoms as an "objective" measure of a MSD,[77, 91, 138, 164, 213, 219] whereas others used visits to a medical service[238] or sick leave[122] as outcome measures. Because they measure both risk factors and health simultaneously, cross-sectional study designs cannot distinguish cause from effect, for example: Do concerns about job security result in a stress response such as increased muscle tension which can then lead to a MSD, or does having a MSD create a heightened concern that one's job may be in jeopardy because of fear of being laid off because of the MSD? Longitudinal studies, which can determine the temporal relationship between exposure factors and disease, have supported the association of work-place psychosocial factors or stressors

*References 24, 40, 52, 58, 62, 91, 122, 129, 130, 139, 188, 217, 218, and 238

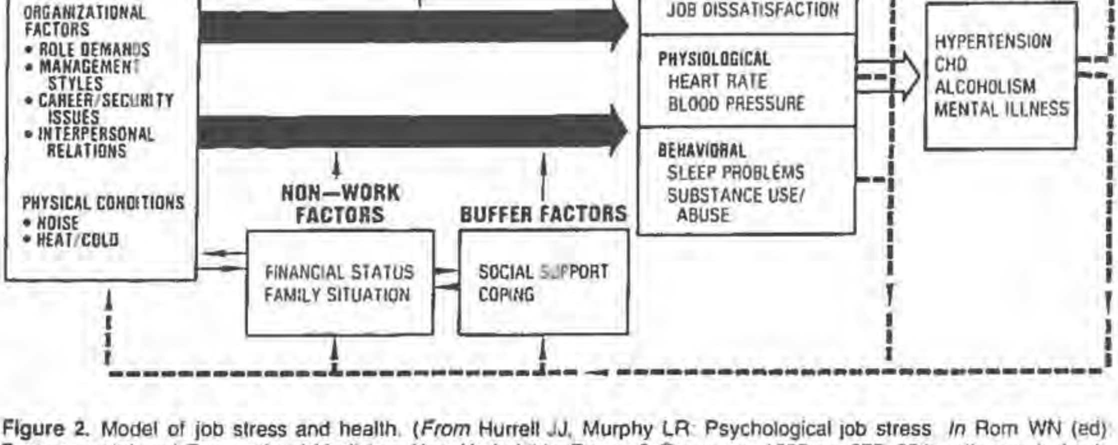

Figure 2. Model of job stress and health. (*From* Hurrell JJ, Murphy LR: Psychological job stress. *In* Rom WN (ed): Environmental and Occupational Medicine. New York, Little, Brown & Company, 1992, pp 675–684, with permission.)

(see Table 10) and upper extremity MSDs defined by both symptoms and symptoms plus physical examination.[30, 77, 213, 221, 227]

Individual and Nonwork Factors

For the few studies investigating the contribution of individual psychological factors and upper-extremity MSD, the results are mixed. Type A behavior[62, 77] and affective disorders (depression and anxiety)[85, 127, 138, 184] have been associated with neck and shoulder disorders. Other investigators did not find a relationship.[218, 221]

Low Back Disorders

Work-place Factors

Many cross-sectional studies support the relationship between work-place psychosocial stressors and LBP and low back disorders.[52, 84, 91, 93, 129, 130, 132, 137, 209, 210, 211] After controlling for potentially confounding physical factors, two studies maintained the positive association.[84, 210] The most consistently reported stressors include monotonous work, poor social relations at work, increasing work pressure, and lack of job control. On the other hand, two cross-sectional studies did not find positive associations.[13, 199]

Only two longitudinal studies have addressed the relationship between work-place psychosocial stressors and low back disorders.[14, 29] Åstrands[14] (1988) found no association, whereas Bigos[27] reported an association between poor social relationships at work and reports of LBP to the medical department or filed workers' compensation claims (WCC). Bigos[27] also reported job dissatisfaction as a significant predictor of future WCC for LBP (OR = 1.7).[27] Most researchers consider job dissatisfaction as a "stress response" to work place and individual psychosocial stressors rather than as a stressor itself (see Fig. 2). Unfortunately, Bigos[27] did not investigate any of the potentially precipitating job or task demand stressors listed in Table 10. Other studies have examined the relationship between job dissatisfaction and MSD while controlling for these and other potential confounders. One cross-sectional study[211] and one longitudinal study[27] found a positive association; three cross-sectional studies[61, 129, 210] and two longitudinal studies[14, 25] found no association. Studies examining the relationship between job dissatisfaction and back MSD therefore are not consistent.

Individual and Nonwork Factors

As with upper extremity disorders, a host of psychosocial factors associated with the individual worker (e.g., personality traits and emotional problems) and the nonwork environment (e.g., living alone) have been linked to back pain and disability in both cross-sectional and longitudinal studies. Bongers[32, 33] summarized this data in two excellent reviews. These studies show clear associations between psychological distress or dysfunctioning and self-reported back pain. Few studies have investigated the association with low socioeconomic status while controlling for workplace physical factors (e.g., high force, high repetition, etc.)

In summary, the psychosocial factors (work place, individual, and nonwork) most consistently associated with upper extremity and low back MSD are intensified work load, monotonous work, limited job control, and little social support. These same factors have been identified in some longitudinal studies that have accounted for physical demands, so their contribution to MSD should be relatively independent of physical load. These associations are not limited to office work involving the use of VDTs, but are found in a variety of work situations. The mechanism by which these factors or stressors exert their contribution remains to be elucidated. Most clinicians accept that psychosocial factors probably influence the reporting of, and recovery from, work-related MSDs. Longitudinal studies mentioned in this article suggest they also play a role in the development of upper-extremity and low back disorders. This latter statement, that psychosocial factors can contribute to the development of a MSD, is less well accepted. Despite numerous studies documenting the association between psychological stress and other physical disorders such as hypertension,[141, 194, 195, 215] coronary artery and other cardiovascular disease,[4, 99, 101, 104, 173, 186, 187, 193] and immune function and infections,[48, 71] many clinicians remain skeptical about the association between psychosocial factors and the development of MSD. Perhaps this skepticism persists because of the lack of a well-accepted mechanism by which the psychological stress could lead to a MSD.

CONCLUSION

The human and financial costs of work-related MSD in the United States is staggering. This article outlines the financial costs and provides evidence that a variety of workplace risk factors (physical and psychosocial) contribute to their development. Reducing work-place risk factors encountered by the affected employee during his or her job task is an important component of any treatment plan. The clinician can play a critical role in emphasizing this responsibility to the employer. This both allows affected employees to remain at work and be productive members of the work force and should prevent the development of similar disorders in other workers.

ACKNOWLEDGMENT

We gratefully acknowledge Mitch Singal and Joe Hurrell for their timely reviews and helpful comments, and Kathy Mitchell for her tireless efforts preparing the document.

References

1. Aaras A: The impact of ergonomic intervention on individual health and corporate prosperity in a telecommunications environment. Ergonomics 37:1679–1696, 1994
2. Abenhaim L, Suissa S: Economic scope of occupationally-induced back pain. Research Summary No. 66. Quebec, Canada, Institute de recherche en sante et en securite du travail du Quebec, 1988
3. Allander E: Prevalence, incidence, and remission rates of some common rheumatic diseases or syndromes. Scand J Rheum 3:145–153, 1974
4. Alterman T, Shekells RB, Vernon SW, et al: Decision latitude, psychologic demand, job strain and coronary heart disease in the Western Electric study. Am J Epidemiol 139:620–627, 1994
5. Andersen JH, Gaardboe O: Musculoskeletal disorders of the neck and upper limb among sewing machine operators: A clinical investigation. Am J Indust Med 24:689–700, 1993
6. Anderson JAD: Epidemiologic aspects of back pain. J Soc Occup Med 36:90–94, 1986
7. Andersson GBJ: Epidemiologic aspects of low back pain in industry. Spine 6:53, 1981
8. Armstrong TJ, Chaffin DB: Carpal tunnel syndrome and selected personal attributes. J Occup Med 21:481–496, 1979
9. Armstrong TJ, Buckle P, Fine LJ, et al: A conceptual model for work-related neck and upper-limb musculoskeletal disorders. Scand J Work Environ Health 19:73–84, 1993
10. Armstrong TJ, Fine LJ, Goldstein SA, et al: Ergonomic considerations in hand and wrist tendinitis. J Hand Surg 12A:830–837, 1987
11. Aro S, Leino P: Overweight and musculoskeletal morbidity: A 10-year follow-up. Int J Obesity 9:267–275, 1985
12. Asbury FD, et al: Repetitive strain injuries and gender in Ontario, 1986–1991. J Occup Environ Med 37:479–485, 1995
13. Åstrand NE: Medical, psychological, and social factors associated with back abnormalities and self-reported back pain: A cross-sectional study of male employees in a Swedish pulp and paper industry. Br J Indust Med 44:327–336, 1987
14. Åstrand NE, Isacsson S-O: Back pain, back abnormalities, and competing medical, psychological, and social factors as predictors of sick leave, early retirement, labour turnover, and mortality: A 22-year follow-up of male employees in a Swedish pulp and paper company. Br J Indust Med 45:387–395, 1988
15. Barnhart S, Demers PA, Miller M, et al: Carpal tunnel syndrome among ski manufacturing workers. Scand J Work Environ Health 17:46–52, 1991
16. Baron S, Milliron M, Habes D, et al: Shoprite Supermarkets, NIOSH HETA Report 88-344-2092. Cincinnati, National Institute for Occupational Safety and Health, 1991
17. Battié MC, Bigos SJ, Fisher LD, et al: A prospective study of the role of cardiovascular risk factors and fitness in industrial back pain complaints. Spine 14:141–147, 1989
18. Battié MC, Bigos SJ, Fisher LD, et al: Isometric lifting strength as a predictor of industrial back pain. Spine 14:851–856, 1989
19. Berg M, Sanden A, Torell G, et al: Persistence of musculoskeletal symptoms: A longitudinal study. Ergonomics 31:1281–1285, 1988
20. Bergenuud H, Nilsson B: Back pain in middle age: Occupational workload and psychologic factors: An epidemiologic survey. Spine 13:58–60, 1988
21. Bergqvist-Ullman M, Larson N: Acute low back pain in industry. Acta Orthop Scand 170(suppl):1–117, 1977
22. Bergqvist-Ullman M, Wolgast E, Nilsson B, et al: The influence of VDT work on musculoskeletal disorders. Ergonomics 38:754–762, 1995
23. Bernard B, Sauter S, Petersen M, et al: Job task and psychosocial risk factors for work-related musculoskeletal disorders among newspaper employees. Scand J Work Environ Health 20:417–426, 1994
24. Bernard B, Sauter S, Fine LJ: Los Angeles Times, NIOSH HETA Report 90-013-2277. Cincinnati, National Institute for Occupational Safety and Health, 1993
25. Biering-Sorenson F, Thomsen CE, Hilden J: Risk indicators for low back trouble. Scand J Rehabil Med 21:151–157, 1989
26. Biering-Sorenson F: A prospective study of low-back pain in a general population: I. Occurrence, recurrence, and aetilogy. Scand J Rehabil Med 15:71, 1983
27. Bigos SJ, Battié MC, Spengler DM, et al: A prospective study of work perceptions and psychosocial factors affecting the report of back injury. Spine 16:1–6, 1991
28. Bigos S, Bowyer O, Braen G, et al: Acute Low Back Problems in Adults: Clinical Practice Guideline, Quick Reference Guide Number 14 [AHCPR publication no. 95-0643]. Rockville, MD, US Department of Health and Human Services, Public Health Service, Agency for Health Care Policy and Research, 1994
29. Bigos SJ, Spengler DM, Martin NA, et al: Back

injuries in industry: A retrospective study. II. Injury factors. Spine 11:246–251, 1986
30. Bigos SJ, Spengler DM, Martin NA, et al: Back injuries in industry: A retrospective study. III. Employee-related factors. Spine 11:252–256, 1986
31. Bjelle A, Hagberg M, Michaelson F: Clinical and ergonomic factors in prolonged shoulder pain among industrial workers. Scand J Work Environ Health 5:205–210, 1979
32. Bongers PM, de Winter CR: Psychosocial Factors and Musculoskeletal Disease: A Report of the Literature [report no. 92.028]. The Netherlands, TNO Institute of Preventive Health Care, 1992
33. Bongers PM, Winter CR, Kompier MAJ, et al: Psychosocial factors at work and musculoskeletal disease. Scand J Work Environ Health 19:297–312, 1993
34. Bovenzi M: Medical aspects of the hand–arm vibration syndrome. Ergonomics 6:61–73, 1990
35. Bovenzi M: Italian Study Group on Physical Hazards in the Stone Industry: Hand–arm vibration syndrome and dose–response relation for vibration-induced white finger among quarry drillers and stonecarvers. Occup Environ Med 51:603–611, 1994
36. Bovenzi M, Zadini A, Franzinelli A, et al: Occupational musculoskeletal disorders in the neck and upper limbs of forestry workers exposed to hand-arm vibration. Ergonomics 34:547–562, 1991
37. Broberg E: Ergonomic injuries at work. ISA-Information System on Occupational Injuries, Report no. 1984:3E. Swedish National Board of Occupational Safety and Health, 1984
38. Bureau of Labor Statistics: Workplace Injuries and Illnesses in 1994 [publication no. 95-508]. Washington, DC, US Department of Labor, 1995
39. Burry HC, Gravis V: Compensated back injury in New Zealand. NZ Med J 101:542–544, 1988
40. Burt S, Hornung R, Fine L: Newsday, Inc, NIOSH HETA Report 89-250-2046. Cincinnati, National Institute for Occupational Safety and Health, 1990
41. Cady LD, Bischoff DP, O'Connell ER, et al: Strength and fitness and subsequent back injuries in firefighters. J Occup Med 21:269–272, 1979
42. Cannon LJ, Bernacki EJ, Walter SD: Personal and occupational factors associated with carpal tunnel syndrome. J Occup Med 23:255–258, 1981
43. Castorina JS, Deyo RA: Back and lower extremity disorders. *In* Rosenstock L, Cullen MD (eds): Clinical Occupational and Environmental Medicine. Philadelphia, WB Saunders Company, 1994, pp 364–375
44. Chaffin DB: Manual mataerials handling—the cause of overexertion injury and illness in industry. J Environ Pathol Toxicol 2:67–73, 1979
45. Checkoway H, Pearce NE, Crawford-Brown DJ: Research Methods in Occupational Epidemiology. New York, Oxford University Press, 1989
46. Chiang H, Chen S, Yu H, et al: The occurrence of carpal tunnel syndrome in frozen food factory employees. Kaohsiung J Med Sci 6:73–80, 1990
47. Chiang H-C, Ko Y-C, Chen S-S, et al: Prevalence of shoulder and upper-limb disorders among workers in the fish-processing industry. Scand J Work Environ Health 19:126–131, 1993
48. Cohen S, Tyrrell DAJ, Smith AP: Psychological stress and susceptibility to the common cold. N Engl J Med 325:606–612, 1991
49. Cummings K, Maizlish N, Rudolph L, et al: Occupational disease surveillance: Carpal tunnel syndrome. MMWR 38:485–489, 1989
50. Cummings SR, Kelsey JL, Nevitt MC, et al: Epidemiology of osteoporosis and osteoporotic fractures. Epidemiol Rev 7:178–208, 1985
51. Cunningham LS, Kelsey JL: Epidemiology of musculoskeletal impairments and associated disability. Am J Public Health 74:574–579, 1984
52. Dehlin OH, Berg S: Back symptoms and psychological perception of work: A study among nursing aides in a geriatric hospital. Scand J Rehabil Med 9:61–65, 1977
53. Dehlin O, Hedenrud B, Horal J: Back symptoms in nursing aides in a geriatric hospital. Scand J Rehabil Med 8:47, 1976
54. deKrom MC, Kester AD, Knipschild PG, et al: Risk factors for carpal tunnel syndrome. Am J Epidemiol 132:1102–1110, 1990
55. Deyo RA, Tsui-Wu Y-J: Descriptive epidemiology of low-back pain and its related medical care in the United States. Spine 12:264–268, 1987
56. Dimberg L: The prevalence and causation of tennis elbow (lateral humeral epicondylitis) in a population of workers in an engineering industry. Ergonomics 30:573–580, 1987
57. Dixon SJ: Progress and problems in back pain research. Rheumatol Rehabil 12:165, 1973
58. Ekberg K, Björkqvist B, Malm P, et al: Case-control study of risk factors for disease in the neck and shoulder area. J Occup Environ Med 51:262–266, 1994
59. English CJ, Maclaren WM, Hughes SPF, et al: Relations between upper limb soft tissue disorders and repetitive movements at work. Am J Indust Med 27:75–90, 1995
60. Falk B, Aarnio P: Left-sided carpal tunnel syndrome in butchers. Scand J Work Environ Health 9:291–297, 1983
61. Feyer AM, Williamson A, Mandryk J, et al: Role of psychosocial risk factors in work-related low back pain. Scand J Work Environ Health 18:368–375, 1992
62. Flodmark B, Aase G: Musculoskeletal symptoms and type A behavior in blue collar workers. Br J Indust Med 49:683–687, 1992
63. Frank JW, Pulcins IA, Kerr MS, et al: Occupational back pain—an unhelpful polemic. Scand J Work Environ Health 21:3–14, 1995
64. Franklin GM, Haug J, Heyer N, et al: Occupational carpal tunnel syndrome in Washington state, 1984–1988. Am J Public Health 81:741–746, 1991
65. Frymoyer JW, Cats-Baril WL: An overview of the incidence and costs of low back pain. Orthop Clin North Am 22:262–271, 1991
66. Frymoyer JW, Pope MH, Clements JH: Risk factors in low back pain. J Bone Joint Surg 65:213, 1983
67. Frymoyer JW, Pope MH, Constanza MC, et al: Epidemiologic studies of low back pain. Spine 5:419–423, 1980
68. Garg A, Moore SJ: Epidemiology of low-back pain in industry. *In* Moore JS, Garg A (eds): Occupational Medicine, State of the Art Reviews: Ergonomics: Low-back Pain, Carpal Tunnel Syndrome, and Upper Extremity Disorders in the Workplace. Philadelphia, Hanley & Belfus, 1992, pp 599–608
69. Gerr F, Letz R: Letter to the editor. J Occup Med 34:1117–1119, 1992
70. Gerr F, Letz R, Landrigan PJ: Upper-extremity musculoskeletal disorders of occupational origin. Annu Rev Public Health 12:543–566, 1991
71. Graham NM, Douglas RM, Ryan P: Stress and acute respiratory infection. Am J Epidemiol 124:389–401, 1986

72. Guo HR, Tanaka S, Cameron LL, et al: Back pain among workers in the United States: National estimates and workers at high risk. Am J Indust Med 28:591–602, 1995
73. Hadler NM: Arm pain in the workplace: A small area analysis. J Occup Med 34:113–119, 1992
74. Hagberg M, Wegman DH: Prevalence rates and odds ratios of shoulder-neck diseases in different occupational groups. Br J Indust Med 44:602–610, 1987
75. Hagberg M, Morgenstern H, Kelsh M: Impact of occupations and job tasks on the prevalence of carpal tunnel syndrome. Scand J Work Environ Health 18:337–345, 1992
76. Hagberg M, Silverstein B, Wells R, et al: Work-related musculoskeletal disorders (WMSDs): A reference book for prevention. *In* Kuorinka I, Forcier L (eds): London, Taylor & Francis, 1995, p 1
77. Hägg GM, Suurküla J, Kilbom Å: Predictors for work-related shoulder/neck disorders: A longitudinal study of female assembly workers. Stockholm, Sweden, Arbetarskyddsverket, 1990, Arbete och Hälsa, no 10
78. Hales TR: Letter to the editor. J Hand Surg 16B:230–232, 1991
79. Hales TR, Fine L: Cargill Poultry Division [NIOSH HETA report no. 89-251-1997]. Cincinnati, National Institute for Occupational Safety and Health, 1989
80. Hales TR, Habes D, Fine L, et al: John Morrell and Co. [NIOSH HETA report no. 88-180-1958]. Cincinnati, National Institute for Occupational Safety and Health, 1989
81. Hales TR, Sauter SL, Peterson MR, et al: Musculoskeletal disorders among visual display terminal users in a telecommunications company. Ergonomics 37:1603–1621, 1994
82. Hanrahan LP, Moll MB: Injury surveillance. *In* Baker FL (ed): Surveillance in Occupational Health and Safety. Am J Public Health 79(suppl):38–45, 1989
83. Heliövaara M, Knekt P, Aromaa A: Incidence and risk factors of herniated lumbar intervertebral disc or sciatica leading to hospitalization. J Chronic Dis 40:251–258, 1987
84. Heliövaara M, Mäkelä M, Knekt P, et al: Determinants of sciatica and low back pain. Spine 16:608–614, 1991
85. Helliwell PS: Work related upper limb disorders: The relationship between pain, cumulative load, disability, and psychological factors. Ann Rheum Dis 51:1325–1329, 1992
86. Herberts P, Kadefors R, Andersson G, et al: Shoulder pain in industry: An epidemiological study on welders. Acta Orthop Scand 52:299–306, 1981
87. Herberts P, Kadefors R, Hogfors C, et al: Shoulder pain and heavy manual labor. Clin Orthop 191:166–178, 1984
88. Heyer N, Checkoway H, Daniell, et al: Self-reported musculoskeletal symptoms among office video display terminal operators. *In* Sakurai H, Okazaki I, Omae I (eds): Occupational Epidemiology. Amsterdam, The Netherlands, Elsevier Science Publishers, BV, 1990, pp 255–258
89. Hill AB: Principles of Medical Statistics. New York, Oxford University Press, 1966
90. Hirsch C, Jonsson B, Lewin T: Low back symptoms in a Swedish female population. Clin Orthop 63:171, 1969
91. Hoekstra EJ, Hurrell JJ, Swanson NG: Social Security Administration Teleservice Centers, Boston [NIOSH HETA report no. 92-0382-2450]. Cincinnati, National Institute for Occupational Safety and Health, 1994
92. Holmström E: Musculoskeletal disorders in construction workers. Lund, Sweden, Lund University, Department of Physical Therapy, 1992, pp 1–175
93. Houtman LD, Bongers PM, Smulders PGW, et al: Psychosocial stressors at work and musculoskeletal problems. Scand J Work Environ Health 139–145, 1994
94. Hrubec A, Nashbold BS Jr: Epidemiology of lumbar disc lesions in the military in World War II. Am J Epidemiol 102:366, 1975
95. Hurrell JJ, Murphy LR: Psychological job stress. *In* Rom WN (ed): Environmental and Occupational Medicine. New York, Little, Brown & Company, 1992, pp 675–684
96. Ignatius YTS, Lee TY, Yan LT: Self-reported musculoskeletal problems among typists and possible risk factors. Journal of Human Ergonomics 22:83–93, 1993
97. Jenson RC: Disabling back injuries among nursing personnel: Research needs and justification. Res Nurs Health 10:29–38, 1987
98. Jenson RC: Epidemiology of work-related back pain. Topics in Acute Care, Trauma and Rehabilitation 2:1–15, 1988
99. Johnson JV, Wtewart W, Hall EM, et al: Long-term psychological work environment and cardiovascular mortality among Swedish men. Am J Public Health 86:324–331, 1996
100. Jonsson B, Persson J, Kilbom Å: Disorders of the cervicobrachial region among female workers in the electronics industry: A two year follow-up. International Journal of Industrial Ergonomics 3:1–12, 1988
101. Jorgensen D, Nicolaisen T: Trunk extensor endurance: Determination and relation to low-back trouble. Ergonomics 30:259–267, 1987
102. Kamwendo K, Linton S, Moritz U: Neck and shoulder disorders in medical secretaries. Scand J Rehab Med 23:127–133, 1991
103. Karasek RA, Baker D, Marxer F, et al: Job decision latitude, job demands, and cardiovascular disease: A prospective study of Swedish men. Am J Public Health 71:694–705, 1981
104. Karasek RA, Theorell T, Schwartz JF, et al: Job characteristics in relation to the prevalence of myocardial infarction in the US Health Examination Survey (HANES). Am J Public Health 78:910–918, 1988
105. Kelley JD, Lombardo SJ, Pink M, et al: Electromyographic and cinematographic analysis of elbow function in tennis players with lateral epicondylitis. Am J Sports Med 22:359–363, 1994
106. Kellgren JH, Lawrence JS: Rheumatism in miners, part II: X-ray study. Br J Indust Med 9:197–207, 1953
107. Kelsey JL: An epidemiological study of acute herniated lumbar intervertebral disc. Rheumatol Rehabil 14:144, 1975
108. Kelsey JL, Golden AL: Occupational and workplace factors associated with low back pain. *In* Deyo RA (ed): Occupational Medicine, State of the Art Reviews: Back Pain in Workers. Philadelphia, Hanley & Belfus, 1988, pp 7–16
109. Kelsey JL, Hochberg MC: Epidemiology of chronic musculoskeletal disorders. Ann Rev Public Health 9:379–401, 1988
110. Kelsey JL, Githens PB, White AA III, et al: An epidemiologic study of lifting and twisting on the job

and risk factors for acute prolapsed lumbar intervertebral disc. J Orthop Res 2:61, 1984
111. Kiken S, Stringer W, Fine LJ: Perdue Farms [NIOSH HETA report no. 89-307-2009]. Cincinnati, National Institute for Occupational Safety and Health, 1990
112. Kilbom Å, Persson J: Work technique and its consequences for musculoskeletal disorders. Ergonomics 30:273–279, 1987
113. Kilbom Å, Persson J, Jonsson BG: Disorders of the cervicobrachial region among female workers in the electronics industry. Intern J Indust Ergon 1:37–47, 1986
114. King JW, Brelsford HJ, Tullos HS: Analysis of the pitching arm of the professional baseball pitcher. Clin Orthop Rel Res 67:116–123, 1969
115. Kivekäs J, Riihimäki H, Husman K, et al: Seven-year follow-up of white-finger symptoms and radiographic wrist findings in lumberjacks and referents. Scand J Work Environ Health 20:101–106, 1994
116. Klein BP, Jensen RC, Sanderson LM: Assessment of workers' compensation claims for back strains/sprains. J Occup Med 26:443–448, 1984
117. Kopf T, Von Feder T, Karmaus W: Risks for musculoskeletal disorders of the low back, the shoulders, the elbows and the wrists in bricklayers. *In* Hogstedt C, Reuterwall C (eds): Progress in Occupational Epidemiology. Amsterdam, The Netherlands, Elsevier Science Publishers BV, 1988, pp 219–222
118. Koskimies K, Farkkila M, Pyykko I, et al: Carpal tunnel syndrome in vibration disease. Br J Indust Med 47:411–416, 1990
119. Kukkonen R, Luopajarvi, Riihimäki V: Prevention of fatigue amongst data entry operators. *In* Kvalseth TO (ed): Ergonomics of Workstation Design. London, England Buttersworth, 1983, pp 28–34
120. Kuorinka I, Koskinen P: Occupational rheumatic diseases and upper limb strain in manual jobs in a light mechanical industry. Scand J Work Environ Health 5(suppl 3):39–47, 1979
121. Kurppa K, Viikari-Juntura E, Kuosma E, et al: Incidence to tenosynovitis or peritendinitis and epicondylitis in a meat-processing factory. Scand J Work Environ Health 17:32–37, 1991
122. Kvarnström S, Halden M: Occupational cervicobrachial disorders in an engineering company. Scand J Rehab Med 8:1–114, 1983
123. Last JM (ed): A Dictionary of Epidemiology, ed 3. New York, Oxford University Press, 1995
124. Lawrence RC, Hochberg MC, Kelsey JL, et al: Estimates of the prevalence of selected arthritic and musculoskeletal diseases in the United States. J Rheumatol 16:427–441, 1989
125. Leigh JP, Sheetz RM: Prevalence of back pain among fulltime United States workers. Br J Indust Med 46:651–657, 1989
126. Leigh JP, Markowitz S, Fahs M, et al: Costs of Occupational Injuries and Illnesses in 1992 [NIOSH Cooperative Agreement with E.R.C., Inc. U60/CCU902886]. Cincinnati, NIOSH, 1996
127. Leino P, Lyyra A: The effect of mental stress and social support on the development of musculoskeletal morbidity in the engineering industry. *In* Sakurai H, Okazaki L, Omae I (eds): Occupational Epidemiology. Amsterdam, The Netherlands, Elsevier, 1990, pp 267–272
128. Letz R, Cherniack MG, Gerr F, et al: A cross-sectional epidemiological survey of shipyard workers exposed to hand-arm vibration. Br J Indust Med 49:53–62, 1992
129. Linton SJ: Risk factors for neck and back pain in a working population in Sweden. Work and Stress 4:41–49, 1990
130. Linton SJ, Kamwendo K: Risk factors in the psychosocial work environment for neck and shoulder pain in secretaries. J Occup Med 31:609–613, 1989
131. Liss GM, Jesin E, Kusiak R, et al: Musculoskeletal problems among Ontario dental hygienists. Am J Indust Med 28:521–540, 1995
132. Lundberg U, Granqvist M, Hansson T, et al: Psychological and physiological stress responses during repetitive work at an assembly line. Work and Stress 3:143–153, 1989
133. Luopajarvi T, Kuorinka I, Virolainen M, et al: Prevalence of tenosynovitis and other injuries of the upper extremities in repetitive work. Scand J Work Environ Health 5(suppl 3):48–55, 1979
134. Maeda K, Hirayama H, Takamatsu M: Occupational cervicobrachial disorders in workwomen in assembly lines of a cigarette factory. Jpn J Indust Health 19:8–21, 1977
135. Magora A: Investigation of the relat n between low back pain and occupation: Physi requirements: Bending, rotation, reaching, and dden maximal effort. Scand J Rehabil Med 5:186–1), 1973
136. Magora A: Investigation of the rela n between low back pain and occupation: III. ysical requirements: Sitting, standing, and wei lifting. Intern Med 41:5–9, 1972
137. Magora A: Investigation of the r ation between low back pain and occupation. Sca d J Rehab Med 5:191–196, 1973
138. Mäkelä M, Heliövaara M, Sievers K, et al: Prevalence, determinants, and consequences of chronic neck pain in Finland. Am J Epidemiol 134:1356–1367, 1991
139. Marcus M, Gerr F: Upper extremity musculoskeletal symptoms among female office workers: Associations with video display terminal use and occupational psychosocial stressors. Am J Indust Med 29:161–170, 1996
140. Martin DK, Dain SJ: Postural modifications of VDU operators wearing bifocal spectacles. Applied Ergonomics 12:293–300, 1988
141. Mathews KA, Cottington E, Talbott D, et al: Stressful work conditions and diastolic blood pressure among blue-collar factory workers. Am J Epidemiol 126:280–290, 1987
142. McBryde A: Running injuries. A OS Instruction Course Lectures 23:253–282, 1984
143. McCormack RR Jr, Inman RD, Wel A, et al: Prevalence of tendinitis and related diso ers of the upper extremity in a manufacturing work rce. J Rheumatol 17:958–964, 1990
144. McKenna KM, McGrann S, Blan AD, et al: An investigation into the acute vascula effects of riveting. Br J Indust Med 50:160–166, 1 93
145. Milerad E, Ekenwall L: Symptoms of the neck and upper extremities in dentists. Scand J Work Environ Health 16:129–134, 1990
146. Mirbod SM, Inaba R, Iwata H: A study on the vibration–dose limit for Japanese workers exposed to hand-arm vibration. Indust Health 30:1–22, 1992
147. Mirbod SM, Yoshida H, Komura Y, et al: Prevalence of Raynaud's phenomenon in different groups of workers operating hand-held vibrating tools. Int Arch Occup Environ Health 66:13–22, 1994
148. Miyashita K, Morioka I, Tanabe T, et al: Symptoms of construction workers exposed to whole body vi-

bration and local vibration. Int Arch Occup Environ Health 64:347–351, 1992
149. Monson RR: Occupational Epidemiology, ed 2. Boca Raton, FL, CRC Press, 1990, p 88
150. Moore JS, Garg A: Determination of the operational characteristics of ergonomic exposure assessments for prediction of disorders of the upper extremities and back. *In* Proceeding of the 11th Congress of the International Ergonomics Association. London, Taylor & Francis, 1991, pp 144–146
151. Moore JS: Carpal tunnel syndrome. *In* Moore JS, Garg A (eds): Occupational Medicine, State of the Art Reviews: Ergonomics: Low-back Pain, Carpal Tunnel Syndrome, and Upper-Extremity Disorders in the Workplace. Philadelphia, Hanley & Belfus, 1992, pp 741–763
152. Moore JS, Garg A: Upper extremity disorders in a pork processing plant: Relationships between job risk factors and morbidity. Am Ind Hyg Assoc J 55:703–715, 1994
153. Morgenstern H, Kilsh M, Kraus J, et al: A cross-sectional study of hand/wrist symptoms in female grocery checkers. Am J Indust Med 20:209–218, 1991
154. Nagata C, Yoshida H, Mirbod SM, et al: Cutaneous signs (Raynaud's phenomenon, sclerodactylia, and edema of the hands) and hand–arm vibration exposure. Int Arch Occup Environ Health 64:587–591, 1993
155. Nagi SZ, Riley LE, Newby LG: A social epidemiology of back pain in a general population. J Chronic Dis 26:769–779, 1973
156. Nathan PA, Keniston RC, Myers LD, et al: Obesity as a risk factor for slowing of sensory conduction of the median nerve in industry: A cross-sectional and longitudinal study involving 429 workers. J Occup Med 34:379–383, 1992
157. Nathan PA, Meadows KD, Doyle LS: Occupation as a risk factor for impaired sensory conduction of the median nerve at the carpal tunnel. J Hand Surg 13-B:167–170, 1988
158. National Institute for Occupational Safety and Health: Criteria for a recommended standard: Occupational exposure to hand-arm vibration [DHHS (NIOSH) publication no. 89-106]. Cincinnati, National Institute for Occupational Safety and Health, 1989
159. Nilsson T, Burstrom L, Hagberg M: Risk assessment of vibration exposure and white fingers among platers. Int Arch Occup Environ Health 61:473–481, 1989
160. Nilsson T, Hagberg M, Burstrom L, et al: Impaired nerve conduction in the carpal tunnel of platers and truck assemblers exposed to hand–arm vibration. Scand J Work Environ Health 20:189–199, 1994
161. Nirschl RP: Tennis elbow. Orthop Clin North Am 4:787–800, 1973
162. Nirschl RP: The etiology and treatment of tennis elbow. J Sports Med 2:308–319, 1975
163. Ohara H, Aoyama H, Itani T: Health hazard among cash register operators and the effects of improved working conditions. J Hum Ergol (Tokyo) 5:31–40, 1976
164. Ohara H, Nakagiri S, Itani T, et al: Occupational health hazards resulting from elevated work rate situations. J Hum Ergol (Tokyo) 5:173–182, 1976
165. Ohlsson K, Attewell RG, Johnsson B, et al: An assessment of neck and upper extremity disorders by questionnaire and clinical examination. Ergonomics 37:891–897, 1994
166. Ohlsson K, Attewell R, Paisson B, et al: Repetitive industrial work and neck and upper limb disorders in females. Am J Indust Med 27:731–747, 1995
167. Ohlsson K, Attewell R, Skerfving S: Self-reported symptoms in the neck and upper limbs of female assembly workers. Scand J Work Environ Health 15:75–80, 1989
168. Olafsdottir H, Rafnsson V: New techniques increase the prevalences of musculoskeletal symptoms from upper limbs among women in fish fillet plants. *In* Second International Scientific Conference on Prevention of Work-related Musculoskeletal Disorders, Montreal, 1995, pp 248–249
169. Onishi N, Namura H, Sakai K, et al: Shoulder tenderness and physical features of female industrial workers. J Hum Ergol (Tokyo) 5:87–102, 1976
170. Osorio AM, Ames RG, Jones J, et al: Carpal tunnel syndrome among grocery store workers. Am J Ind Med 25:229–245, 1994
171. Papageorgiou AC, Croft PR, Ferry S, et al: Estimating the prevalence of low back pain in the general population: Evidence from the South Manchester back pain survey. Spine 20:1889–1894, 1995
172. Pieper C, LaCroix AZ, Karasek RA: The relation of psychosocial dimensions of work with coronary heart disease risk factors: A meta-analysis of five United States databases. Am J Epidemiol 129:483–494, 1989
173. Pope MH, Andersson GBJ, Frymoyer JW, et al: Occupational low back pain: Assessment, treatment, and prevention. St Louis, Mosby-Year Book, 1991, pp 105–108
174. Priest JD, Braden V, Gerberich SG: The elbow and tennis, part 1: An analysis of players with and without pain. Physician Sports Medicine 8:81–91, 1980
175. Priest JD, Hones HH, Tichenor CJ, et al: Arm and elbow changes in expert tennis players. Minn Med 60:399–404, 1977
176. Punnett L, Robins JM, Wegman DH, et al: Soft-tissue disorders in the upper limbs of female assembly workers: Impact of length of employment, work pace, and selection. Scand J Work Environ Health 11:417–425, 1985
177. Pyykko I, Starak J: Pathophysiologic and hygienic aspects of hand–arm vibration. Scand J Work Environ Health 12:237–241, 1986
178. Ranney D, Wells R, Moore A: Upper limb musculoskeletal disorders in highly repetitive industries: Precise anatomical physical findings. Ergonomics 38:1408–1423, 1995
179. Riihimäki H: Hands up or back to work—future challenges in epidemiologic research on musculoskeletal diseases. Scand J Work Environ Health 21:401–403, 1995
180. Riihimäki H, Wickström G, Hänninen K, et al: Predictors of sciatic pain among concrete reinforcement workers and house painters: A 5-year follow-up. Scand J Work Environ Health 15:415–423, 1989
181. Ringel SP, Treihaft M, Carry M, et al: Suprascapular neuropathy in pitchers. Am J Sports Med 18:80–86, 1990
182. Rossignol AM, Morse EP, Summers VM, et al: Video display terminal use and reported health symptoms among Massachusetts clerical workers. J Occup Med 29:112–118, 1987
183. Rothman KJ: A show of confidence. N Engl J Med 299:1362, 1978
184. Rothman KJ: Modern Epidemiology. Boston, Little, Brown & Company, 1986

185. Roto P, Kivi P: Prevalence of epicondylitis and tenosynovitis among meatcutters. Scand J Work Environ Health 10:203–205, 1984
186. Ruberman W: Psychosocial influences on mortality of patients with coronary heart disease. JAMA 267:559–560, 1992
187. Ruberman W, Weinblatt E, Goldberg JD, et al: Psychosocial influences on mortality after myocardial infarction. N Engl J Med 311:552–559, 1984
188. Ryan GA, Bampton M: Comparison of data process operators with and without upper-limb symptoms. Commun Health Studies XIII1):63–68, 1988
189. Ryan GA, Hage B, Bampton M: Postural factors, work organization and musculoskeletal disorders. *In* Buckle P (ed): Musculoskeletal Disorders at Work. Proceedings of a conference held at the University of Surry, Guilford, April 13–15, 1987. London, Taylor & Francis, 1987, pp 251–253
190. Sakakibara H, Masaru M, Kondo T, et al: Relation between overhead work and complaints of pear and apple orchard workers. Ergonomics 30:805–815, 1987
191. Sakakibara H, Miyao M, Kondo T, et al: Overhead work and shoulder-neck pain in orchard farmers harvesting pears and apples. Ergonomics 38:700–706, 1995
192. Sauter SL, Swanson NG: Psychological aspects of musculoskeletal disorders in office work. *In* Moon S, Sauter S (eds): Psychosocial Factors and Musculoskeletal Disorders. London, Taylor & Francis, 1995
193. Schnall PL, Landsbergis PA, Baker D: Job strain and cardiovascular disease. Annu Rev Public Health 15:381–411, 1994
194. Schnall PL, Pieper C, Schwartz JE, et al: The relationship between job strain, workplace diastolic blood pressure, and left ventricular mass. Results of a case-control study. JAMA 263:1929–1935, 1990
195. Schnall PL, Schwartz JE, Landsbergis PA, et al: The relationship between job strain, alcohol, and ambulatory blood pressure. Hypertension 19:488–494, 1992
196. Schottland JR, Kirschberg GJ, Fillingim R, et al: Median nerve latencies in poultry processing workers: An approach to resolving the role of industrial "cumulative trauma" in the development of carpal tunnel syndrome. J Occup Med 33:627–631, 1991
197. Silverstein BA, Fine LJ, Armstrong TJ: Hand and wrist cumulative trauma disorders in industry. Br J Indust Med 43:779–484, 1986
198. Silverstein BA, Fine LJ, Armstrong TJ: Occupational factors and the carpal tunnel syndrome. Am J Indust Med 11:343–358, 1987
199. Skovron ML, Mulvihill MN, Sterling RC, et al: Work organization and low back pain in nursing personnel. Ergonomics 30:359–366, 1987
200. Slocum D: Overuse syndromes of the lower leg and foot in athletes. AAOS Instructional Course Lectures, 1960, pp 359–367
201. Snook SH: Low back pain in industry. *In* White AA, Gordon SL (eds): American Academy of Orthopaedic Surgeons Symposium on Idiopathic Low Back Pain. St Louis, CV Mosby, 1982, pp 23–38
202. Spengler DM, Bigos SS, Martin NF, et al: Back injuries in industry: A retrospective study I. Overview and cost analysis. Spine 11:241, 1986
203. Stenlund B, Goldie I, Hagberg M, et al: Radiographic osteoarthrosis in the acromioclavicular joint resulting from manual work or exposure to vibration. Br J Indust Med 49:588–593, 1992
204. Stetson DS, Silverstein BA, Keyserling WM, et al: Median sensory distal amplitude and latency: Comparisons between nonexposed managerial/professional employees and industrial workers. Am J Indust Med 24:175–189, 1993
205. Stevens JC, Sun MD, Beard CM, et al: Carpal tunnel syndrome in Rochester, Minnesota, 1961 to 1980. Neurology 38:134–138, 1988
206. Stock SR: Workplace ergonomic factors and the development of musculoskeletal disorders of the upper limbs: A meta-analysis. Am J Indust Med 19:87–107, 1991
207. Susser M: Causal Thinking in the Health Sciences, chap. 11. New York, Oxford University Press, 1973
208. Svane O: National prevention of musculoskeletal workplace injury: Denmark—a sum ry. Ergonomics 30:181–184, 1987
209. Svensson H-O: Low back pain in 40 to 47 year old men: II. Socio-economic facto and previous sickness absence. Scand J Rehab Med 14:55–60, 1982
210. Svensson H-O, Andersson GBJ: L -back pain in 40 to 47-year old men: Work histor nd work environment factors. Spine 8:272–276, 1 3
211. Svensson H-O, Andersson GBJ: Th relationship of low-back pain, work history and w environment, and stress: A retrospective cross-se tional study of 38- to 64-year old women. Spine 14 17–522, 1989
212. Sweeney M, Petersen M, O'Neill Ohio Chapter, Registry of Interpreting for the Dea [NIOSH HETA report no. 92-0268-2477]. Cincinnati, National Institute for Occupational Safety and Health, 1994
213. Takala EP, Viikari-Juntara E, Moneta G, et al: Predictors for the natural course of neck-shoulder symptoms and headache in light sedentary work. *In* Queinnec Y, Daniellou F (eds): Designing for Everyone. Proceedings of the 11th Congress of the International Ergonomics Association, Paris, 1991. London, Taylor and Francis, 1991, pp 129–131
214. Tanaka S, Wild DK, Seligman PJ, et al: Prevalence of work-related carpal tunnel syndrome among U.S. workers: Analysis of the occupational health supplement data of 1988 National Health Interview Survey. Am J Ind Med 27:451–470, 199
215. Theorell T, Ahlberg-Hulten G, Sigal F, et al: Influence of job strain and emotion on blood pressure levels in female hospital personn during work hours. Scand J Work Environ Health 19:264–269, 1993
216. Theorell T, de Faire U, Johnson JV, et al: Job strain and ambulatory blood pressure profiles. Scand J Work Environ Health 17:380–385, 1991
217. Theorell T, Hams-Ringdahlk, Ahlberg-Hultén G, et al: Psychosocial job factors and symptoms from the locomotor system: A multicausal analysis. Scand J Rehabil Med 23:165–173, 1991
218. Tola S, Riihimäki H, Videman T, et al: Neck and shoulder symptoms among men in machine operating, dynamic physical work and sedentary work. Scand J Work Environ Health 14:299–305, 1988
219. Toomingas A, Theorell T, Michélsen H, et al: Associations between perceived psychosocial job factors and prevalence of musculoskeletal disorders in the neck and shoulder regions. *In* Hagberg M, Kilbom Å (eds): Book of Abstracts of the International Scientific Conference on Prevention of Work-Related Musculoskeletal Disorders, Premus, Sweden, 1992. Stockholm, Sweden, Arbetarskyddsverket, Arbete och hälsa 17:307–309, 1992

220. Ursin H, Endresen IM, Ursin G. Psychosocial factors and self-reports of muscle pain. Eur J Appl Physiol 57:282–290, 1991
221. Veiersted KG, Westgaard RH: Work-related risk factors for trapezius myalgia. *In* Hagberg M, Kolbom Å (eds): Book of Abstracts of the International Scientific Conference on Prevention of Work-Related Musculoskeletal Disorders, Premus, Sweden, 1992. Stockholm, Arbetarskyddsverket, Arbete och hälsa 17:307–309, 1992
222. Vender MI, Kasdan ML, Truppa KL: Upper extremity disorders: A literature review to determine work-relatedness. J Hand Surg 20A:534–541, 1995
223. Videman T, Nurminen T, Tola S, et al: Low back pain in nurses and some loading factors of work. Spine 9:400, 1984
224. Viikari-Juntura E: The role of physical stressors in the development of hand/wrist, and elbow disorders. *In* Gordon SL, Blair SJ, Armstrong, et al (eds): Pathophysiology and Clinical Factors in Upper Extremity Repetitive Motion Syndromes. Bethesda, MD, American Academy of Orthopedic Surgeons 1995
225. Viikari-Juntura E, Kurppa K, Kuosma E, et al: Prevalence of epicondylitis and elbow pain in the meat-processing industry. Scand J Work Environ Health 17:38–45, 1991
226. Viikari-Juntura E, Riihimäki H, Tola S, et al: Neck trouble in machine operating, dynamic physical work and sedentary work: A prospective study on occupational and individual risk factors. J Clin Epidemiol 47:1411–1422, 1994
227. Vikari-Juntura EJ, Vuori J, Silverstein BA, et al: A life-long prospective study on the role of psychosocial factors in neck–shoulder and low back pain. Spine 16:1056–1061, 1991
228. Virokannus H: Dose-response relation between exposure to two types of hand-arm vibration and sensorineural perception of vibration. Occup Environ Med 52:332–336, 1995
229. Waersted M, Bjorklund R, Westgaard RH: Generation of muscle tension related to a demand of continuing attention. *In* Knave B, Wideback PG (eds): Work With Display Units. New York, Elsevier Science North-Holland, 1986, pp 288–293
230. Waris P, Kuorinka I, Kurppa K: Epidemiologic screening of occupational neck and upper limb disorders: Methods and criteria. Scand J Work Environ Health 5:25–38, 1979
231. Waters TR, Putz-Anderson V, Garg A, et al: Revised NIOSH lifting equation for the design and evaluation of manual lifting tasks. Ergonomics 36:749–776, 1993
232. Webster BS, Snook SH: The cost of compensable upper extremity cumulative trauma disorders. J Occup Med 36:713–727, 1994
233. Webster BS, Snook SH: The cost of 1989 workers' compensation low back pain claims. Spine 19:1111–1116, 1994
234. Weislander G, Norback D, Gothe CJ, et al: Carpal tunnel syndrome (CTS) and exposure to vibration, repetitive wrist movements, and heavy manual work: A case-referent study. Br J Ind Med 46:43–47, 1989
235. Welch LS, Hunting KL, Kellogg J: Work-related musculoskeletal symptoms among sheet metal workers. Am J Ind Med 27:783–791, 1995
236. Wells JA, Zipp JF, Schuette PT, et al: Musculoskeletal disorders among letter carriers. J Occup Med 25:814–820, 1983
237. Werner S, Franzblau A: The relationship between body mass index and the diagnosis of carpal tunnel syndrome. Muscle Nerve 1492, 1994
238. Westerling D, Jonsson BG: Pain from the neck-shoulder region and sick leave. Scand J Soc Med 8:131–136, 1980
239. Westgaard R, Aaras A: The effect of improved work design on the development of work-related musculoskeletal disorders. Applied Ergonomics 16:91–97, 1985
240. Westgaard R, Bjorklund R: Generation of muscle tension additional to postural muscle load. Ergonomics 30:911–923, 1987
241. White AA, Gordon SL: Synopsis: Workshop on idiopathic low back pain. Spine 7:141–149, 1982
242. Winkel J, Westgaard R: Occupational and individual risk factors for shoulder–neck complaints, part II: The scientific basis (literature review) for the guide. International Journal of Industrial Ergonomics 10:79–83, 1992
243. World Health Organization. Identification and control of work-related diseases [Technical report series no. 714]. Geneva, World Health Organization, 1985

Address reprint requests to

Thomas R. Hales, MD
4676 Columbia Parkway, R-10
Cincinnati, OH 45226