CHAPTER 6

Low-Back Musculoskeletal Disorders: Evidence for Work-Relatedness

SUMMARY

Over 40 recent articles provided evidence regarding the relationship between low-back disorder and the five physical workplace factors that were considered in this review. These included (1) heavy physical work, (2) lifting and forceful movements, (3) bending and twisting (awkward postures), (4) whole-body vibration (WBV), and (5) static work postures. Many of the studies addressed multiple work-related factors. All articles that addressed a particular workplace factor contributed to the information used to draw conclusions about that risk factor, regardless of whether results were positive or negative.

The review provided **evidence** for a positive relationship between back disorder and heavy physical work, although risk estimates were more moderate than for lifting/forceful movements, awkward postures, and WBV. This was perhaps due to subjective and imprecise characterization of exposures. Evidence for dose-response was equivocal for this risk factor.

There is **strong evidence** that low-back disorders are associated with work-related lifting and forceful movements. Of 18 epidemiologic studies that were reviewed, 13 were consistent in demonstrating positive relationships. Those using subjective measures of exposure showed a range of risk estimates from 1.2 to 5.2, and those using more objective assessments had odds ratios (ORs) ranging from 2.2 to 11. Studies using objective measures to examine specific lifting activities generally demonstrated risk estimates above three and found dose-response relationships between exposures and outcomes. For the most part, higher ORs were observed in high-exposure populations (e.g., one high-risk group averaged 226 lifts per hour with a mean load weight of 88 newtons [N]) . Most of the investigations reviewed for this document adjusted for potential covariates in analyses; nevertheless, some of the relatively high ORs that were observed were unlikely to be caused by confounding or other effects of lifestyle covariates. Several studies suggested that both lifting and awkward postures were important contributors to the risk of low-back disorder. The observed relationships are consistent with biomechanical and other laboratory evidence regarding the effects of lifting and dynamic motion on back tissues.

The review provided **evidence** that work-related awkward postures are associated with low-back disorders. Results were consistent in showing positive associations, with several risk estimates above three. Exposure-response relationships were demonstrated. Many of the studies adjusted for potential covariates and a few examined the simultaneous effects of other work-related physical factors. Again, it appeared that lifting and awkward postures both contribute to risk of low-back disorder.

There is **strong evidence** of an association between exposure to WBV and low-back disorder. Of 19 studies reviewed for this document, 15 studies were consistent in demonstrating positive associations, with risk estimates ranging from 1.2 to 5.7 for those using subjective exposure measures, and from 1.4 to 39.5 for those using objective assessment methods. Most of the studies that examined relationships in high-exposure groups using detailed quantitative exposure measures found strong positive associations and exposure-response relationships between WBV and low back disorders. These relationships were observed after adjusting for covariates.

Both experimental and epidemiologic evidence suggest that WBV may act in combination with other work-related factors, such as prolonged sitting, lifting, and awkward postures, to cause

increased risk of back disorder. It is possible that effects of WBV may depend on the source of exposure (type of vehicle).

With regard to static work postures and low-back disorder, results from the studies that were reviewed provided **insufficient evidence** that a relationship exists. Few investigations examined effects of static work postures, and exposure characterizations were limited.

INTRODUCTION

Low-back pain (LBP) is common in the general population: lifetime prevalence has been estimated at nearly 70% for industrialized countries; sciatic conditions may occur in one quarter of those experiencing back problems [Andersson 1981]. Studies of workers' compensation data have suggested that LBP represents a significant portion of morbidity in working populations: data from a national insurer indicate that back claims account for 16% of all workers' compensation claims and 33% of total claims costs [Snook 1982; Webster and Snook 1994b]. Studies have demonstrated that back disorder rates vary substantially by industry, occupation, and by job within given industries or facilities [see Bigos et al. 1986a; Riihimäki et al. 1989a; Schibye et al. 1995; Skovron et al. 1994].

Back disorder is multifactorial in origin and may be associated with both occupational and nonwork-related factors and characteristics. The latter may include age, gender, cigarette smoking status, physical fitness level, anthropometric measures, lumbar mobility, strength, medical history, and structural abnormalities [Garg and Moore 1992]. Psychosocial factors, both work- and nonwork-related, have been associated with back disorders. These relationships are discussed at length in Chapter 7 and Appendix B.

The relationship of the disorder with employment can be complex: individuals may experience impairment or disability at work because of back disorders whether the latter was directly caused by job-related factors or not. The degree to which ability to work is impaired is often dependent on the physical demands of the job. Furthermore, when an individual experiences a back disorder at work, it may be a new occurrence or an exacerbation of an existing condition. Again, originally it may have been directly caused by work or by nonwork-related factors. Those suffering back pain may modify their work activities in an effort to prevent or lessen pain. Thus, the relationship between work exposure and disorder may be direct in some cases, but not in others.

When discussing causal factors for low-back disorders, it is important to distinguish among the various outcome measures, such as LBP, impairment, and disability. LBP can be defined as chronic or acute pain of the lumbosacral, buttock, or upper leg region. Sciatic pain refers to pain symptoms that radiate from the back region down one or both legs; lumbago refers to an acute episode of LBP. In many cases of LBP, specific clinical signs are absent. Low-back impairment is generally regarded as a loss of ability to perform physical activities. Low-back disability is defined as necessitating restricted duty or time away from the job. Although it is not clear which outcome measure is best suited for determining the causal relationship between low-back disorder and work-related risk factors, it is important to consider severity when evaluating the literature.

In addition to level of severity, outcomes may be defined in a number of other ways, ranging from subjective to objective. Information on symptoms can be collected by interview or questionnaire self-report. Back “incidents” or “reports” include conditions reported to medical authorities or on injury/illness logs; these may be symptoms or signs that an individual has determined need for medical or other attention. They may be due to acute symptoms, chronic pain, or injury related to a particular incident, and may be subjectively or objectively determined. Whether an incident is reported depends on the individual’s situation and inclinations. Other back disorders can be diagnosed using objective criteria—for example, various types of lumbar disc pathology.

There are many conditions in the low back which may cause back pain, including muscular or ligamentous strain, facet joint arthritis, or disc pressure on the annulus fibrosis, vertebral end-plate, or nerve roots. In most patients, the anatomical cause of LBP, regardless of its relationship to work exposures, cannot be determined with any degree of clinical certainty. Muscle strain is probably the most common type of work or nonwork back pain. While there is sometimes a relationship between pain and findings on magnetic resonance imaging (MRI) of disc abnormalities (such as a herniated disc and clinical findings of nerve compression), unfortunately, the most common form of back disorder is “non-specific symptoms,” which often cannot be diagnosed.

It is important to include subjectively defined health outcomes in any consideration of work-related back disorders because they comprise such a large subset of the total. It may be too restrictive to define cases of back disorder using “objective” medical criteria. Therefore, in contrast to chapters for musculoskeletal disorders or other anatomic regions, this review of literature on the back used slightly different evaluation criteria. For consideration of back disorders, use of a subjective health outcome was not necessarily considered a study limitation. Furthermore, because back disorders were rarely defined by medical examination criteria, the evaluation criterion related to blinding of assessors (to health or exposure status) was also less relevant to a discussion of this literature.

In this review, epidemiologic studies of all forms of back disorder were included. The term “back disorder” is used to encompass all health outcomes related to the back. It should be pointed out that, in some studies, disorders of the low back were not distinguished from total back disorders. We assumed that a significant portion of these related to the low back, and articles using such a definition were included in our review.

The 42 epidemiologic studies discussed below were selected according to criteria that appear in the introduction of this document. Most (30) used a cross-sectional design, followed by prospective cohort (5), case-control (4), and retrospective cohort (2) designs. One study combined both cross-sectional and cohort analyses. Full descriptions of the studies appear in Table 6-6. Twenty-four investigations defined the health outcome only by report of symptoms on questionnaires or in interviews (for example, total back pain, LBP, and sciatica); used symptoms plus medical examination (back pain, low-back syndrome, sciatica, back insufficiency, lumbago, herniated lumbar disc, and lumbar disc pathology), 2 used sick leaves and medical disability retirements, and 6 used injury/illness reports. The last category included outcomes defined as "low-back complaints, injuries caused specifically by lifting or mechanical energy," and "acute industrial back injury." Clearly, the 42 studies used outcome definitions that correspond to several regions of the back and include disorders that may have been acute or chronic and subjectively or objectively determined.

In the studies included in this review, exposures were assessed primarily by questionnaire or interview (n=17), followed by observation or direct measurement (n=15) and by job title only (n=10). Study groups included general populations (Swedish, Dutch, U.S., Finnish, and English) and occupational groups (nurses, clerical employees, school lunch preparers, baggage handlers, and individuals working in construction, agriculture, maritime, petroleum, paper products, transportation, automobile, aircraft, steel, and machine manufacturing industries).

This review of epidemiologic studies of low-back disorder examined the following potential risk factors related to physical aspects of the workplace: (1) heavy physical work, (2) lifting and forceful movements, (3) bending and twisting (awkward postures), (4) WBV, and (5) static work postures. Psychosocial workplace factors were also included in a number of studies; these relationships are discussed separately in Chapter 7. Following are discussions of the evidence for each work-related physical risk factor.

HEAVY PHYSICAL WORK

Definition

Heavy physical work has been defined as work that has high energy demands or requires some measure of physical strength. Some biomechanical studies interpret heavy work as jobs that impose large compressive forces on the spine [Marras et al. 1995]. In this review, the definition for heavy physical work includes these concepts, along with investigators' perceptions of heavy physical workload, which range from heavy tiring tasks, manual materials handling tasks, and heavy, dynamic, or intense work. In several studies, evaluation of this risk factor was subjective on the part of participant or investigator, and in many cases, "heavy physical work" appeared to include other potential risk factors for back disorder, particularly lifting and awkward postures.

Studies Reporting on the Association Between LBP and Heavy Physical Work

Eighteen studies appeared to address the risk factor related to heavy physical work, although none of them fulfilled all four evaluation criteria (Table 6-1, Figure 6-1). In fact, most (78%) had acceptable participation rates, but only three defined health outcomes using both symptoms and medical exam criteria, and only two assessed exposure independent of self-report.

In nearly all of these studies, covariates were addressed in at least minimal fashion, such as restricting the study population as to gender and conducting age-stratified or adjusted analyses; in many, multivariate analyses were carried out. With regard to health outcome, while only three used medical exams, in addition to symptoms or injury reports, to arrive at case definitions, in many instances standard questionnaire instruments were used. The major study limitations, overall, were related to relatively poor ascertainment of exposure status.

Following are descriptions of seven studies that were most informative. Detailed descriptions for all 18 investigations can be found in Table 6-6.

Bergenudd and Nilsson [1988] followed a Swedish population-based cohort established in 1938. Back pain (total) presence and severity were self-assessed by questionnaire, as of 1983; exposures (light, moderate, or heavy physical work) were assessed based on questionnaires completed by the cohort from 1942 onward. Univariate results demonstrated that those with moderate or heavy physical demands in their jobs had more back pain than those with light physical demands (OR 1.83, 95% Confidence Interval [CI] 1.2-2.7). When stratified by gender, the relationship was slightly stronger for females (OR 2.03, 95% CI 1.1–3.7) than for males (OR 1.76, 95% CI 1.01–3.1). When prevalence was examined by exposure category, rates were 21.4%, 32.8%, and 31.3% for males (no trend was available for females, as none worked in the highest exposure category). Analyses were stratified by gender but did not account for other potential covariates. The longitudinal design ensured that exposures preceded health outcomes. Shortcomings included a relatively low response rate (67%), minimal exposure assessment, limited adjustment for covariates in analyses, and self-reporting of health symptoms.

Burdorf and Zondervan [1990] carried out a cross-sectional study comparing 33 male workers who operated cranes with age-matched workers from the same Dutch steel plant who did not operate cranes. Symptoms of LBP and sciatica were assessed by questionnaire. Exposure was assessed by job title (crane operators were noted to experience frequent twisting, bending, stooping, static sedentary postures, and WBV) and by questionnaire (exposures to sedentary postures, WBV, heavy physical work, and frequent lifting were assessed for both current and past jobs). Crane operators were significantly more likely to experience LBP (OR 3.6, 95% CI 1.2–10.6). Among crane operators alone, the OR for heavy work was 4.0 (95% CI 0.76–21.2) after controlling for age, height, and weight. It was determined that this heavy work occurred in past and not in current jobs. Among crane operators alone, the OR for frequent lifting was 5.2 (95% CI 1.1–25.5). The frequent lifting in crane operators was also determined to be from jobs held in the past. Among workers who were not crane operators, history of frequent lifting was not associated with LBP (OR 0.70, 95% CI 0.14–3.5). Among crane operators, univariate ORs for WBV and prolonged sedentary postures were 0.66 (95% CI 0.14–3.1) and 0.49 (95% CI 0.11–2.2), respectively. In multivariate analyses controlled for age, height, weight, and current crane work, most of the associations with specific work-related factors were substantially reduced. The high prevalence of LBP in crane operators was explained only by current crane work. No measures of dose-response were examined.

Limitations included a relatively low response rate for crane operators (67%)—with some suggestion that those with illness may have been under-represented (perhaps underestimating the OR)—and self-reporting of health outcomes and exposures. The investigators attempted to clarify the temporal relation between exposure and outcome by excluding cases of back pain with onset before the present job.

As part of a Finnish population-based health survey, Heliövaara et al. [1991] conducted a cross-sectional analysis of chronic low-back syndrome, sciatica, and LBP. Health outcomes were determined by interview and examination; work-related exposure information was obtained by a self-administered questionnaire, which included items related to lifting, carrying heavy objects, awkward postures, WBV, repeated movements, and paced work. The total number of factors was designated the "sum index of occupational physical stress." Mental work stress measures were also included. A dose-response was observed for sciatica and the physical stress score (with an OR of 1.9, 95% CI 0.8–4.8 for the highest score) and for low-back syndrome and physical stress (OR 2.5, 95% CI 1.4–4.7), after adjusting for a number of covariates. The study did not address temporal relationships, and exposure information was derived from self-reports. Strengths included a high response rate, objective measure of health outcomes, and multivariate adjustment for covariates.

Johansson and Rubenowitz [1994] examined low-back symptoms cross sectionally in 450 blue- and white-collar workers employed in eight Swedish metal companies. The exposed group included assemblers, truck drivers, welders, smiths, and operators of several types of machines (lathes, punch presses, and milling). Outcome information was obtained by questionnaire. Exposure data were also obtained by questionnaire and included information on occupational, psychosocial, and physical workloads, including sitting, carrying, pushing, pulling, lifting, work postures, and repetitive movements. Questionnaire items related to carrying, pushing, pulling, and lifting were combined to produce an index of manual materials handling. The prevalence of work-related LBP was significantly higher in blue-collar employees than in white-collar workers (RR 1.8, $p<0.05$). In both white and blue-collar workers, work-related LBP was not significantly associated with either heavy or light materials handling, or bent or twisted work postures, after adjustment for age and gender. LBP was significantly associated with extreme work postures (blue-collar workers only) and monotonous working movements (white-collar workers only). In these analyses, relationships were presented as partial correlations; thus, a comparison of risk estimates was not possible. Limitations of the study included the cross-sectional design, collection of outcome and exposure data by self-report, and potential problems with multiple comparisons, as many independent variables were examined in analyses. Many of the exposed group (blue-collar workers) were engaged in machine operation tasks with perhaps limited opportunity for exposure to work with heavy physical demands. Also, heavy physical work and lifting were combined into a single index. Strengths included consideration of age and gender as covariates and inclusion of both physical and psychosocial workplace measures.

Svensson and Andersson [1989] examined LBP in a population-based cross-sectional study of employed Swedish women. Information on LBP and sciatica was obtained by questionnaire, as were exposure-related items. Physical exposures included lifting, bending, twisting, other work postures, sitting, standing, monotony, and physical activity at work. Lifetime incidence rates (IRs) varied by occupation, with ranges from 61%–83% in younger age groups and 53%–75% in older groups. *A posteriori*, the authors noted that, for these women, the highest lifetime incidence of LBP was not found in the jobs with the highest physical demands. The measure for "physical activity at work" was also not significantly associated with LBP in univariate analyses. Bending forward (RR 1.3), lifting (RR 1.2), and standing (RR 1.3) were associated with lifetime incidence of LBP in univariate analyses ($p<0.05$). None of the measures of physical workplace factors were associated with lifetime incidence of LBP in multivariate analyses.

A cross-sectional study of LBP in Finnish nurses was conducted [Videman et al. 1984]. LBP and sciatica were ascertained by questionnaire; exposure information was also self-reported and included items related to both physical loading factors at work and to work history. Exposures were reclassified as "heavy," "intermediate," and "light," based on questionnaire responses. The derivation of this classification was not clear, but it may have been a combination of responses to questions on lifting, bending, rotation, standing, walking, and sitting. A dose-response was observed between prevalence of previous LBP and workload category in younger women (77%, 79%, and 83% for light, intermediate, and heavy categories). The trend was not observed in older age groups, nor for sciatica in any age group. LBP and sciatica rates were slightly higher for nurse aides than for qualified nurses, although the differences were not statistically significant. The authors suggested that aides had higher rates of back pain because of heavier workload, including patient handling and lifting. Lack of consistency of LBP OR across exposure and age groups suggested that a healthy worker effect was operating and that injured workers might be leaving the field, a phenomenon that the cross-sectional study design could not address.

Videman et al. [1990] carried out a cross-sectional study of 86 males who died in a Helsinki hospital to determine degree of lumbar spinal pathology. Disc degeneration and other pathologies were assessed in the cadaver specimens by discography and radiography. Subjects' symptoms and work exposures—heavy physical work, sedentary work, driving, and mixed—were determined by interview of family members. In comparison to those with mixed work exposures, those with sedentary and heavy work had increased risk of symmetric disc degeneration with ORs of 24.6 (95% CI 1.5–409) and 2.8 (95% CI 0.3–23.7), respectively). Similar relationships were seen for vertebral end-plate defects and facet joint osteoarthrosis. Risk of vertebral osteophytosis was highest for those in the heavy work category (OR 12.1, 95% CI 1.4–107). For most pathologic changes, sedentary work appeared to have a stronger relationship than heavy work. Back pain symptoms were consistently higher in those with any form of spinal pathology, although the difference was significant only for anular ruptures. Results of this study were notable in that anular rupture, a classic pathologic condition of the disc, was not associated with exposure. This study was unusual in design in that it examined a combination of spinal pathological outcomes, symptoms, and workplace factors. However, participation in the study was dependent on obtaining information from family members; participation rates were not stated. While recall bias is often a problem in studies of the deceased, in this case, it should have been nondifferential, if present.

Strength of Association

The most informative studies were generally those that carried out exposure assessments which ranked physical workload based on questionnaire report. In a prospective study of back injury reports, Bigos et al. [1991b] found no associations with physical job characteristics (although the authors stated that the study population had low overall exposures). This study described the biomechanical methods that were used to directly assess spinal loads associated with jobs, but no results related to these measures were presented. Svensson and Andersson [1989] appear to have examined a measure for physical activity at work and its relationship to LBP in Swedish women. No associations were observed. In a population-based study, Bergenudd and Nilsson [1988] observed significantly more back pain in those with heavier physical work (OR 1.8 for moderate/heavy versus light work, $p<0.01$). ORs were slightly higher for females (OR 2.0) than for males (OR 1.8). Leigh and Sheetz [1989] found that back symptoms were associated with self-reporting that “job requires a lot of physical effort” (OR 1.5, 95% CI 1.0–2.2). Masset and Malchaire [1994] observed that LBP was not associated with overall physical workload in a group of Belgian steelworkers, although LBP was related to heavy shoulder efforts. In a study of blue-and white-collar workers, Johansson and Rubenowitz [1994] found higher LBP rates in blue-collar workers (RR 1.8, $p<0.05$). However, in more detailed analyses of exposure, back pain was not associated with indices for heavy or light materials handling after adjustment for age and gender (with partial correlation coefficients of less than 0.10). Burdorf and Zondervan’s 1990 study of crane operators demonstrated increased risk of LBP with exposure to heavy work (OR 4.0, 95% CI 0.8–21.2) after controlling for age, height, and weight. Two studies used indices of physical stress to create questionnaire responses related to lifting, carrying heavy objects, awkward postures, repeated movements, and others. Heliövaara et al. [1991] found that both low-back syndrome and sciatica were associated with physical stress scores, with ORs of 2.5 ($p<0.05$) and 1.9 (not significant) for the highest scores, respectively. A study of Finnish nurses classified exposures as “heavy,” “intermediate,” and “light” based on questionnaire response scores [Videman et al. 1984]; prevalence of LBP was slightly higher in the heavy category than in the light (RR 1.1, not significant) for younger women only. Sciatica was also examined, and no relationships were found.

The other studies that examined heavy physical work as a risk factor for back disorder classified exposure in a simpler manner, either by job title alone or by grouping jobs based on prior knowledge of the work or questionnaire responses. Burdorf et al. [1991] found that heavy physical work was associated with back pain in concrete workers in univariate, but not multivariate models (no risk estimate was reported). Hildebrandt [1995] found that individuals in jobs described as "heavy non-sedentary" were more likely to experience back pain than those in sedentary jobs (OR 1.2, $p<0.05$). In a cadaver study of lumbar disc pathology, Videman et al. [1990] found that those with jobs involving heavy physical work had increased risk of disc pathology in comparison to those with mixed work exposures (e.g., an OR of 2.8, 95% CI 0.3–23.7, for symmetric disc degeneration and an OR of 12.1, 95% CI 1.4–107, for vertebral osteophytosis). For most pathologic changes, sedentary work had a stronger relationship than heavy work.

Finally, several studies examined back disorder rates by job title or occupation alone. Hildebrandt et al. [1996] observed differences in back symptom rates by unit and task group in "nonsedentary" steel workers. The reference group also had high symptom rates; comparisons between the two groups did not yield significant differences. In multivariate analyses, Riihimäki et al. [1989b] found no significant difference in sciatic pain for carpenters and office workers (OR 1.0, 95% CI 0.8–1.3). Partridge and Duthie [1968] found that dock workers had slightly higher LBP rates than civil servants (RR 1.2, not significant). In a similar study, Åstrand [1987] classified pulp mill jobs as heavy and the referent group of clerical jobs as light; mill workers were 2.3 times more likely to experience back pain than clerical staff ($p=0.002$). Clemmer et al. [1991] found that floor hands, roustabouts, and derrickhands had the highest rates for low-back strains and impact injuries, with RRs of 2.2 and 4.3 (no significance testing was done) in comparison to control room operators and maintenance professionals, those with the lowest rates. A study of hospital employees that matched cases with controls by department found that those on the day shift had an OR of 2.2 ($p<0.005$) in comparison to those working other shifts [Ryden et al. 1989]. In the last two studies, the authors determined *a posteriori* that job titles (or shifts) that were observed to have high back disorder rates were those requiring the heaviest physical effort.

Although in all 18 of these studies the authors stated that "heavy physical effort or work" was at least one of the risk factors of interest, the actual estimates of these exposures varied from assumptions based on job title to self-reported scores based on self-reported work activities. In no case were measured physical loads used as independent variables. Study populations included individuals working in health care, office work, manufacturing, construction, and general populations, all with varying degrees of physical work requirements. Some studies created physical "stress" indices that included more than one risk factor. Since most estimates of physical load were subjective, they tended to reflect the relative requirements of the jobs and individuals included in each study. Health outcomes also varied.

In summary, the strength of the relationship between back disorder and heavy physical work in some of the studies with more quantitatively defined exposures ranged from none [Bigos et al. 1991b; Johannsson and Rubenowitz, 1994; Masset and Malchaire 1994; Svensson and Andersson 1989; Videman et al. 1984] to ORs of 1.9 (not significant) for sciatica and 2.5 ($p<0.05$) for low-back syndrome [Heliövaara et al. 1991], 1.5 (95% CI 1.0–2.2) [Leigh and Sheetz 1989], 1.8 (95% CI 1.2–2.7) [Bergenudd and Nilsson 1988], and 4.0 ($p<0.05$) for LBP [Burdorf and Zondervan 1990]. In another study, which used a scoring system and focused on a subject group of nurses, the RR was 1.1 (not significant) for the high-exposure category [Videman et al. 1984].

Dichotomous estimates of physical workload yielded ORs of 1.2 [Hildebrandt 1995], 2.8-12.1 [Videman et al. 1990], and no association (results were observed in univariate but not multivarate analyses, with no risk estimates reported) [Burdorf et al. 1991]. Exposures based on job title alone yielded estimates from none [Hildebrandt et al. 1996], nonsignificant ORs of 1.0 and 1.2 [Partridge and Duthie 1968; Riihimäki et al. 1989b], to significant ORs of 2.2–4.3 [Åstrand 1987; Clemmer et al. 1991; Ryden et al. 1989]. Half of the studies had positive point estimates for this risk factor but were low to moderate in magnitude. In five studies that found no association between back disorder and heavy physical work, no details were given. Two of the highest significant ORs were based on exposed groups in the oil and steel industries [Burdorf and Zondervan 1990; Clemmer et al. 1991]. For these, true exposure to heavy physical work was probably more likely than for some of the other study populations. For many of the investigations, exposure estimates were subjectively assessed. In many cases, study groups had potentially low exposures or exposure to heavy physical work in combination with other risk factors.

Temporal Relationship

Fourteen of the 18 reviewed studies had a cross-sectional design that could not directly address this issue. Three mentioned potential problems related to this study design. Åstrand [1987] suggested that exposure misclassification occurred in her study of paper mill workers (some individuals were transferred to clerical jobs—the unexposed group—after experiencing a back injury in the mill). In the Videman et al. 1984 study of nurses, lack of consistency of LBP OR by age and exposure group suggested that injured workers were leaving the field. A study of cadavers carried out by Videman et al. [1990] seemed to have potential for problems with temporal relationships, as exposure information for past periods depended on recall of study participants' activities by family members.

Two cross-sectional studies attempted to clarify temporal relationships by excluding from analysis the cases with disorder onset prior to current job [Burdorf et al. 1991; Burdorf and Zondervan 1990]. Both showed results suggesting a positive relationship between exposure and back disorders. Three studies had cohort designs in which temporal relationships between outcome and exposure could be determined [Bergenudd and Nilsson 1988; Bigos et al. 1991b; Clemmer et al. 1991]: in one, no association was observed, in another, a modest increase in risk was seen. In the third, exposure (assessed *a posteriori* by job title) was significantly associated with back injuries. A case-control study conducted using hospital personnel records appeared free from recall bias and showed a significant association between low-back injury and working the day shift (assessed *a posteriori* as having the heaviest workload) [Ryden et al. 1989].

Although the majority of studies were limited by their cross-sectional designs, results were similar for these and other studies with designs that could assess temporal relationships.

For most studies, the data are compatible with a temporal relationship in which exposure preceded disorder.

Consistency in Association

Half of the 18 studies examined demonstrated no significant association between exposure and outcome. All of those which showed significant associations (n=9) were positive in direction, (one OR of 1.2, two ORs between 1.5 and 2, and six ORs between 2.2 and 12.1).

Study groups included males working in industrial environments, office workers, health care employees—female, for the most part—and population-based groups that included both genders and many occupations. That some consistency in results was noted among these diverse groups, particularly after adjustment for covariates, suggests that the observed associations have validity and can be generalized across working populations.

Coherence of Evidence

Information derived from a large number of laboratory and field studies using a wide variety of approaches provides a plausible explanation for associations between LBP and physically demanding jobs [Waters et al. 1993]. Research conducted in the 1950s demonstrated that disc degeneration occurs earlier in life among workers who perform heavy physical work than among those who perform lighter work. Similar findings are reported in more recent investigations [Videman et al. 1990]. The stresses induced at the low back during manual materials handling are due to a combination of the weight lifted, and the person's method of handling the load. The internal reaction forces needed to equilibrate the body segment weights and external forces such as weight of the load being lifted are supplied by muscle contraction, ligaments, and body joints. Injury to the supporting tissues can occur when the forces from the load, body position, and movements of the trunk create compressive, shear, or rotational forces that exceed the capacities of the discs and supporting tissues needed to counteract the load moments. Rowe [1985] hypothesized that disc and facet degeneration and ligament strain are responsible for the potentially high rates of LBP disability in those whose jobs demand heavy physical activity.

The Videman et al. [1990] cross-sectional study of cadavers addressed two aspects of the causal chain linking exposure to heavy physical work and back disorder. First, the study demonstrated an association between subjective health outcome measures and more objective measures: back pain symptoms (assessed from family members) were consistently higher in those with signs of spinal pathology. Second, the study demonstrated an association between objective measures of disorder and heavy work exposures: individuals whose jobs included heavy work exposures showed increased risk of symmetric disc degeneration, vertebral osteophytosis, and facet joint osteoarthrosis. Significant relationships were also found for back pain and disability. We agree with the conclusion of Videman et al. [1990] that states that "back injury and sedentary or heavy (but not mixed) work contributed to the development of pathologic findings in the spine. The severity of back pain was related to the heaviness of work. Work-related factors may be responsible for the development of pathologic changes and for increased episodes of LBP and disability."

Another important contribution to the coherence of evidence is that the Bureau of Labor Statistics Annual Survey of Injuries and Illnesses has demonstrated significant elevations in overexertion injuries and disorders in industries which are associated with heavy work, such as nursing and personal care and air transportation. Some broad population surveys such as the National Health Interview Survey (NHIS) from 1988 and the 1990 Ontario Health Survey (OHS) found increased back pain or long-term back problems with exposure to factors such as lifting, pulling, and physical pushing [Guo et al. 1995; Liira et al. 1996]. In the NHIS, the two occupations with the highest significant rates of work-related LBP were male construction laborers (with a prevalence ratio [PR] of 2.1) and female nursing aides, orderlies, and attendants (PR 2.8) [Guo et al. 1995]. In the OHS, the number of simultaneous physical exposures was directly related to risk increase after adjustment for covariates. For the highest exposure index level, the adjusted OR was 3.18 (95% CI 1.72–5.8), which occurred in 3% of the population [Liira et al. 1996]. It is important to point out that truly heavy work probably occurs in only a tiny proportion of all jobs in most industries and in only a minority of many high-risk industries, which is why misclassification of exposures is likely in population-based studies.

Exposure-Response Relationships

Only a few studies examined exposure in sufficient detail to assess exposure-response relationships with low-back disorders. Results were mixed. Heliövaara et al. [1991] observed an exposure-response between sciatica and physical stress score; the Videman et al. [1984] results demonstrated a dose-response between LBP prevalence and workload categories in younger nurses, but not in older groups, or for sciatica in any age group. In Åstrand's 1987 "high exposure group" (pulp mill workers), duration of employment was associated with back pain. Bergenudd and Nilsson [1988] and Johansson and Rubenowitz [1994] observed no exposure-response relationships between back disorders and their exposure measures. On the whole, evidence of exposure-response is equivocal, based on the paucity of information available.

Conclusions: Heavy Physical Work

The reviewed epidemiologic investigations provided evidence that low-back disorders are associated with heavy physical work. Despite the fact that studies defined disorders and assessed exposures in many ways, all studies which demonstrated significant associations between exposure and outcome were positive in direction and showed low to moderate increased risk. Exposures were assessed subjectively, for the most part; and in some cases, classification schemes were crude. This study limitation may have led to misclassification of exposure status to the extent that it caused a dampening effect on risk estimates, where nondifferential misclassification caused bias toward a null value for the measure of association. This may account for the moderate ORs that were observed. A few studies were able to examine dose-response relationships between outcomes and exposure; these results were equivocal. Most studies utilized cross-sectional study designs; however, five of six studies which used specific methodologies to address temporality showed positive associations between exposure and outcome. Many studies addressed potential effects of covariates by restriction in selection of study participants, stratification, or multivariate adjustment in statistical analyses.

In many studies, "heavy physical work" exposure appeared to include other work-related physical factors (particularly lifting and awkward postures).

LIFTING AND FORCEFUL MOVEMENTS

Definition

Lifting is defined as moving or bringing something from a lower level to a higher one. The concept encompasses stresses resulting from work done in transferring objects from one plane to another as well as the effects of varying techniques of patient handling and transfer. Forceful movements include movement of objects in other ways, such as pulling, pushing, or other efforts. Several studies included in this review used indices of physical workload that combined lifting/forceful movements with other work-related risk factors (particularly heavy physical work and awkward postures). Some studies had definitions for lifting which include criteria for number of lifts per day or average amount of weight lifted.

Studies Reporting on the Association Between LBP and Lifting and Forceful Movements

Eighteen studies examined relationships between back disorders and lifting or forceful movements. Only one, Punnett et al. 1991 case-control study of back pain in auto workers, fulfilled the four evaluation criteria (Table 6-2, Figure 6-2). The majority (66%) had adequate participation rates; four defined outcomes using both symptoms and medical exam criteria. Blinding of investigators with regard to case/exposure status was not mentioned in most, but it could be confirmed in two papers and inferred (by study methodology) in two others. Seven studies used an exposure assessment that included observation or direct measurement; an additional nine obtained exposure information by self-report on questionnaire or interview. Only two relied on job title alone to characterize exposure.

Thirteen investigations were cross-sectional in design; three were case-control, and two were prospective. Eleven defined the health outcome by symptom report on interview or questionnaire.

Descriptions of seven studies which provided the most information regarding the relationship between low-back disorder and lifting and forceful movements follow. Detailed descriptions for all 18 investigations can be found in Table 6-6.

The Punnett et al. [1991] case-control study examined the relationship between back pain and occupational exposures in auto assembly workers. Back pain cases (n=95) were determined by symptoms at interview and medical examination; controls included those free of back pain. For all participants (or proxies in the same jobs), jobs were videotaped and work cycles were reviewed using a posture analysis system. Exposures included time spent in various awkward postures. Peak biomechanical forces were estimated for up to nine postures where a load weighing at least 10 lb was held in the hands. In multivariate analyses that adjusted for a number of covariates (age, gender, length of employment, recreational activities, and medical history), time in non-neutral postures (mild or severe flexion and bending) was strongly associated with back disorder (OR 8.09, 95% CI 1.4–44). Lifting was also associated with back disorder (OR 2.16, 95% CI 1.0–4.7). When the subset with physical medical findings was examined, associations were more pronounced. Although few study subjects were unexposed to all of the postures studied, a strong increase in risk was observed with both intensity and duration of exposure. It was not possible to determine the relative contributions of different awkward postures because all were highly correlated. Only participants' current jobs (for referents), or job when symptoms started (for cases) were analyzed; the study design thus assumed a short-term relationship between exposure and outcome (although length of time in job was also included in the models). The authors attempted to ensure that exposure preceded disease by identifying time of onset and measuring exposures in the job held just prior. The strong associations, after adjustment for covariates, are notable.

Burdorf et al. [1991] examined back pain symptoms in a cross-sectional study of male concrete fabrication workers and a referent group of maintenance workers. Back pain symptoms were assessed by questionnaire. Exposures were measured using the Ovako Working Posture Analysis System, which assessed postures for the back and lower limbs along with lifting load. Information on exposures in previous jobs was also collected. Concrete workers experienced significantly more back symptoms than referents (OR 2.8, 95% CI 1.3–6.0). Univariate results showed associations between back pain and both posture index and WBV in current job (correlations were presented). Lifting was not found to be associated with back pain (and exposure was found not to vary significantly across the six job categories examined in the study). In multivariate analyses adjusting for age, both posture index and WBV were significantly associated with back pain, with ORs of 1.23 (p=0.04) (for an ordinal scale of 6) and 3.1 (p=0.01) (dichotomous), respectively. These two measures were highly correlated and analyzed separately. Strengths of the study include use of a standard symptom questionnaire, high participation rates, an objective measure of exposure, and an attempt to clarify the temporal relation between exposure and outcome by excluding cases of back pain with onset before the present job.

Chaffin and Park [1973] carried out a prospective study of back complaints in 411 employees of four electronics manufacturing plants. The outcome included visits to the plant medical department because of back complaints over a one-year period. Exposure was assessed by evaluating 103 jobs with a range of manual lifting for lifting strength rating (LSR) and load weights. The LSR is a ratio of the maximum weight lifted on the job to the lifting strength, in the same load position, for a large/strong man. Results showed a strong increase in back complaint incidence with LSR for both males and females (with an approximate five-fold increase in risk comparing males in the highest and lowest LSR). A similar increase was observed for females, although there were no women in the highest exposure category. No dose-response was observed by frequency of lifts (a relatively high risk of back complaints was observed for the lowest exposure category). Covariates (age, weight, and stature) were examined and found not to contribute to back complaints. The prospective study design helped increase the likelihood that exposure preceded disorder. Study limitations include lack of information on participation rates and an outcome consisting of incident reports. Time of true onset was not ascertained, and it is possible that symptom onset preceded or coincided with exposure assessment despite the longitudinal study design. The detailed exposure assessment addressed only lifting as a risk factor; presence of other risk factors related to back disorders was not identified.

A case-control study of prolapsed lumbar disc was carried out using a hospital population-based design [Kelsey et al. 1984]. Cases (n=232) included individuals diagnosed with prolapsed lumbar disc; an equal number of controls matched on sex, age, and medical service were selected. Exposure was assessed using a detailed occupational history that was not described but presumably was obtained by interview. An association with work-related lifting without twisting the body was observed at the highest lifting level (25 lb or more) (OR 3.8, 95% CI 0.7–20.1). Twisting without lifting was associated with disc prolapse (OR 3.0, 95% CI 0.9–10.2); a combination of both risk factors had an OR of 3.1 (95% CI 1.3–7.5). The highest risk was observed for simultaneous lifting and twisting with straight knees (OR 6.1, 95% CI 1.3–27.9). Despite the fact that exposures were self-reported, these associations were notably strong. The potential existed for differential recall bias for cases and controls because study subjects were interviewed about work-related factors after case status was established. Interviewers may not have been blinded to case/control status.

In Liles et al. [1984] prospective study of 453 individuals working in jobs with manual material handling requirements, incidence of back injuries was examined with regard to lifting. The study group included those who lifted frequently (at least 25 lifts per day of not less than 4.53 kg, with exposure of at least two hours per day). The outcome included reported or recorded lifting injuries to the back. Lifting exposures were assessed until job change (up to a two-year period) using the Job Severity Index (JSI). The JSI is a measure of the physical stress level associated with lifting jobs and is a function of the ratio of job demands to the lifting capacities of the person performing the job. Information on weight, frequency of lifting, and task geometry is collected through comprehensive task analysis. When the study group (working in 101 jobs from 28 plants) was classified into 10 equal categories according to JSI, a dose-response relationship with injury was observed (RR 4.5, 95% CI 1.02–19.9 for total injuries, comparing category 10 to category 1). Study limitations included no statement relating to response rate or participant selection, no adjustment for confounders, and no statistical testing. The outcome definition specified that the back injury be lifting-related, which increased the likelihood that the outcome would be related to the exposure measured. The prospective designassured that measured exposures preceded injury onset. Other strengths included objective assessment of exposure.

Using an unusual cross-sectional study design, Marras et al. [1993, 1995] examined the relationship between low-back disorders and spinal loading during occupational lifting. A total of 403 jobs from 48 diverse manufacturing companies were assessed for risk of low-back disorder using plant medical department injury reports. Jobs were ranked into three categories according to risk, then assessed for position, velocity, and acceleration of the lumbar spine during lifting motions in manual materials handling using electrogoniometric techniques. Those in high-risk jobs averaged 226 lifts per hour, with an average load weight of 88.4 N. A combination of five factors distinguished between high- and low-risk jobs: lifting frequency, load moment, trunk lateral velocity, trunk twisting velocity, and trunk sagittal angle. The highest combination of exposure measures produced an OR of 10.7 (95% CI 4.9–23.6 in comparison to the lowest combined measures). In univariate analyses, the most powerful single variable was maximum moment (a combination of both weight of the object and distance from the body), which yielded a significant OR of 3.3 between low- and high-risk groups [Marras et al. 1995]. The study design was unusual in that the unit of analysis appeared to be the job rather than the individual. Neither participation rates nor total number of participants was stated. No information appeared regarding the proportions of individuals within jobs who were recruited for measurement of lifting motions. However, the unit of analysis was job, and each was characterized by measurement of at least one study subject. Effects of covariates were not addressed (multivariate analyses appeared to include only biomechanical variables). The study results emphasized the multifactorial etiology of back disorders, including contributions of lifting frequency, loads, and trunk motions and postures. The study design did not allow for examination of temporal relationships.

Walsh et al. [1989] examined the relationship between self-reported LBP and work-related factors in a population-based cross-sectional study of 436 English residents. LBP was ascertained by interview, as was lifetime occupational history (including exposures to standing, walking, sitting, driving, lifting, and using vibrating machinery). Exposures were ascertained either as of the birthday prior to onset of symptoms or by lifetime occupational history prior to onset of symptoms. Using the most recent job (as of the birthday prior to symptoms), driving was associated with symptoms in males (RR 1.7, 95% CI 1.0–2.9), as was lifting or moving weights of 25 kg or more (RR 2.0, 95% CI 1.3–3.1), when all exposures were considered in multivariate analyses. For women, lifting (RR 2.0, 95% CI 1.1–3.7) was associated with symptoms. When lifetime exposures were considered, lifting remained significantly associated for males (RR 1.5, 95% CI 1.0–2.4). Both sitting (RR 1.7, 95% CI 1.1–2.6) and use of vibrating machinery (RR 5.7, 95% CI 1.1–29.3, based on one case) were associated with symptoms in females. The multivariate analyses stratified on sex and adjusted for age and simultaneous work exposures. While information on symptoms and exposures was obtained crosssectionally, the authors attempted to construct a retrospective cohort design by gathering data on lifetime work exposures and back symptoms. While in the design lifetime exposures were cumulated only prior to disorder onset, it would not be expected that participants could recall these relationships accurately. Temporal relationships were unclear.

Strength of Association

The most informative studies included those that employed independent measures of exposure to assess lifting demands, as they provided the best contrast among levels of exposure and were subject to the least misclassification. A case-control study by Punnett et al. [1991] found an OR of 2.16 (95% CI 1.0–4.7) for the relationship between back pain (ascertained by symptoms and medical exam) and lifting, after adjusting for covariates (including awkward postures). In their 1973 investigation, Chaffin and Park found a strong increase in incidence of medical visits related to back problems with increased LSR (with an approximate five-fold increase in risk comparing males in the highest and lowest categories); they did not find a similar dose-response relationship for frequency of lifts. Marras et al. [1993, 1995] examined the relationship between low-back injury reports and spinal loading during lifting, and found an OR of 10.7 (95% CI 4.9–23.6) for simultaneous exposures to lifting frequency, load weight, two trunk velocities, and trunk sagittal angle. Both lifting and postures contributed to the high ORs. In Magora's [1972, 1973] studies of LBP and occupational physical efforts, the highest LBP rate was observed in those who lifted rarely. When LBP was ranked by level of sudden maximal effort, the highest rate was seen for those who did it often, with a dose-response for three categories (10.9, 11.3, and 18.0, respectively, with a RR of 1.65 [95% CI 1.3–2.1]) when comparing lowest to highest). Liles et al. [1984] found a significant association between incidence of back injuries related to lifting and lifting exposures as assessed by JSI: the RR was 4.5 (95% CI 1.02–19.9) comparing the highest and lowest exposure categories. Burdorf et al. [1991] found no association between back pain symptoms and lifting load (the latter did not vary across the six job categories examined in the study). Huang et al. [1988] conducted detailed ergonomic evaluations of two school lunch preparation centers with differing rates of musculoskeletal (including back) disorders. The center with higher disorder rates had greater lifting and other work-related demands. Unfortunately, the study was ecologic in design and did not link exposures and outcomes to calculate risk estimates for the study groups, although several areas for ergonomic intervention were identified.

Other studies assessed exposures by self-report on interview or questionnaire. Johansson and Rubenowitz [1994] examined low-back symptoms by index of manual materials handling (which included lifting and other risk factors). In neither white- nor blue-collar workers was LBP significantly associated with the index. In Kelsey's 1975 case-control study of herniated lumbar discs, cases and controls had similar histories of occupational lifting (RR 0.94, p=0.10). In a second case-control study of prolapsed lumbar disc, Kelsey et al. [1984] found that an association with work-related lifting without twisting was observed only at the highest lifting level (OR 3.8, 95% CI 0.7–20.1). A combination of both risk factors at moderate levels yielded an OR of 3.1 (95% CI 1.3–7.5). The highest risk was seen for simultaneous lifting and twisting with straight knees (OR 6.1, 95% CI 1.3–27.9). Svensson and Andersson [1989] found a significant association between lifetime incidence of LBP and lifting in univariate analyses (RR 1.2, $p<0.05$), but not in multivariate analyses. Holmström et al. [1992] found an association between one-year prevalence of LBP and an index of manual materials handling (OR 1.27, 95% CI 1.2–1.4), after adjusting for age. No association was observed in multivariate analyses. Toroptsova et al. [1995] found that LBP and lifting were related in univariate analyses (OR 1.4, $p<0.05$); no multivariate analyses were conducted. In the Walsh et al. [1989] examination of LBP and work-related factors, LBP was associated with lifting (in jobs just prior to injury) (RR 2.0, 95% CI 1.1–3.7), when age, sex, and all exposures were considered in multivariate analyses. When lifetime exposures were considered, lifting remained significantly associated for males (RR 1.5, 95% CI 1.0–2.4). In Burdorf and Zondervan's 1990 study, an OR of 5.2 (95% CI 1.1–25.5) was observed for LBP and frequent lifting among crane operators. No relationship was seen for the referent group of noncrane operators from the same plant (OR 0.70, 95% CI 0.14–3.5).

In a study that determined exposure status on the basis of job title, Videman et al. [1984] found slightly higher rates (not significant) of LBP in nursing aides than in qualified nurses. The authors stated that aides had higher workloads related to patient handling and lifting. Knibbe and Friele [1996] found that LBP rates were higher for registered nurses than for nursing aides, whom they stated had more lifting responsibilities (OR 1.2, $p=0.04$). After adjusting for hours worked, however, aides had the higher rate (RR 1.3, no statistical testing done). Undeutsch et al. [1982] examined back pain in baggage handlers, a group characterized by frequent bending, lifting, and carrying of loads. Although no exposures were estimated for this group, symptoms were significantly associated with length of employment after adjusting for age ($p=0.035$).

In the studies using more quantitative exposure assessments, strengths of association for the relationships between low-back disorder and lifting included estimates including a negative relationship [Magora 1972], no association [Burdorf et al. 1991], and several positive associations with ORs in the 2.2–10.0 range. One study found a positive relationship between sudden maximal efforts and LBP (OR 1.7) [Magora 1973]. Punnett et al. [1991] found a point estimate of 2.16 after adjusting for other covariates; Chaffin and Park [1973] found a strong relationship (OR 5) for LSR (but not lifting frequency); Marras et al. [1993, 1995] found that the highest risk of injury was related to lifting in combination with posture-related risk factors (OR 10.7). Liles et al. [1984] observed an OR of 4.5 for back injuries and the highest JSI. The investigation of school lunch preparers did not calculate risk estimates [Huang et al. 1988].

Studies that used subjective measures of exposure found point estimates including none [Johansson and Rubenowitz 1994; Kelsey 1975a,b; Videman et al. 1984] to a range including 1.3, 1.4, 2.0, 3.8, and 5.2 [Burdorf and Zondervan 1990; Holmström et al. 1992; Kelsey et al. 1984; Knibbe and Freile 1996; Toroptsova et al. 1995; Undeutsch et al. 1982; Walsh et al. 1989]. Although the Kelsey et al. [1984] exposure estimates were based on self-report, they showed important relationships between lifting and posture in multivariate analyses. While the OR for lifting alone was 3.8 (for the highest lifting level), the OR rose to 6.1 when postures related to twisting and bent knees were included in the model.

In summary, the articles reviewed provide evidence of a strong positive association between low-back disorder and lifting. Results from these and other studies emphasized the importance of awkward postures in the risk of low-back disorder.

Temporal Relationship

Two prospective studies assessed exposures prior to identification of back disorders. Both demonstrated positive associations between exposure and back disorder. Thirteen of the 18 studies were cross-sectional analyses. In two of these, investigators excluded cases of LBP with onset prior to the current job to increase the likelihood that exposure preceded disorder. A third cross-sectional study truncated self-reported exposures on the birthday preceding disorder onset. One case-control study truncated exposures prior to disorder onset. Of the four cross-sectional and case-control studies which attempted to address temporality, three found positive relationships between lifting and back disorder.

Consistency in Association

Although the 18 studies used varying designs, outcomes, and exposure assessment methods, they were fairly consistent in demonstrating a relationship between lifting and low-back disorder when objective measures of exposure were used to evaluate populations with high exposures. Results were less consistent when subjective exposure measures were utilized.

A NIOSH review of earlier publications related to patient lifting demonstrated results consistent with this review [Jensen 1990]. A comprehensive literature search evaluated all studies published between 1967 and 1987 that contained original research on nursing personnel and back problems. Of 90 studies, six were identified which distinguished between two or more groups of nurses with differing frequencies of patient handling and reported on back problems for each group. A weighted analysis of results from the six reports demonstrated an overall increase in back problems of 3.7 in those in the higher lifting frequency category.

Coherence of Evidence

Lifting and manual materials handling have been studied as risk factors for low back disorder for decades. Studies of workers' compensation claims have shown that manual material handling tasks, including lifting, are associated with back pain in 25%-70% of injuries [Cust et al. 1972; Horal 1969; Snook and Ciriello 1991]. Data from the 1994 Bureau of Labor Statistics annual Survey of Occupational Injuries and Illnesses demonstrated that the industry with the highest rate of time-loss injuries due to overexertion was nursing and personal care facilities (where employees are required to engage in frequent patient handling and lifting).

During lifting, three types of stress are transmitted through the spinal tissues of the low back: compressive force, shear force, and torsional force [Waters et al. 1993]. It has been suggested that disc compression is believed to be responsible for vertebral end-plate fracture, disc herniation, and resulting nerve root irritation [Chaffin and Andersson 1984]. In early biomechanical assessments, models showed that large moments are created in the trunk area during manual lifting. Static evaluations of the trunk demonstrated that lifting results in large compressive forces on the spine.

More recently, biomechanical investigations have focused on spine loading and disc tolerances associated with asymmetric loading of the trunk. In laboratory experiments, dynamic trunk motion components of lifting have been associated with greater spine loading. Increased trunk motion during lifting activities has been associated with increased trunk muscle activity and intra-abdominal measures, among other changes [Marras et al. 1995]. Some laboratory studies have shown that lateral shear forces make trunk motions more vulnerable to injury than in a compressive loading situation. There is also *in vitro* evidence that the viscoelastic properties of the spine may cause increased strain during increased speed of motion [Marras et al. 1995].

Current models for lifting-related musculoskeletal injury stress that biomechanical considerations comprise only part of the assessment of risk [Waters et al. 1993]. Other criteria include physiologic measures of metabolic stress and muscle fatigue and psychophysical considerations (the worker's perception of his/her lifting capacity, a combination of perceived biomechanical and physiologic attributes of the job). All three criteria are important in assessing risk across the full spectrum of job and individual worker variability.

Exposure-Response Relationships

Eight studies examined exposure-response relationships in some form. Of these, four found dose-response relationships between low-back disorder and objective measures of lifting [Chaffin and Park 1973; Liles et al. 1984; Marras et al. 1995; Punnett et al. 1991]; another found a dose-response between disorder and sudden maximal efforts [Magora 1973]. A study of baggage handlers found an association between back disorder and length of employment [Undeutsch et al. 1982]. Two studies found no dose-response relationship (using a posture analysis assessment and a manual materials handling index) [Burdorf et al. 1991; Johansson and Rubenowitz 1994].

The majority of studies which examined exposure-response relationships, and in particular those that utilized quantitative exposure measures, demonstrated these trends.

Conclusions: Lifting and Forceful Movements

There is strong evidence that low-back disorders are associated with work-related lifting and forceful movements. The five studies reviewed for this chapter which showed no association between lifting and back disorder used subjective measures of exposure, poorly described exposure assessment methodology, or showed little differentiation of exposure within the study group. The remaining 13 studies were consistent in demonstrating positive relationships, where those using subjective measures of exposure showed a range of risk estimates from 1.2 to 5.2, and those using more objective assessments had ORs ranging from 2.2 to 11. Studies using objective measures to examine specific lifting activities generally demonstrated risk estimates above three and found dose-response relationships between exposures and outcomes. For the most part, higher ORs were observed in high-exposure populations (e.g., one high-risk group averaged 226 lifts per hour with a mean load weight of 88 N. Evidence from other studies and reviews has also suggested that groups with high- frequency exposure to lifting of heavy loads, such as nursing staff, are at high risk of back disorder.

Most of the investigations reviewed for this document adjusted for potential covariates in analyses: two-thirds of the studies showing positive associations examined effects of age and gender. Nevertheless, some of the relatively high ORs that were observed were unlikely to be caused by confounding or other effects of lifestyle covariates. Several studies suggested that both lifting and awkward postures were important contributors to the risk of low-back disorder. The observed relationships are consistent with biomechanical and other laboratory evidence regarding the effects of lifting and dynamic motion on back tissues.

BENDING AND TWISTING (AWKWARD POSTURES)

Definition

Bending is defined as flexion of the trunk, usually in the forward or lateral direction. Twisting refers to trunk rotation or torsion. Awkward postures include non-neutral trunk postures (related to bending and twisting) in extreme positions or at extreme angles. Several studies focus on substantial changes from non-neutral postures. Risk is likely related to speed or changes and degree or deviation from non-neutral position. For the purposes of this review, awkward postures also included kneeling, squatting, and stooping. In most of the studies included in this review, awkward postures were measured concurrently with other work-related risk factors for back disorder.

Studies Reporting on the Association Between LBP and Awkward Postures

Twelve studies examined the relationship between low back disorder and bending, twisting, and awkward postures (Table 6-3, Figure 6-3). Most (nine) also examined the effects of occupational lifting. See the previous discussion of lifting and forceful movements. Nine studies were cross-sectional in design, two case-control, and one prospective.

Participation rates were adequate for 83% of the investigations (Table 6-3). Four studies assessed postures using objective measures (however, in the study by Magora [1972], details on their observation methods were not reported; the rest estimated exposures from interview or questionnaire responses). Health outcomes included low-back and sciatic pain symptoms, lumbar-disc prolapse, and back injury reports. In four investigations, outcomes were defined using both symptoms and medical examination criteria. Only one investigation, the Punnett et al. [1991] case-control study of back pain in auto workers, fulfilled the four evaluation criteria (Table 6-3, Figure 6-3).

Several other studies, while not meeting all of the four criteria, are particularly notable because they used objective measures of exposure assessment [Burdorf et al. 1991; Marras et al. 1993, 1995] or met more than one of the criteria [Holmström et al. 1992; Kelsey et al. 1984]. As discussed earlier, the physical examination criterion may be less important in low-back disorders because of the paucity of specific physical findings in most cases of low-back disorders.

Descriptions of five studies which offered the most information regarding the effects of bending, twisting, and awkward postures follow. Please note that there is some overlap with studies that examined lifting effects. Detailed descriptions of the 12 studies appear in Table 6-6.

The Punnett et al. [1991] case-control study examined the relationship between back pain and occupational exposures in auto assembly workers. Back pain cases (n=95) were determined by symptoms at interview and medical examination; controls included those free of back pain. For all participants or proxies in the same jobs, jobs were videotaped and work cycles were reviewed using a posture analysis system. Exposures included time spent in various awkward postures. Peak biomechanical forces were estimated for up to nine postures where a load weighing at least 10 lb was held in the hands. In multivariate analyses that adjusted

for a number of covariates (age, gender, length of employment, recreational activity and medical history), time in non-neutral postures mild or severe flexion and bending were strongly associated with back disorder (OR 8.0, 95% CI 1.4–44). In the same model, lifting was also associated (OR 2.16, 95% CI 1.0–4.7). When the subset with physical medical findings was examined, associations were more pronounced. Although few study subjects were unexposed to all of the postures studied, a strong increase in risk was observed with both intensity and duration of exposure. It was not possible to determine the relative contributions of different awkward postures because all were highly correlated. Only participants' current jobs (for referents) or jobs when symptoms started (for cases) were analyzed; the study design thus assumed a short-term relationship between exposure and outcome. Although length of time in job was also included in the models, the authors attempted to ensure that exposure preceded disease by identifying time of onset and measuring exposures in the job held just prior. The strong associations, after adjustment for covariates, are notable.

Burdorf et al. [1991] examined back pain symptoms in a cross-sectional study of male concrete fabrication workers and a referent group of maintenance workers. Back pain symptoms were assessed by questionnaire. Exposures were measured using the Ovako Working Posture Analysis System, which assessed postures for the back and lower limbs, along with lifting load. Information on exposures in previous jobs was also collected.

Concrete workers experienced significantly more back symptoms than referents (OR 2.8, 95% CI 1.3–6.0).

Univariate results showed associations between back pain and both posture index and WBV in current job. Correlations were presented showing lifting was not found to be associated with back pain or to vary significantly across the six job categories examined in the study. In multivariate analyses adjusting for age, both posture index and WBV were significantly associated with back pain, with ORs of 1.23 (p=0.04) (for an ordinal scale of 6) and 3.1 (p=0.001) (dichotomous), respectively. Those in the highest posture index category were steel benders, who spent an average of 47% of their time in bent back postures (compared to 12% for the lowest exposed group). The posture index and WBV measures were highly correlated and analyzed separately. Strengths of the study included use of a standardized symptom questionnaire, high participation rates and objective measure of exposure, and an attempt to clarify the temporal relation between exposure and outcome by excluding cases of back pain with onset before the present job.

Using an unusual cross-sectional study design, Marras et al. [1993, 1995] examined the relationship between low-back disorders and spinal loading during occupational lifting. A total of 403 jobs from 48 diverse manufacturing companies were assessed for risk of low-back disorder using plant medical department injury reports. Jobs were ranked into three categories according to risk then assessed for position, velocity, and acceleration of the lumbar spine during lifting motions in manual materials handling using electrogoniometric techniques. A combination of five factors distinguished between high- and low-risk jobs: lifting frequency, load moment, trunk lateral velocity, trunk twisting velocity, and trunk sagittal angle. The highest combination of exposure measures produced an OR of 10.7 (95% CI 4.9–23.6) (in comparison to the lowest combined measures). The study design was unusual in that the unit of analysis appeared to be job rather than individual. Neither participation rate nor total number of participants was stated. No information appeared regarding the proportions of individuals within jobs who were recruited for measurement of lifting motions. However, the unit of analysis was job, and each was characterized by measurement of at least one study subject. Effects of other covariates were not addressed (multivariate models appeared to include only biomechanical variables). The study results emphasize the multifactorial etiology of back disorders, including contributions of lifting frequency, loads, and trunk motions and postures. The study design did not allow for examination of temporal relationships.

A case-control study of prolapsed lumbar disc was carried out using a hospital population-based design [Kelsey et al. 1984]. Cases (n=232) included individuals diagnosed with prolapsed lumbar disc; an equal number of controls matched on sex, age, and medical service were selected. Exposure was assessed using a detailed occupational history (not described, but presumably obtained by interview). An association with work-related lifting, without twisting the body, was observed at the highest lifting level (OR 3.8, 95% CI 0.7–20.1). Twisting without lifting was associated with disc prolapse (OR 3.0, 95% CI 0.9–10.2); a combination of both risk factors had an OR of 3.1 (95% CI 1.3–7.5).

The highest risk was observed for simultaneous lifting and twisting with straight knees (OR 6.1, 95% CI 1.3–27.9). Despite the fact that exposures were self-reported, these associations were notably strong. The potential existed for differential recall bias for cases and controls, because study subjects were interviewed about work-related factors after case status was established. Interviewers may not have been blinded to case/control status.

Holmström et al. [1992] examined the relationship between LBP and work task activities in a cross-sectional study of male construction workers. One-year prevalence of LBP was ascertained by questionnaire. A sample of workers was clinically examined. Exposure relative to lifting, handling, and work postures was obtained by self-report. After adjustment for age, the index for manual material handling, which included lifting, was associated with LBP with a RR of 1.27 (95% CI 1.2–1.4). Stooping and kneeling postures showed a dose-response relationship with LBP, particularly severe LBP (with ORs 1.3, 1.8, and 2.6 in comparison to those with no stooping; ORs 2.4, 2.6, and 3.5 in comparisons to those with no kneeling, respectively). No association was observed with sitting. In multiple regression analyses, LBP was associated with stooping ($p<0.001$) and kneeling ($p<0.01$). While the authors attempted to adjust for some covariates (age, gender, and psychosocial factors) in analyses, they did not appear to examine simultaneous effects of physical work-related factors in a single model. The cross-sectional design could not ascertain the temporal relationships between exposure and disorder.

Strength of Association

The more informative studies included the Punnett et al's [1991] case-control investigation, which fulfilled the four evaluation criteria, plus several others that used independent exposure assessments. In the Punnett et al. study, multivariate analyses that adjusted for covariates demonstrated that time in non-neutral postures was strongly associated with back disorders (OR 8.09, 95% CI 1.4–44). In the same model, the OR for lifting was 2.2. Burdorf et al. [1991] found associations between posture index and back symptoms in both univariate and multivariate analyses: in multivariate analyses adjusting for age, the OR for posture index was 1.23 (p=0.04), for an ordinal scale of six levels. Posture index was highly correlated with WBV. However, the Kelsey et al's [1984] case-control study of prolapsed lumbar discs found that twisting without lifting had an OR of 3.0 (95% CI 0.9–10.2); in combination, the two had an OR of 3.1 (95% CI 1.3–7.5). The highest risk was observed for a combination of lifting, twisting, and straight knees (OR 6.1, 95% CI 1.3–27.9). In the Marras et al. [1993, 1995] cross-sectional study, back injuries were associated with spinal loading during lifting, which included simultaneous exposures to lifting frequency, load weight, trunk lateral velocity, trunk twisting velocity, and trunk sagittal angle. An OR of 10.7 (95% CI 4.9–23.6) was observed for the highest combination of exposure measures. Univariate ORs were 1.73 (95% CI 1.38–2.15) for trunk lateral velocity, 1.66 (95% CI 1.34–2.05) for trunk twisting velocity, and 1.60 (95% CI 1.31–193) for maximum sagittal flexion when comparing the high-and low-risk groups [Marras et al. 1993].

The other studies showed a range of point estimates. In univariate analyses, Magora [1972, 1973] found that for bending, the highest rate of LBP was observed for the rarely/never category. For twisting and reaching, the highest LBP rate was in the sometimes category. Johansson and Rubenowitz [1994] found no associations between low-back symptoms and bent or twisted work postures in blue- and white-collar workers. After adjustment for age and gender, however, extreme work postures were significantly associated with the outcome in blue-collar workers. Relationships were presented as partial correlations, thus preventing calculation of risk estimates. Riihimäki et al. [1994] observed that occupational exposure to twisted and bent postures were associated with incidence of sciatic pain in univariate but not multivariate analyses. No risk estimates were provided. In Svensson and Andersson's 1989 study of LBP in Swedish women, bending forward was associated with lifetime incidence in univariate (RR 1.3, $p<0.05$) but not multivariate analyses. The Masset and Malchaire [1994] univariate analyses demonstrated that trunk torsions were associated with LBP in steel workers (OR 1.55, $p<0.05$); no associations were shown in multivariate analyses. Toroptsova et al. [1995] demonstrated that LBP in the past year was associated with bending (OR 1.7, $p<0.01$) in univariate analyses (multivariate analyses were not conducted). Riihimäki et al. [1989a] observed a dose-response for sciatic pain and self-reported twisted or bent postures; the OR for the highest exposure category was 1.5 [95% CI 1.2–1.9]. Holmström et al. [1992] observed that stooping and kneeling postures were associated with LBP, particularly severe disorder, with ORs of 2.6 and 3.5 ($p<0.05$), respectively.

In summary, three of the four studies using more quantitative exposure assessments showed elevated risk estimates for the relationship between low-back disorder and bending, twisting, or awkward postures, with ORs ranging from 1.23 (for a scaled variable) to 8.09; the highest risk estimate, an OR of 10.7, was based on combined exposure to lifting and posture risk factors. Most of these were based on multivariate analyses that adjusted for covariates (usually age and gender). The remaining studies demonstrate risk estimates ranging from no association (in one study), 1.3–1.7 in univariate but not multivariate analyses, to a high of 3.5 in another study. Studies utilized a number of definitions for awkward postures, as noted**.**

Temporal Relationship

One prospective study assessed exposures prior to identification of back disorders. Results demonstrated positive associations in univariate but not multivariate analyses. [Riihimäki et al. 1994]. Nine of 12 studies were cross-sectional in design. In one of these, investigators excluded cases of LBP with onset prior to the current job to increase the likelihood that exposure preceded disorder. [Burdorf et al. 1991]. No association between exposure and back disorder was observed. One case-control study examined only exposures experienced in the job just prior to disorder onset [Punnett et al. 1991]. A strong association between exposure to awkward postures and back pain was observed.

Consistency in Association

Although the 12 studies used varying designs, outcomes, and exposure assessment methods, the studies using quantitative exposure measures were fairly consistent in demonstrating a moderate relationship between awkward postures and low-back disorder.

Coherence of Evidence

Nine of the 12 studies which examined posture effects also studied effects of lifting. Therefore, a discussion of coherence of evidence for the former relationship is similar to that found in the section on lifting and forceful movements. Forward flexion can generate compressive forces on the structures of the low back similar to lifting a heavy object. Similarly, rapid twisting can generate shear or rotational forces on the low back [Marras et al. 1995].

Exposure-Response Relationships

Six studies examined dose-response relationships between posture and low-back disorder. In one, no dose-response relationship was found between LBP and estimates for bending and twisting/reaching. In the other five studies, relationships were demonstrated between back injury and spinal loading score, LBP and posture index, sciatic pain and awkward postures, LBP and stooping, and low-back symptoms and kneeling.

Conclusions: Awkward Postures

The investigations that were reviewed provided evidence that low-back disorders are associated with work-related awkward postures. Results were consistent in showing increased risk of back disorder with exposure, despite the fact that studies defined disorders and assessed exposures in many ways. Several studies found risk estimates above three and dose-response relationships between exposures and outcomes. Many of the studies adjusted for potential covariates in their analyses, and a few examined the simultaneous effects of other work-related risk factors in analyses. Several studies suggested that both lifting and awkward postures were important contributors to risk of low back disorder.

WHOLE BODY VIBRATION (WBV)

Definition

WBV refers to mechanical energy oscillations which are transferred to the body as a whole (in contrast to specific body regions), usually through a supporting system such as a seat or platform. Typical exposures include driving automobiles and trucks, and operating industrial vehicles.

Studies Reporting on the Association Between LBP and Whole Body Vibration

Nineteen investigations addressed WBV as a risk factor for back disorder. Fifteen study designs were cross-sectional, two were cohort, one was case-control, and one had both cross-sectional and cohort components.

None of the 19 studies fulfilled all of the four evaluation criteria (Table 6-4, Figure 6-4). Participation rates were over 70% for 13 investigations. Seven used independent measures of exposure for estimation of WBV; in 10 studies, exposure information was obtained by questionnaire or interview. In two studies, exposure to WBV was based on job title alone. Health outcomes included symptom report of LBP, sciatica, or lumbago, sick leaves or disability retirements related to back disorders, and medically confirmed herniated lumbar disc.

Five of the nine studies which met two or more of the evaluation criteria used similar methodologies and offered the most information regarding the association between WBV and back disorder. Detailed descriptions for all 19 investigations can be found in Table 6-6.

Bovenzi and Betta [1994] examined the relationship between WBV and back disorder in a cross-sectional study of male tractor drivers. The unexposed group included male revenue inspectors and administration workers with no vibration exposure. Outcomes included various types of back symptoms reported by questionnaire. Vibration measures were obtained from a representative sample of tractors and linked to individual information on number of hours driven yearly (obtained by questionnaire). Self-reported exposures to postural loads were also obtained. In comparison to referents, tractor drivers demonstrated an OR of 3.22 (95% CI 2.1–5.2) for lifetime LBP. For LBP in the past year, the OR was 2.39 (95% CI 1.6–3.7). For LBP in the past year, ORs ranged from 2.31 to 3.04 by exposure levels for total vibration dose, equivalent vibration magnitude, and duration of exposure, after adjustment for covariates. In multivariate analyses, chronic LBP showed a dose-response relationship with total vibration dose (OR 2.00, 95% CI 1.2–3.4, for the highest category), equivalent vibration magnitude (OR 1.78, 95% CI 1.04–3.0, for the highest category), and duration of exposure (OR 2.13, 95% CI 1.2–3.8, for the highest category). Exposure-response relationships were observed for postural load categories, with ORs of 4.56 (95% CI 2.6–8.0) for LBP in the past year and 2.30 (95% CI 1.2–4.5) for chronic LBP (for the highest exposure categories). Multivariate analyses adjusted for age, body mass index, education, sports activity, car driving, marital status, mental stress, climatic conditions, back trauma and postural load (or vibration dose, depending upon the exposure examined).

Bovenzi and Zadini [1992] used a similar cross-sectional study design to examine low back symptoms in male bus drivers. Referents included maintenance employees who worked for the same company. Back pain symptoms were assessed by questionnaire. WBV was measured for a sample of buses used over the relevant time period. Cumulative vibration exposures were calculated using this information, along with questionnaire items related to work duration, hours, and previous exposures. In comparison to referents, bus drivers demonstrated an OR of 2.80 (95% CI 1.6–5.0) for lifetime LBP; the OR for LBP in the past year was 2.57 (95% CI 1.5–4.4). In multivariate analyses, the ORs for LBP in the previous year were 1.67, 3.46, and 2.63 for three total vibration dose categories. Similar trends were observed for other measures of vibration (equivalent vibration magnitude and total duration of exposure), and after exclusion of those with exposure in previous jobs. Statistically significantly increasing trends were observed for nearly all types of back symptoms by exposure level (to all three measures of vibration) after adjustment for covariates. Multivariate analyses adjusted for age, awkward postures, duration of exposure, body mass index, mental workload, education, smoking, sports activities, and previous exposures.

Three studies of WBV effects were conducted by the same group of Dutch investigators. The first examined back pain and WBV exposures cross sectionally in male helicopter pilots [Bongers et al. 1990]. A referent group of nonflying Air Force officers (with characteristics similar to pilots) was also included. Information on back symptoms was obtained by questionnaire. Vibration measures were assessed in two helicopters of each type used by the study group. Individual exposures were calculated by matching this with questionnaire items related to hours of flying time and types of helicopters flown. Information on exposure to bent/twisted postures was also obtained by questionnaire. In comparison to controls, ORs for pilots were elevated for a number of back symptoms: 9.0 (95% CI 4.9–16.4) for LBP and 3.3 (95% CI 1.3–8.5) for sciatica. All of the above were adjusted for age, height, weight, climate, bent and twisted postures, and feeling tense at work. In multivariate analyses, ORs for LBP were 13.8, 7.5, 6.0, and 13.4 for four categories for total flight time (in comparison to controls). ORs for LBP by total vibration dose were 12.0, 5.6, 6.6, and 39.5. By hours of flight time per day, ORs were 5.6, 10.3, and 14.4 for LBP. Although there was some concern that pilots with back pain may have dropped out of employment, risk estimates were high (particularly in analyses by exposure level). Transient back pain appeared to increase with daily exposure time, while chronic back pain appeared more associated with total flight time and total vibration dose.

In a second study by the same group, WBV exposures were examined in male tractor drivers and a referent group of inspectors and maintenance technicians [Boshuizen et al. 1990a,b]. Two investigations were conducted using the same population: a 1986 cross-sectional study of a cohort identified in 1975, and a cohort analysis of sick leaves and disability retirements due to back disorder through the same time period. For the cross-sectional analyses, information on back symptoms was obtained by questionnaire. Vibration was measured for a sample of vehicles and linked with questionnaire information related to types of vehicles driven, hours, and previous employment. Information regarding exposure to awkward postures was also collected. Results from the cohort analysis showed an incidence density ratio of 1.47 (95% CI 1.04–2.1) for a comparison of sick leaves due to back disorders in exposed and referent groups. An increase in sick leaves for disc disorders by vibration dose was observed, with an OR of 7.2 (95% CI 0.92–179) for the highest category. Cross-sectional study results demonstrated increases in LBP symptom prevalence by vibration dose category. Multivariate ORs increased by vibration dose (an OR of 2.8, 95% CI 1.6–5.0, for the highest category) and years of exposure (an OR of 3.6, 95% CI 1.2–11, for the highest category) after adjustment for duration of exposure, age, height, smoking, awkward postures, and mental workload.

Boshuizen et al. [1992] also conducted a cross-sectional study of back pain in fork-lift truck and freight container tractor drivers exposed to WBV. Referents included other employees working for the same shipping company, but with no vibration exposure. Back pain symptoms were assessed by questionnaire. Exposures were estimated by measurement of vibration in a sample of vehicles, combined with questionnaire responses. Cumulative exposures were calculated, truncating at time of symptom onset. Prevalence of back pain was higher in the exposed group than in referents: the RR for back pain was 1.4 ($p<0.05$); RRs for LBP and lumbago were 1.4 ($p<0.05$) and 2.4 ($p<0.05$), respectively, after adjusting for age. Differences in LBP were observed only in younger age groups after multivariate adjustment for mental stress, years of lifting, awkward postures, height, smoking, and hours of sitting. There was no association between total vibration dose and back pain (OR 0.99, 95% CI 0.85–1.2) or lumbago (OR 1.14, 95% CI 0.91–1.4). Only vibration in the 5 years immediately preceding symptom onset was significantly associated with back pain (OR 2.4, 95% CI 1.3–4.2) and lumbago (OR 3.1, 95% CI 1.2–7.9). It appeared that a healthy worker selection effect was operating, as differences in back pain were observed only for those in younger age groups.

Evaluation of the Causal Relationship Between Back Disorder and Whole Body Vibration

Strength of Association

Recent studies that included quantitative exposure assessments provided the most information regarding the relationship between WBV and back disorder [Bongers et al. 1988; Boshuizen et al.1990a, b; Bovenzi and Betta 1994; Bovenzi and Zadini 1992]. (Two other recent studies also described quantitative exposure assessments, but no results relating to these were presented [Burdorf et al. 1993; Magnusson et al. 1996]). In all five, ORs were calculated by levels of vibration exposure, expressed in several ways (usually including magnitude and duration of exposure). In the five studies, overall ORs comparing back pain in exposed and referent groups ranged from 1.4 [Boshuizen et al. 1992] to 9.5 [Bongers et al. 1990]. Analyses conducted by exposure level demonstrated stronger relationships. In Bovenzi and Betta's 1994 study of tractor drivers, ORs for lifetime LBP were 3.79 for total vibration dose, 3.42 for equivalent vibration magnitude, and 4.51 for duration of exposure (for the highest exposure levels). For LBP in the previous year, ORs were 2.36, 2.29, and 2.74 for the highest levels of the same three exposure measures. In Bovenzi and Zadini's 1992 study of urban bus drivers, the highest ORs for LBP were observed for intermediate rather than the highest exposure categories: 3.46 for total vibration dose, 3.77 for equivalent vibration magnitude, and 3.08 for total duration of WBV exposure. The Bongers et al. [1990] investigation of back pain in helicopter pilots demonstrated that the highest ORs for LBP were found in the highest categories for total flight time (OR 13.4, 95% CI 5.7–32), total vibration dose (OR 39.5, 95% CI 10.8–156) and hours of flight time per day (OR 14.4, 95% CI 5.4–38.4). A study of tractor drivers demonstrated LBP ORs of 2.8 (95% CI 1.6–5.0) for the highest total vibration dose and 3.6 (95% CI 1.2–11) for the highest exposure duration category [Boshuizen et al. 1990a]. In the same population, the OR for all sick leaves due to back disorder was 1.47, comparing exposed (95% CI 1.04–2.1) and referent groups [Boshuizen et al. 1990b]. For sick leaves related to intervertebral disc disorders, the highest OR was observed for the highest exposure category (OR 7.2, 95% CI 0.92–179). The Boshuizen et al. [1992] study of forklift truck and freight container tractor drivers showed no association between back pain and total vibration dose (OR 0.99, 95% CI 0.85–1.2) but did show an association for vibration in the preceding five years (OR 2.4, 95% CI 1.3–4.2). In this study the increase in LBP prevalence in the exposed group was only significant for those in younger age groups (an OR of 5.6 for those age 25-34) in multivariate analyses. In all five of these cross-sectional studies, ORs were calculated by vibration exposure category after adjusting for a number of covariates, as mentioned in the detailed study descriptions, above.

Other studies assessed both exposure and low-back disorder by interview or questionnaire. Burdorf and Zondervan [1990] observed no association between WBV exposure and LBP in crane operators in univariate analyses (OR 0.66, 95% CI 0.14–3.1); no associations were observed in multivariate analyses. Toroptsova et al. [1995] also found no association between LBP and vibration in their study (no definition for vibration was provided, but WBV was suggested). In the Riihimäki et al. 1994 prospective study, sciatic pain was associated with vibration in univariate but not multivariate models (no risk estimates were provided). While the definition for "vibration" was not clear, the authors suggested it could be interpreted as low-level WBV. The Masset and Malchaire [1994] cross-sectional study found that LBP was associated with vehicle driving (OR 1.2, $p<0.001$) in univariate analyses. Similar results were observed in multivariate analyses (OR 1.2, $p<.005$). Riihimäki et al. [1989a] observed an OR of 1.3 (95% CI 1.1–1.7) for longshoremen and earthmovers in comparison to a referent group with no vibration exposure. In the same study, no association was seen for annual car driving (OR 1.1, 95% CI 0.9–1.4). Walsh et al. [1989] found that driving (on job held prior to symptoms) was significantly associated with low-back symptoms in males (RR 1.7, 95% CI 1.0–2.9) after adjusting for age and other job exposures in multivariate analyses. Burdorf et al. [1991] found that WBV was significantly associated with back pain (OR 3.1, $p=0.001$) in multivariate analyses that adjusted for age. The Kelsey [1975a] case-control study found a significant association between herniated lumbar disc and time driving (OR 2.75, $p=0.02$), and more specifically, working as a truck driver (OR 4.7, $p<0.02$). Burdorf et al. [1993] investigation demonstrated an OR of 3.29 (95% CI 1.5–7.1) for crane operators and 2.51 (95% CI 1.5–5.4) for vibration-exposed straddle-carrier drivers after adjusting for a number of covariates. In a study of Danish salespeople, annual driving distance was associated with low-back symptoms [Skov et al. 1996]. A dose-response relationship was observed in multivariate analyses, with an OR of 2.79 (95% CI 1.5–5.1) for the highest category.

Four studies assessed exposures primarily by job title. Magnusson et al. [1996] observed an OR of 1.79 (95% CI 1.2–2.8) for bus and truck drivers in comparison to an unexposed referent group. In a study of crane operators, the exposed group demonstrated ORs of 2.00 (95% CI 1.1–3.7) for all intervertebral disc disorders and 2.95 (95% CI 1.2–7.3) for disc degeneration after adjustment for age and shift [Bongers et al. 1988]. An examination of risk estimates of disc degeneration by years of exposure showed the highest OR (5.73) in the highest exposure category. In the Johanning [1991] study of subway train operators, an OR of 3.9 (95% CI 1.7–8.6) was observed for sciatica. While not a primary focus of the Magora [1972, 1973] studies of LBP in eight selected occupations, it was observed that bus drivers had back pain rates similar to those of the comparison group of bankers (RR 1.19, 95% CI 0.8–1.7).

Thus, four out of five studies using quantitative exposure assessments demonstrated positive associations between back disorder outcomes and vibration exposures, with ORs ranging from 1.4 to 39.5. The fifth cross-sectional study found no overall association between exposure and back disorder but found associations in selected subgroups (which suggested that the study population was biased, as noted above). In all of these studies, risk estimates by exposure category were calculated after adjustment for many covariates.

In the remaining studies, risk estimates varied, including no association (n=3), ORs of 1.2, 1.7, and 2.8 for driving, an OR of 1.8 for truck or bus driving, an OR of 4.7 for truck driving, an OR of 1.3 for machine operation, ORs of 2.0, 2.95 and 5.73 for crane operation, an OR of 3.1 for WBV, and an OR of 3.9 for subway train operation.

In summary, the evidence from these investigations suggests a positive association between WBV and back disorder. Relationships were particularly strong for high-exposure groups where exposures were assessed using observational or measurement approaches.

Temporal Relationship

Three studies had prospective designs in which temporal relationships between outcome and exposure could be determined [Bongers et al. 1988; Boshuizen et al. 1990b; Riihimäki et al. 1994]. In two of these, clear positive relationships between back disorder and exposure were demonstrated [Bongers et al. 1988; Boshuizen et al. 1990b]. Twelve studies had a cross-sectional design that could not directly address temporality. However, three attempted to clarify relationships by excluding from analysis the cases with disorder onset prior to current job [Burdorf et al. 1991, 1993; Burdorf and Zondervan 1990]. A fourth cross-sectional study truncated self-reported exposures on the birthday preceding disorder onset [Walsh et al. 1989]. In these four investigations, positive relationships between back disorder and WBV were also observed.

Consistency in Association

Results with regard to the relationship between low back disorder and WBV were most consistent in the studies using observational or measurement approaches to exposure assessment. The strength of association was more variable in studies using job titles or questionnaires to assess exposures. The variability in the associations does not appear to be related to confounding exposures, since most studies adjusted for age, gender and at least several other confounders. Studies using more quantitative exposure measures were fairly consistent in showing the higher risk estimates.

In addition to the epidemiologic investigations that were reviewed for this document, many more were conducted in the 1960s though the 1980s. Others have summarized this evidence in earlier reviews. Hulshof and Veldhuijzen van Zanten [1987] concluded that, although studies varied in methodologies and quality, most showed a strong tendency toward a positive association between WBV exposure and LBP. Seidel and Heide [1986] stated that the literature they reviewed indicated an increased risk of spine disorders after intense long-term exposure to WBV. Bongers and Boshuizen [1990] conducted a meta-analysis of studies published through 1990 that examined the relationship between WBV and several back disorders. The overall OR for WBV exposure and degenerative changes of the spine was 1.5; the summary OR for LBP was also 1.5. These conclusions are consistent with the positive associations observed in the evidence reviewed above (although the studies published in the 1990s have tended to report larger ORs).

Other evidence for the relationship is provided by surveillance data. The U.S. population-based National Health Interview Survey, carried out in 1988, found that males employed as truck drivers and tractor equipment operators had a RR of 2.0 for back pain in comparison to all male workers [Guo et al. 1995].

Coherence of Evidence

Laboratory studies have shown that exposure to WBV causes spine changes that may be related to back pain. These include fatigue of the paraspinal muscles and ligaments, lumbar disc flattening, disc fiber strain, intradiscal pressure increases, disc herniation, and microfractures in vertebral end-plates [Wilder and Pope 1996]. Studies of acute effects have shown that the vertebral end-plate is the structure that is most sensitive to high WBV exposure, followed by the intervertebral disc [Wikström et al. 1994]. Experimental investigations have demonstrated that high exposures to vibration cause injuries such as degeneration and fracturing of the vertebral end-plate. With regard to intervertebral discs, several studies have suggested that vibration causes creep, an increase in intradiscal pressure resulting from compressive loading. Pressure peaks may cause ruptures in the superficial structure of the disc and changes in the nutritional balance that lead to degeneration. Thus, prolonged vibration exposure may cause spine pathology through mechanical damage and/or changes in tissue metabolism.

In addition to pathology of the vertebrae and intervertebral discs, vibration exposure has been shown to cause changes in electromyographic (EMG) activity in muscles of the lower back [Wikström et al. 1994]. For example, EMG experiments have demonstrated that lower back muscle exhaustion increases during WBV exposure in truck driving. Decreased stability of the lower back may result from slower muscle response, perhaps increasing the risk of injuring other structures.

Laboratory investigations have shown that other work-related factors, including prolonged sitting, lifting, and awkward postures, may act in combination with WBV to cause back disorder [Dupuis 1994; Wikström et al. 1994; Wilder and Pope 1996].

Exposure-Response Relationships

Five of six studies which carried out quantitative exposure assessment demonstrated exposure-response relationships between WBV and back disorder.

Bovenzi and Betta [1994] observed a dose-response between chronic LBP and total vibration dose, equivalent vibration magnitude, and duration of exposure. Bovenzi and Zadini [1992] found statistically significantly increasing trends for nearly all types of back symptoms by exposure level, after adjustment for covariates. Bongers et al. [1990] demonstrated increased ORs for sciatic pain and transient back pain with increasing hours of daily flight time. In their cohort of tractor drivers, Boshuizen et al. [1990b] observed an increase in risk of sick leaves for disc disorder by total vibration dose level.

In other studies, Bongers et al. [1988] found an increase in risk of disc degeneration by years of exposure to crane operation; Skov et al. [1996] found an increase in low-back symptoms with annual driving distance. Johanning [1991] found no association between years of employment as a subway train operator and back pain symptoms.

The majority of studies which examined back disorders by exposure level demonstrated dose-response relationships.

Conclusions: Whole Body Vibration

There is strong evidence of a positive association between exposure to WBV and back disorder. Of the 19 studies reviewed for this chapter, four demonstrated no association between WBV and back pain. Possible explanations for these results included use of subjective exposure assessments that perhaps resulted in misclassification of exposure status and, in one cross-sectional study, operation of a healthy worker selection effect (where those with higher exposures dropped out of the study group). The remaining 15 studies were consistent in demonstrating positive associations, with risk estimates ranging from 1.2 to 5.7 for those using subjective exposure measures, and from 1.4 to 39.5 for those using objective assessment methods. Most of the studies that examined relationships in high-exposure groups using detailed quantitative exposure measures found strong positive associations and exposure-response relationships between WBV and back pain. These relationships were observed after adjusting for age and gender, along with several other covariates (which, depending on the study, may have included smoking status, anthropometric measures, recreational activity, and physical and psychosocial work-related factors). This evidence is supported by results observed in many earlier epidemiologic investigations that have been summarized in other reviews.

Laboratory studies have demonstrated WBV effects on the vertebrae, intervertebral discs, and supporting musculature. Both experimental and epidemiologic evidence suggests that WBV may act in combination with other work-related factors such as prolonged sitting, lifting, and awkward postures to cause increased risk of back disorder.

It is possible that effects of WBV may depend on the source of exposure. For example, in the studies reviewed for this document, ORs were particularly high for helicopter pilots. It was not possible to determine differences for other types of vehicles (automobiles, trucks, and agricultural, construction, and industrial vehicles).

STATIC WORK POSTURES

Definition

Static work postures include isometric positions where very little movement occurs, along with cramped or inactive postures that cause static loading on the muscles. In the studies reviewed, these included prolonged standing or sitting and sedentary work. In many cases, the exposure was defined subjectively and/or in combination with other work-related risk factors.

Studies Reporting on the Association Between LBP and Static Work Postures

Ten studies examined relationships between low back disorder and static work postures, which may have included prolonged sitting, standing, or sedentary work. For none was static work posture the primary occupational exposure of interest. Instead, it was often one of many variables examined in larger studies of several or many work-related risk factors. Nine of the studies were cross-sectional in design; one was a case-control study.

None of the investigations fulfilled the four research evaluation criteria (Table 6-5, Figure 6-5). Participation rates were acceptable for 60%. For four, case definitions included both symptoms and medical examination criteria. Health outcomes included symptom report of back pain, sciatica, or lumbago, back pain as ascertained by symptoms and medical exam, herniated lumbar disc, and lumbar disc pathology. One study claimed to assess job-related exposures by observation; the nine others obtained information on static work postures by self-report on interview or questionnaire.

Below are descriptions of four of the more informative studies. Detailed descriptions for all 10 investigations are found in Table 6-6).

Burdorf and Zondervan [1990] carried out a cross-sectional study comparing 33 male crane operators with noncrane operators from the same Dutch steel plant, matched on age. Symptoms of LBP and sciatica were assessed by questionnaire. Activities in current and past jobs were assessed by questionnaire; exposures were rated according to level of heavy work, frequency of lifting, WBV, and prolonged sedentary posture. Crane operators were significantly more likely to experience LBP (OR 3.6, 95% CI 1.2–10.6). Among crane operators alone, the OR for heavy work was 4.0 (95% CI 0.76–21.2) after controlling for age, height, and weight. It was determined that this heavy work occurred in the past and not in current jobs. Among crane operators alone, the OR for frequent lifting was 5.2 (95% CI 1.1–25.5). The frequent lifting in crane operators was also determined to be from jobs held in the past. Among noncrane operators, history of frequent lifting exposure was not associated with LBP (OR 0.70, 95% CI 0.14–3.5). Among crane operators, univariate ORs for WBV and prolonged sedentary postures were 0.66 (95% CI 0.14–3.1) and 0.49 (95% CI 0.11–2.2), respectively. In multivariate analyses controlled for age, height, weight, and current crane work, associations with specific work-related factors were substantially reduced; the high prevalence of LBP in crane operators was explained only by current crane work. No measures of dose-response were examined. Limitations included a low response rate for crane operators (67%), with some suggestion that those with illness may have been underrepresented (perhaps underestimating the OR), and self-report of health outcomes and exposures. The investigators excluded cases of LBP with onset before the present job to increase the likelihood that exposure preceded disease.

Kelsey [1975b] carried out a hospital population-based case-control study of herniated lumbar discs and their relationship to a number of workplace factors, including time spent sitting, chair type, lifting, pulling, pushing, and driving. Cases were defined by symptoms, medical evaluation, and radiology; exposures were ascertained by interview (over lifetime job history). Cases (n=223) and controls (n=494 unmatched controls) had similar histories of job-related lifting (RR 0.94, p=0.10). Findings indicated that sedentary work (sitting more than half the time at work) was associated with disc herniation, but only for the age group 35 years and older (RR 2.4, p=0.01). (The RR for those less than 35 was 0.81). Disc herniation was also associated with time spent driving (RR 2.75, p=0.02) and, more specifically, with working as a truck driver (RR 4.7, p<0.02), suggesting a relationship with WBV. The study design had several potential limitations, including possible unrepresentativeness of the study population (because the group was hospital-based). As exposure information was obtained retrospectively, cases may have over-reported exposures thought to be associated with back problems. Strengths include a well-defined outcome and consistent results in comparisons to the two control groups.

Svensson and Andersson [1989] examined LBP in a population-based cross-sectional study of employed Swedish women. Information on LBP and sciatica was obtained by questionnaire, as were exposure-related items. Physical exposures included lifting, bending, twisting, other work postures, sitting, standing, monotony, and physical activity at work. Lifetime IRs varied by occupation, with ranges from 61%–83% in younger age groups and 53%–75% in older groups. After the study was completed, the authors noted that for these women, the highest lifetime incidence of LBP was not found in jobs with the highest physical demands. The measure for "physical activity at work" was also not significantly associated with LBP in univariate analyses. Bending forward (RR 1.3), lifting (RR 1.2), and standing (RR 1.3) were associated with lifetime incidence of LBP in univariate analyses (p<0.05). Sitting was not (OR 0.84, p=0.10). None of the measures of physical workplace factors were associated with lifetime incidence of LBP in multivariate analyses.

Videman et al. [1990] studied 86 males who died in a Helsinki hospital to determine the degree of lumbar spinal pathology. Disc degeneration and other pathologies were determined in the cadaver specimens by discography and radiography. Subjects' symptoms and work exposures (heavy physical work, sedentary work, driving, and mixed) were determined by interview of family members. In comparison to those with mixed work exposures, those with sedentary (OR 24.6, 95% CI 1.5–409) and heavy work (OR 2.8, 95% CI 0.3–23.7) had increased risk of symmetric disc degeneration. Similar relationships were seen for end-plate defects and facet joint osteoarthrosis. For most pathologic changes, sedentary work appeared to have a stronger relationship than heavy work. Back pain symptoms were consistently higher in those with any form of spinal pathology, although the difference was significant only for anular ruptures. This study was unusual in design in that it examined a combination of spinal pathological outcomes, symptoms, and workplace factors. However, participation in the study was dependent on obtaining information from family members; participation rates were not stated. While recall bias is often a problem in studies of the deceased, in this case it should have been nondifferential, if present.

Strength of Association

The ten studies were approximately equal in terms of information they provided relating to static work postures. Burdorf and Zondervan [1990] observed an OR of 0.49 (95% CI 0.11–2.2) for the univariate relationship between prolonged sedentary postures and LBP in crane operators. Holmström et al. [1992] found no association between LBP and sitting (in univariate or multivariate analyses). In the Magora [1972, 1973] cross-sectional investigation, the highest LBP rates were observed for those in the "rarely" category for variables related to sedentary postures, sitting, and standing. No dose responses were observed. In the Toroptsova et al. [1995] study of machine manufacturing workers, sitting, standing, and static work postures were not associated with LBP history in univariate analyses. No details were provided. In multivariate analyses, Masset and Malchaire [1994] found a nonsignificant association between LBP and seated posture (OR 1.5, p=0.09) in multivariate analyses. Svensson and Andersson's 1989 study of Swedish women found that standing was associated with lifetime incidence of LBP in univariate analyses (OR 1.3, p<0.05), but not in multivariate models. Sitting was not associated in univariate analyses (OR 0.84, p=0.10). Walsh et al. [1989] found that low-back symptoms were associated with lifetime occupational exposure to sitting in females only (RR 1.7, 95% CI 1.1–2.6) in multivariate analyses that considered other work exposures. Kelsey's 1975b case-control study demonstrated that sedentary work (sitting more than half the time at work) was associated with lumbar disc herniations, but only for those 35 and older (RR 2.4, p=0.01); the RR for those less than 35 was 0.81. In a study of salespeople, a dose-response was observed for sedentary work and low back symptoms. An OR of 2.45 (95% CI 1.2–4.9) was seen for the highest category after adjustment for covariates [Skov et al. 1996]. The Videman et al's [1990] study of cadavers found that those with histories of either sedentary or heavy work exposure had increased risk of symmetric disc degeneration (OR 24.6, 95% CI 1.5–409 and OR of 2.8, 95% CI 0.3–23.7, respectively). Similar results were seen for other disc pathologies. For most pathologic changes, sedentary work appeared to have a stronger relationship than heavy work.

In summary, most (n=6) risk estimates for variables related to static work postures, including standing and sitting, were not significantly different from one. Others found small to moderate significant increases in risk: ORs of 1.3 for standing, 1.7 for sitting (females only), and 2.4 and 2.5 for sedentary work. The Videman et al. [1990] cadaver study found high risks of disc pathology in those with a history of sedentary work. Study quality was similar across the range of point estimates observed.

Therefore, an estimate of the strength of association is difficult to determine. The magnitude cannot be estimated based on the available data.

Temporal Relationship

Eight of 10 studies were cross-sectional in design. Two of these attempted to use additional methodologies to increase the likelihood that exposure preceded disorder by excluding cases with onset prior to current job and truncating exposures prior to disorder onset. One found a positive relationship between prolonged sitting and LBP symptoms.

Consistency in Association

The studies showed poor consistency in estimation of the relationship between low-back disorder and static work postures, perhaps due to considerable differences in definition of exposure.

Coherence of Evidence

As mentioned elsewhere, LBP has been associated with mechanical forces causing an increased load on the lumbar spine [Waters et al. 1993]. Increased loading on the spine causes increased intervertebral disc pressures, which in turn, may be responsible for herniation and back pain. In laboratory experiments, disc pressure has been found to be substantially greater in unsupported sitting than in standing positions [Chaffin and Andersson 1984].

Studies reviewed for this document suggested relationships between back disorder and nonwork activities seemed to be consistent with the hypothesis that static

work postures might be associated with back disorder. Kelsey [1975a] observed that, in addition to sedentary work, amount of time spent sitting on weekends was associated with herniated discs. The finding that sedentary work was associated with herniated discs only in older age groups suggested that duration of exposure may be important and that a threshold may exist. Toroptsova et al. [1995] observed that back pain was lower in those who engaged in sports activity, perhaps suggesting that greater muscle strength prevents back pain.

Several authors offered explanations for the lack of associations they observed. It was pointed out that perception of “sedentary” is subjective and that many jobs that investigators (or subjects) considered to include prolonged static postures may actually have allowed considerable movement throughout the day (such as office workers). Other “sedentary” groups (such as industrial sewing machine operators) may be forced by work schedules to maintain static postures for long periods. It is important to have a true range of exposure if differences in associated disorders are to be detected.

Exposure-Response Relationships

Three studies addressed dose-response relationships, two of which did not demonstrate any trends. Magora [1972, 1973] found the highest risk of LBP in the lowest exposure categories for sedentary postures, sitting, and standing. Videman et al. [1990] found a high rate of lumbar disc pathology in those with histories of sedentary and heavy work, with relationships stronger for sedentary work. A dose-response for LBP symptoms and sedentary work was observed by Skov et al. [1996].

Conclusions: Static Work Postures

Ten studies examined the relationship between low-back disorder and static work postures. In most cases, this exposure was not of primary interest but was one of many potential workplace risk factors that were included in analyses. Static work posture was defined in several ways, including sedentary work and work-related sitting and standing. Exposure information was ascertained by interview for nine of 10 studies. The strength of association could not be easily estimated because a large proportion of point estimates did not differ statistically significantly from unity. As a whole, the results from these studies provide inadequate evidence that a relationship exists between static work postures and low-back disorder.

ROLE OF CONFOUNDERS

As mentioned above, back disorder is multifactorial in origin and may be associated with both occupational and nonwork-related factors and characteristics. The latter may include demographics, leisure time activities, history of back disorder, and structural characteristics of the back [Garg and Moore 1992]. The relative contributions of these covariates may be specific to particular anatomic areas and disorders. For example, a recent study of identical twins demonstrated that occupational and leisure time physical loading contributed more to disc degeneration of the upper than the lower lumbar region [Battié et al. 1995]. For both anatomic areas, age and twin effects (genetic influences and early shared environment) were the strongest identifiable predictors for this particular health outcome.

Psychosocial factors, both work- and nonwork-related, have been associated with back disorders. These relationships are discussed at length in Chapter 7 and Appendix B.

In the studies reviewed for this document, gender and age effects were addressed in most (86% and 74%, respectively). Approximately 40% addressed work-related psychosocial factors. In addition to these, many studies addressed other potential confounders in their analyses.

Table 6-1. Epidemiologic criteria used to examine studies of low back MSDs associated with heavy physical work

Study (first author and year)	Risk indicator (OR, PRR, IR or *p*-value)*,†	Participation rate $70%	Physical examination	Investigator blinded to case and/or exposure status	Basis for assessing back exposure to heavy physical work
Met at least one criterion:					
Åstrand 1987	2.3†	Yes	Yes	No	Job titles or self-reports
Bigos 1991b	No association	No	No	NR†	Observation or measurements
Burdorf 1991	No risk estimate§	Yes	No	No	Observation or measurements
Clemmer 1991	2.2†, 4.3†	Yes	No	NR	Job titles or self-reports
Heliövaara 1991	1.9, 2.5†	Yes	Yes	No	Job titles or self-reports
Hildebrandt 1995	1.2†	Yes	No	No	Job titles or self-reports
Hildebrandt 1996	No association	Yes	No	No	Job titles or self-reports
Johansson 1994	No association	Yes	No	NR	Job titles or self-reports
Leigh 1989	1.5†	Yes	No	NR	Job titles or self-reports
Masset 1994	No association	Yes	No	NR	Job titles or self-reports
Partridge 1968	1.2	Yes	Yes	No	Job titles or self-reports
Riihimäki 1989b	1.0	Yes	No	NR	Job titles or self-reports
Ryden 1989	2.2†	Yes	No	NR	Job titles or self-reports
Svensson 1989	No association	Yes	No	NR	Job titles or self-reports
Videman 1984	1.1	Yes	No	NR	Job titles or self-reports
Videman 1990	2.8, 12.1†	NR	Yes	NR	Job titles or self-reports
Met none of the criteria:					
Bergenudd 1988	1.8†	No	No	NR	Job titles or self-reports
Burdorf 1990	4.0	No	No	NR	Job titles or self-reports

*Odds ratio (OR), prevalence rate ratio (PRR), or incidence ratio (IR).

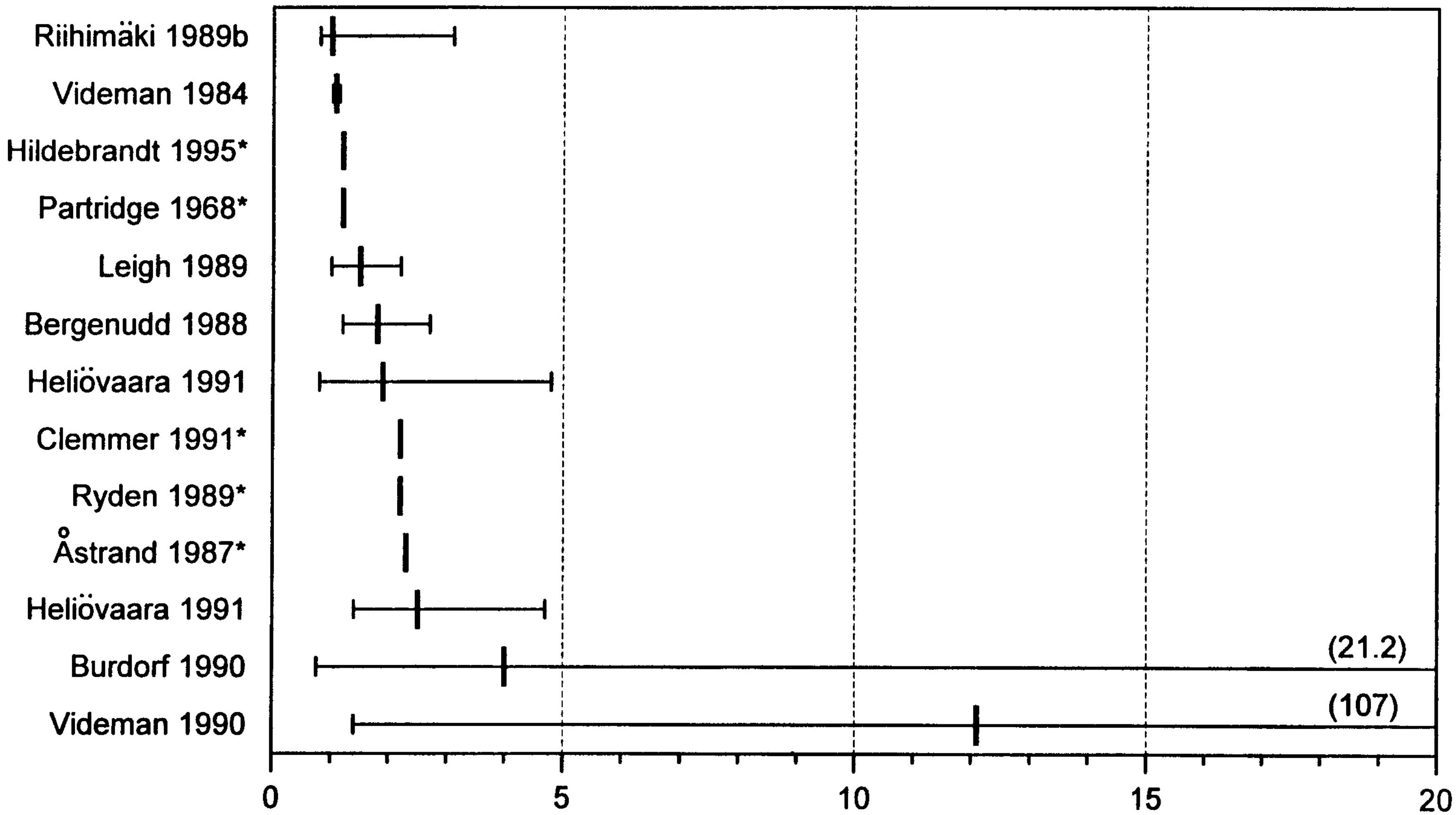
†Indicates statistical significance.

‡Not reported.

§Significant associations found in univariate but not multivariate results.

Figure 6-1. **Risk Indicator for Low-Back MSDs and Heavy Physical Work**

(Odds Ratios and Confidence Intervals)



* Risk factor reported without confidence limits.

Note: One study indicated a statistically significant association without reporting odds ratios. Five studies found no association. See Table 6-1.

Table 6-2. Epidemiologic criteria used to examine studies of low back MSDs associated with lifting and forceful movements

Study (first author and year)	Risk indicator (OR, PRR, IR or *p*-value)*,†	Participation rate $70%	Physical examination	Investigator blinded to case and/or exposure status	Basis for assessing back exposure to lifting and forceful movements
Met all four criteria:					
Punnett 1991	2.2[†]	Yes	Yes	Yes	Observation or measurements
Met at least one criterion:					
Burdorf 1991	No association	Yes	No	No	Observation or measurements
Chaffin 1973	Approx. 5[†]	NR	No	NR	Observation or measurements
Holmström 1992	1.3[§]	Yes	Yes	Yes	Job titles or self-reports
Huang 1988	No risk estimate	Yes	No	NR	Observation or measurements
Johansson 1994	No association	Yes	No	NR	Job titles or self-reports
Kelsey 1975b	0.94	Yes	Yes	NR	Job titles or self-reports
Kelsey 1984	3.8	Yes	Yes	NR	Job titles or self-reports
Knibbe 1996	1.3	Yes	No	No	Job titles or self-reports
Liles 1984	4.5[†]	NR	No	No	Observation or measurements
Magora 1972	No association, 1.7[†]	NR	No	NR	Observation or measurements
Marras 1995	10.7[†]	NR	No	NR	Observation or measurements
Svensson 1989	1.2[§]	Yes	No	NR	Job titles or self-reports
Toroptsova 1995	1.4[†]	Yes	Yes	NR	Job titles or self-reports
Undeutsch 1982	No risk estimate	NR	Yes	NR	Job titles or self-reports
Videman 1984	No association	Yes	No	NR	Job titles or self-reports
Walsh 1989	1.5[†], 2.0[†]	Yes	No	NR	Job titles or self-reports
Met none of the criteria:					
Burdorf 1990	0.70, 5.2[†]	No	No	NR[‡]	Job titles or self-reports

[*]Odds ratio (OR), prevalence rate ratio (PRR), or incidence ratio (IR).

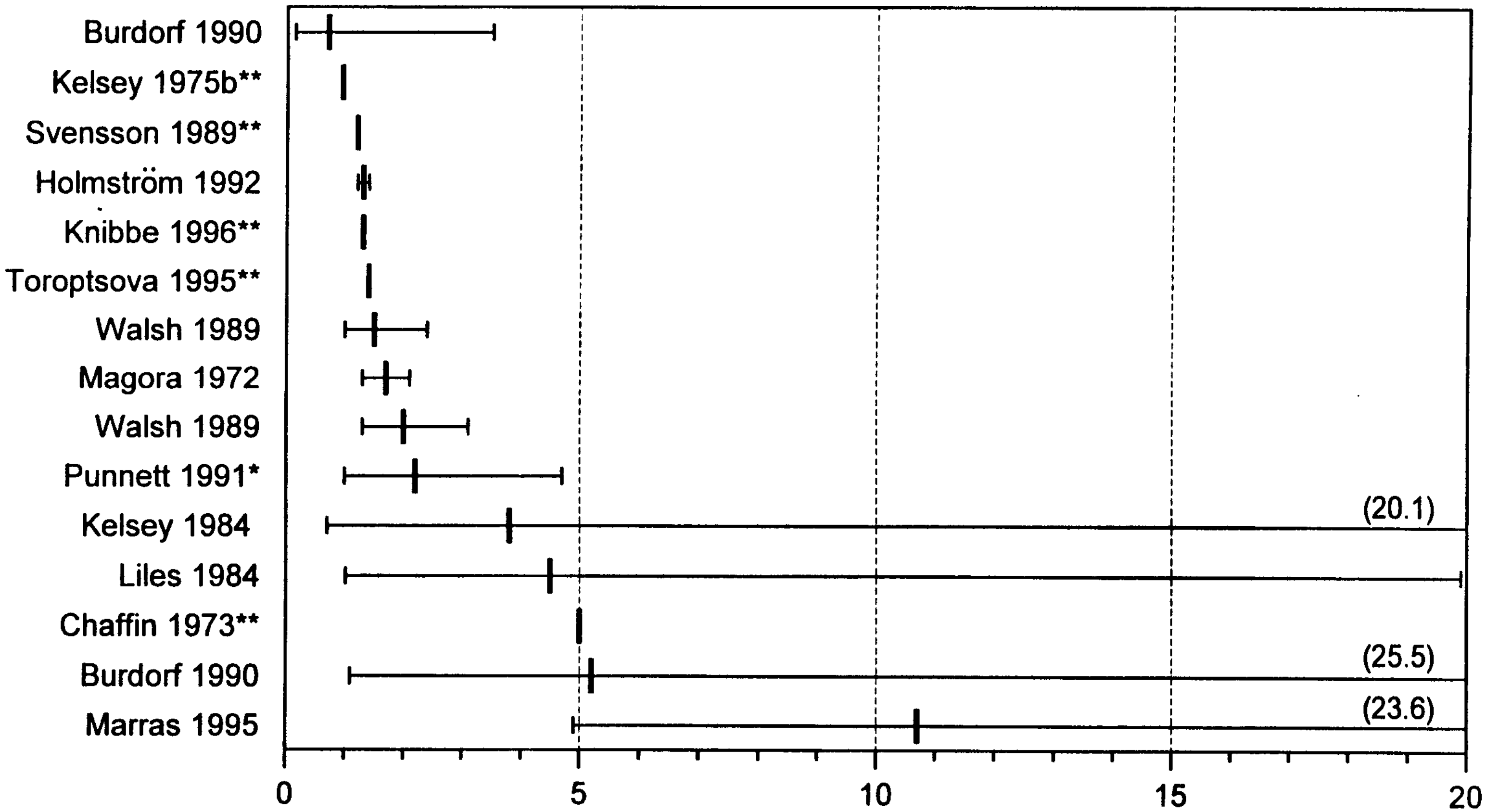
[†]Indicates statistical significance.

[‡]Not reported.

[§]Significant associations found in univariate but not multivariate results.

Figure 6-2. **Risk Indicator for Low-Back MSDs and Lifting and Forceful Movements**

(Odds Ratios and Confidence Intervals)



* Studies which met all four criteria.

**Risk factor reported without confidence limits.

Note: Four studies found no association. Two studies reported results without reporting risk estimates. See Table 6-2.

Table 6-3. Epidemiologic criteria used to examine studies of low back MSDs associated with bending, twisting, or awkward postures

Study (first author and year)	Risk indicator (OR, PRR, IR or *p*-value)*,†	Participation rate $70%	Physical examination	Investigator blinded to case and/or exposure status	Basis for assessing back exposure to bending, twisting, or awkward postures
Met back criteria:					
Punnett 1991	8.09†	Yes	Yes	Yes	Observation or measurements
Met at least one criterion:					
Burdorf 1991	1.2†	Yes	No	No	Observation or measurements
Holmström 1992	2.6†, 3.5†	Yes	Yes	Yes	Job titles or self-reports
Johansson 1994	NR†,‡	Yes	No	NR	Job titles or self-reports
Kelsey 1984	3	Yes	Yes	NR	Job titles or self-reports
Magora 1972, 1973	No association	NR	No	NR	Observation or measurements
Marras 1993, 1995	10.7†	NR	No	NR	Observation or measurements
Masset 1994	No association§	Yes	No	NR	Job titles or self-reports
Riihimäki 1989b	1.5†	Yes	No	NR	Job titles or self-reports
Riihimäki 1994	No association§	Yes	No	NR	Job titles or self-reports
Svensson 1989	No association§	Yes	No	NR	Job titles or self-reports
Toroptsova 1995	1.7†	Yes	Yes	NR	Job titles or self-reports

*Odds ratio (OR), prevalence rate ratio (PRR), or incidence ratio (IR).

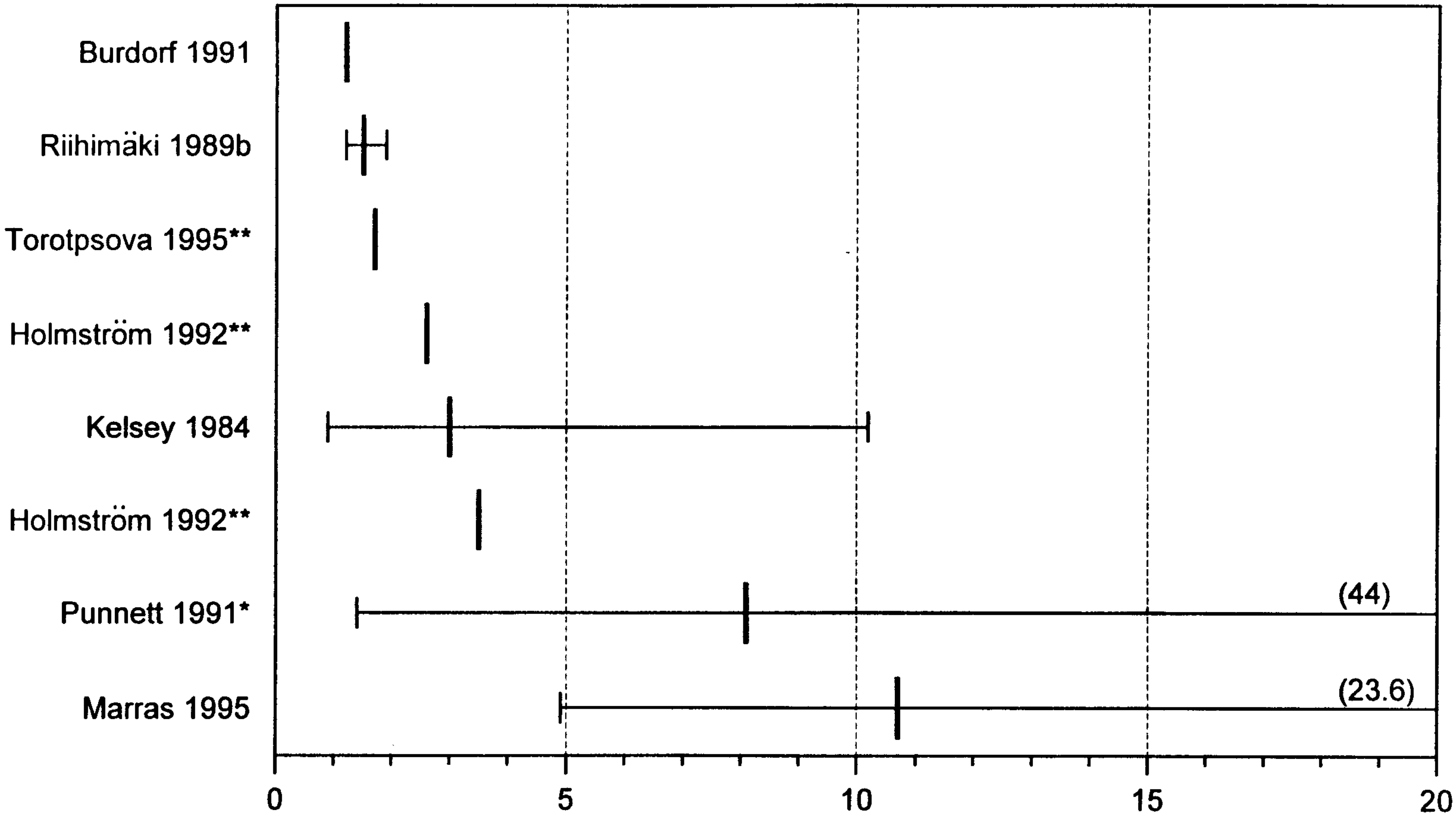
†Indicates statistical significance. If reported with NR, a significant association was reported without a numerical value.

‡Not reported.

§Significant associations found in univariate but not multivariate results.

Figure 6-3. **Risk Indicator for Low-Back MSDs and Bending, Twisting, and Awkward Postures**

(Odds Ratios and Confidence Intervals)



* Studies which met all four criteria.

**Risk factor reported without confidence limits.

Note: Four studies found no association. One study indicated statistically significant association without reporting odds ratio. See Table 6-3.

Table 6-4. Epidemiologic criteria used to examine studies of low back MSDs associated with whole-body vibration

Study (first author and year)	Risk indicator (OR, PRR, IR or *p*-value)*,†	Participation rate ≥70%	Physical examination	Investigator blinded to case and/or exposure status	Basis for assessing back exposure to lifting and whole-body vibration
Met at least one criterion:					
Bongers 1988	2.0†–5.7	Yes	Yes	NR‡	Job titles or self-reports
Bongers 1990	3.3–39.5†	Yes	No	NR	Observation or measurements
Boshuizen 1990a, 1990b	1.5–3.6†	Yes	No	NR	Observation or measurements
Boshuizen 1992	0.99	Yes	No	NR	Observation or measurements
Bovenzi 1992	2.6†	Yes	No	NR	Observation or measurements
Bovenzi 1994	2.4–4.6†	Yes	No	NR	Observation or measurements
Burdorf 1991	3.1†	Yes	No	No	Job titles or self-reports
Burdorf 1993	2.5–3.3†	Yes	No	NR	Observation or measurements
Kelsey 1975b	2.8†, 4.7†	Yes	Yes	NR	Job titles or self-reports
Magnusson 1996	1.8†	NR	No	NR	Observation or measurements
Magora 1972	1.2	NR	No	NR	Observation or measurements
Masset 1994	1.2†	Yes	No	NR	Job titles or self-reports
Riihimäki 1989a	1.3†	Yes	No	NR	Job titles or self-reports
Riihimäki 1994	No association	Yes	No	NR	Job titles or self-reports
Toroptsova 1995	No association	Yes	Yes	NR	Job titles or self-reports
Walsh 1989	1.7†	Yes	No	NR	Job titles or self-reports
Met none of the criteria:					
Burdorf 1990	0.66	No	No	NR	Job titles or self-reports
Johanning 1991	3.9†	No	No	NR	Job titles or self-reports
Skov 1996	2.8†	No	No	NR	Job titles or self-reports

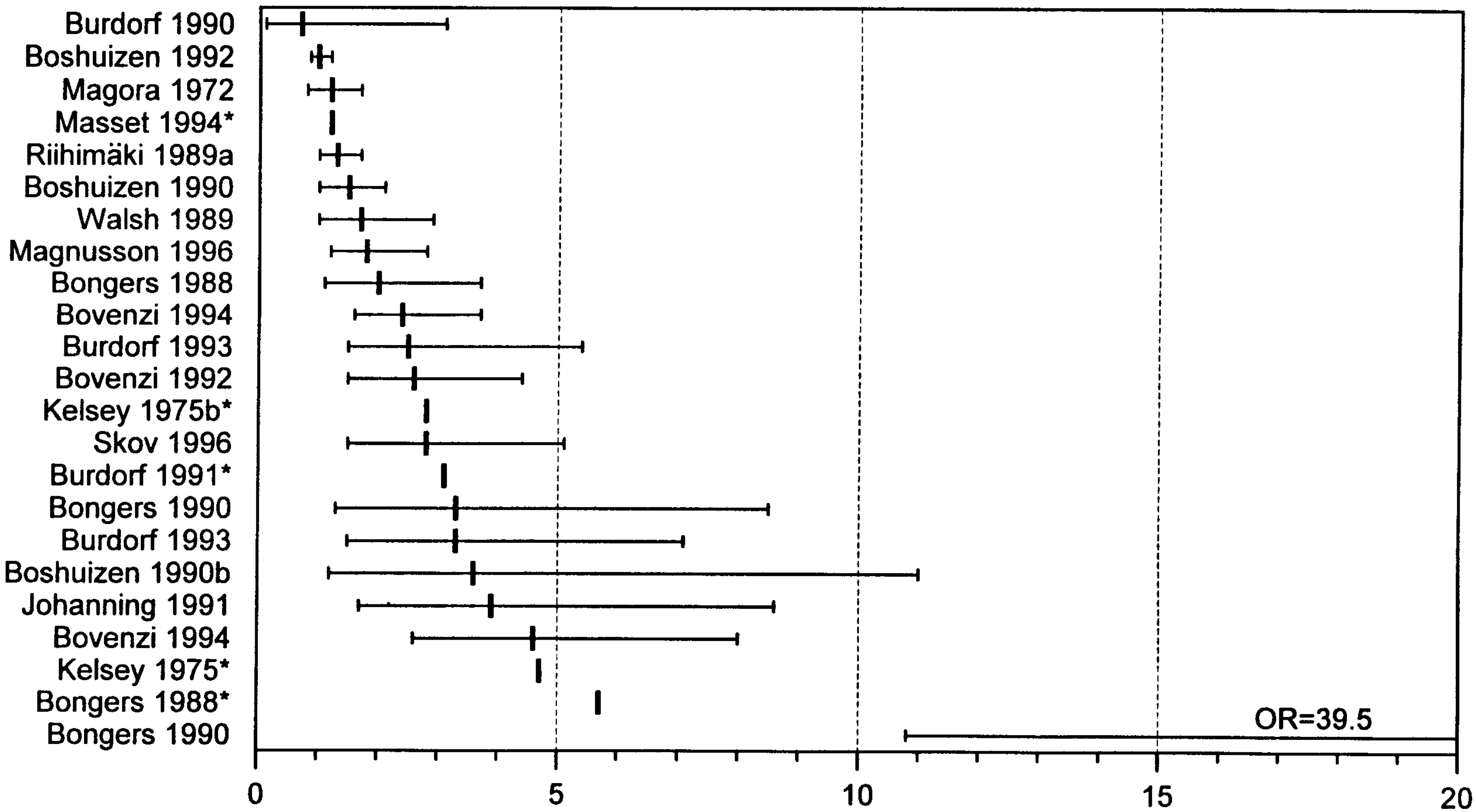
*Odds ratio (OR), prevalence rate ratio (PRR), or incidence ratio (IR).

†Indicates statistical significance.

‡Not reported.

Figure 6-4. **Risk Indicator for Low-Back MSDs and Whole-Body Vibration**

(Odds Ratios and Confidence Intervals)



* Risk factor reported without confidence limits.
Note: Two studies found no association. See Table 6-4.

Table 6-5. Epidemiologic criteria used to examine studies of low back MSDs associated with static work postures

Study (first author and year)	Risk indicator (OR, PRR, IR or *p*-value)*, †	Participation rate $70%	Physical examination	Investigator blinded to case and/or exposure status	Basis for assessing back exposure to static work postures
Met at least one criterion:					
Holmström 1992	No association	Yes	Yes	Yes	Job titles or self-reports
Kelsey 1975b	0.81, 2.4†	Yes	Yes	NR	Job titles or self-reports
Magora 1972, 1973	No association	NR	No	NR	Observation or measurements
Masset 1994	1.5	Yes	No	NR	Job titles or self-reports
Svensson 1989	1.3§	Yes	No	NR	Job titles or self-reports
Toroptsova 1995	No association	Yes	Yes	NR	Job titles or self-reports
Videman 1990	24.6†	NR	Yes	NR	Job titles or self-reports
Walsh 1989	1.7† (females)	Yes	No	NR	Job titles or self-reports
Met none of the criteria:					
Burdorf 1990	0.49	No	No	NR	Job titles or self-reports
Skov 1996	2.45†	No	No	NR	Job titles or self-reports

*Odds ratio (OR), prevalence rate ratio (PRR), or incidence ratio (IR).

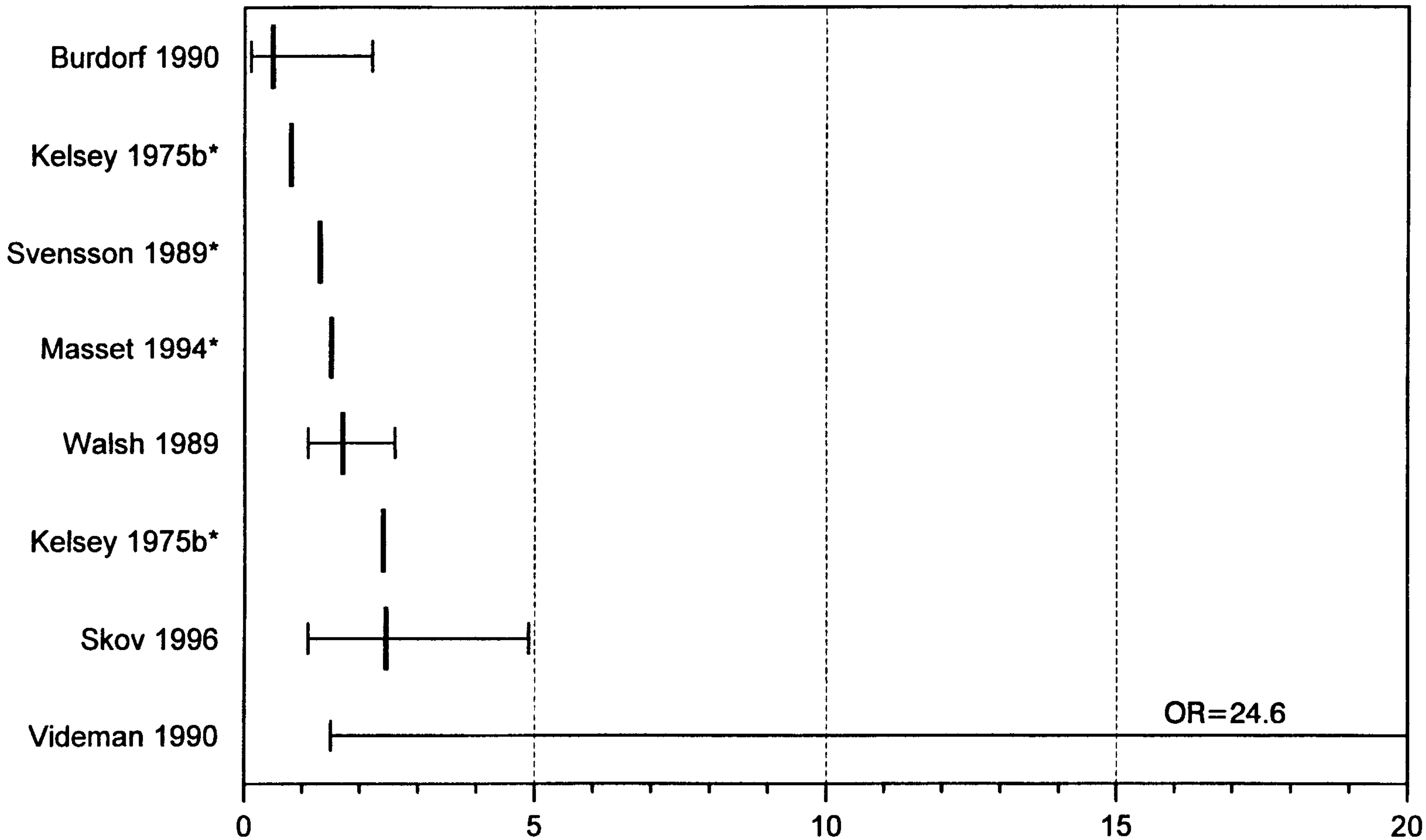
†Indicates statistical significance.

‡Not reported.

§Significant associations found in univariate but not multivariate results.

Figure 6-5. **Risk Indicator for Low-Back MSDs and Static Work Postures**

(Odds Ratios and Confidence Intervals)



* Risk factor reported without confidence limits.
Note: Three studies found no association. See Table 6-5.

Table 6-6. Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Åstrand 1987 Åstrand and Isacsson 1988	Cross-sectional, 1987 Retro-spective 22 years follow up, 1988	391 male employees in a Swedish pulp and paper industry located at one of 4 sites: Mill 1, Mill 2, Mill 3, and Head Office.	Outcome: Medical, psychological and social indicators. Questionnaires on social and psychological factors; medical examination of thoracic and lumbar spine. Exposure: Based on the type of work performed at each job site. All mill work jobs were judged as heavy; all office/clerk jobs were judged as light. Some worker movement between office/clerk jobs and mill work, based on health status.	29.4 % of manual workers reported back pain in response to: "Do you often have back pain?"	12.9% of clerks reported back pain in response to same question.	 Duration of employ-ment:1.2 Neuro-ticism: 2.8	*p*=0.002 1.0-1.5 1.4-5.4	Participation rate: 82.5%. The proportion of backs evaluated as abnormal by physical examination was 16%, similar to U.S. data collected in 1971. 66% of group with back abnormalities reported back pain. Psychosocial work factors did not show any significant association with back pain. The working conditions of back pain sufferers were changed because of their reduced working capacity, which tends to offset differences in prevalence of back pain between groups doing heavy work and control populations. Results support Magora's findings that heavy work over time is associated with increased back pain. Back pain was associated with occupation, low education, duration of employment, and neuroticism. In follow-up study, a "healthy worker effect" was documented.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Bergenudd and Nilsson 1988	Longitudinal	323 males and 252 females; all participants in Malmo, Sweden, Longitudinal Study since 1938.	Outcome: Back pain not tracked by exam. "Attended" for exam but BP based only on self assessment and questionnaire, 1983. Exposure: Exposures and occupations tracked by questionnaires since 1942. Work classified into 3 categories of heaviness based on 10 years work. (1) Light physical work: white collar. (2) Moderate: Nurses, shop assistants, bakers, and light industry. (3) Heavy: Carpenters, bricklayers, and heavy industry.	Point prevalence: LBP males: 28% females: 30% 5% prevalence of sciatica In heavy or moderate work (LBP): males: 32.4% females: 38.9%	LBP in unexposed males: 21.4% females: 23.9%	All: 1.83 Females: 2.03 Males: 1.76	1.2-2.7 1.1-3.7 1.01-3.1	Participation rate: 67% in questionnaire and health survey from 830 individuals living in Malmo. Not controlled for confounders. Exposures rated from job title. Weak support for occupational factors in causation. Some support for workload causing symptoms. Moderate or heavy physical demands had more back pain; then light physical demand group ($p<0.01$) statistically significant only in females. Those with back pain had fewer years of education and were less satisfied with their working conditions. There was no difference in the relationship between family, relatives, or friends.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Bigos et al. 1986a	Retro-spective cohort morbidity (15-month follow-up)	Aircraft manufacturer employees in 33 job classifications (n=31,200).	Outcome: Report of low back injury. Exposure: 33 job classifications.	Highest LB injury rates in mechanics Rate=38.2	Lowest LB injury rates in electronic technicians and tool grinders Rate=NS	Highest to lowest compari-son is in range of 5 to 7 (exact numbers not reported)		Participation rate: 100% (includes all records). Exact rates by job titles not reported. Authors state that differences by job title are difficult to interpret because of overlapping confidence intervals.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Bigos et al. 1991b	Prospective	3,020 aircraft assembly workers; 1,613 involved in work perception and psychosocial portion of study.	Outcome: A case was defined as a subject reporting an acute industrial back injury. Subjects answered series of questionnaires: On demographic and psychosocial factors, a cardiovascular questionnaire, and a take-home questionnaire on psychosocial and individual factors (see comments). Subjects had physical examination to assess physical attributes: Lifting strength, aerobic capacity, and flexibility. Exposure: Based on questionnaire data of work and home activities. Also "All jobs employing >19 workers analyzed for heavy and tiring tasks in terms of maximal loads." Also analyzed "perceived physical exertion" as potential risk factor.	8% to 9% of workers reported an acute industrial back injury.	N/A	Lack of enjoyment of job tasks: OR=1.7 MMPI: tend towards somatic complaint or denial of emotional distress: OR=1.37 Prior back pain: OR=1.7	1.3-2.2 1.1-1.7 1.2-2.5	Participation rate: 43% of the original number of workers solicited 54% of participants returned questionnaire with Minnesota Multiphasic Personality Inventory (MMPI); 75% participated in some part of the study. Of volunteers, respondents and non-respondents were similar. Employees' work exposure not as well documented as psychosocial factors. Take home questionnaire had 566 question Minnesota Multiphasic Personality Inventory (MMPI), family function questionnaire (APGAR), Health locus of control (HLOC). Other information included medical history, previous back discomfort or problem, and previous back injury claims in prior 10 years. Study did not investigate actual presence of back symptoms or specific disorders; subjects followed for three years and became a case if they: (1) reported to medical department, (2) filed an incident or report, (3) filed an industrial insurance claim. Authors state that results may not apply as strongly to cases of severe symptoms or in work involving heavy job requirements (study performed in a manufacturing industry where "job tasks do not tend to be extremely stressful" for the back.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Bongers et al. 1988	Retro-spective cohort (January, 1975-December 1984)	Dutch, male, steel workers (n=1,405)	Outcome: Disability pension for back-related disorder. Exposure: Job title and duration of employment. Measurements of vibration in cranes but not used in this study.	Crane operators (n=743)	Floor workers in same departments (n=662)	Incidence Density Ratios All back disorders: 1.32		Participation rate: $70%. Adjusted for nationality, shiftwork, age, and calendar time. ORs likely are underestimated because of slight vibration exposure of the control group and potential health-based selection of the exposed group before start of the follow-up period. The combination of exposure to W.V., unfavorable postures, and adverse climatic conditions is the probable cause of the back disorders.
						Interverte-bral disc disorders: 2.00	0.84-2.1	
						Degenera-tion of interverte-bral disc: 2.95	1.1-3.7	
						COX regression: IDR for displace-ment of disc: 2.46	1.2-7.3	
						IDR for degenera-tion of interverte-bral disc: 3.28	1.2-12.5	

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Bongers et al. 1990	Cross-sectional	Dutch, male, helicopter aircrew and non-flying air force officers	Outcome: Back symptoms, by questionnaire. Exposure: Hr of flight time, types of helicopters flown, and time spent in bent or twisted postures were obtained by questionnaire. Vibration measurements were taken in two helicopters of each type used in the study. Cumulative exposures were obtained by combining questionnaire and measurement data.	Dutch helicopter pilots and aircrew observers (n=163) Back pain, 68%; LBP, 55%; Lumbago, 13%; Sciatica, 12%; Pattern alternating, 41%	Non-flying air force officers (297) 17% 11% 9% 6% 6%	 8.0 9.0 2.6 3.3 9.5	 4.5-14.3 4.9-16.4 1.1-6.0 1.3-8.5 4.8-18.9	Participation rate: $70%. Adjusted for age, height, weight, climate, bending forward, twisted postures, and feeling tense at work. Prevalence of transient back pain, in particular, was higher for exposed than referent group. Prevalence of transient back pain increased with daily exposure time. Chronic back pain increased with total flight time and total vibration dose. Postures of pilots were constrained due to cockpit conditions. Selection bias possible in that pilots with back trouble could have dropped out of employment.

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Boshuizen et al. 1990a,b	Cross-sectional follow-up of a cohort identified in 1975. Also, includes entire cohort in examination of sick leave and disability follow-ups.	Employees of two Dutch companies performing land reclamation and inspection of roads, dikes, and building sites. Several workers operate vehicles. The cross-sectional study included 577 workers, and the cohort study 689.	Outcome: Back pain symptoms were obtained by questionnaire in the cross-sectional study, and back-related sick leave and disability retirement information was collected in the cohort study. Exposure: Vehicle vibration information was combined with questionnaire data regarding vehicle types driven, awkward postures maintained, hr of work, and previous jobs held.	Sick leave for all back disorders LBP prevalence: by vibration dose, 4 categories By vibration, 3 categories By years of exposure 3 categories Sick leave by vibration dose, 4 categories Dose of 5 years, all back disorders		1.47 RR: 19.1, 29.4, 28.03, 8.1 1.80, 1.78, 2.8 2.44, 2.50, 3.60 1.0, 0.97, 1.51, 1.45 1.13 COX regress. adj. for age	1.04-2.1	Participation rate: 79%. ORs corrected for duration of exposure, age, height, smoking, awkward postures, and mental workload. Association greater with duration of exposure than magnitude.

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

				MSD prevalence				
Study	Study design	Study population	Outcome and exposure	Exposed workers	Referent group	RR, OR, or PRR	95% CI	Comments
Boshuizen et al. 1992	Cross-sectional	Male employees of six Dutch shipping companies (n=452).	Outcome: Back pain symptoms by questionnaire Exposure: Measurement of vibration in sample of vehicles combined with questionnaire responses to calculate cumulative dose (before symptom onset.	Fork-lift truck and freight tractor drivers (n=242).	Employees of the same companies without vibration exposure (n=210)			Participation rate: $70%. Adjusted for age, mental stress, years lifting > 10 kg and twisting spine, height, smoking, looking backwards, and hr sitting. Authors suggested that a healthy-worker effect was operating in that older drivers were subject to health-based selection. Psychosocial factors were not addressed, except for “mental stress from work”.
				Prevalence (age standardized:				
				Back pain, 48%	34%		*p*=<0.05	
				LBP, 41%	30%		*p*=<0.05	
				Lumbago, 19%	8%		*p*=<0.05	
				Cox regression: Back pain and total dose:		0.99	0.85-1.2	
				Lumbago and total dose:		1.14	0.91-1.4	
				Vibration exposure in last 5 years and back pain:		2.4	1.3-4.2	
				and lumbago:		3.1	1.2-7.9	
				Age and prevalence of LBP (multivariate OR):				
				25-34		5.6	Õ	
				35-44		1.96	Õ	
				45-54		0.68	Õ	

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Bovenzi and Zadini 1992	Cross-sectional mail survey	Male bus employees working in Trieste	Outcome: Back-pain symptoms from questionnaire (rev. Nordic). Exposure: WBV measured. Cumulative exposures estimated from measurements plus questionnaire results (duration of work, previous exposures, etc.).	234 bus drivers	125 maintenance workers working for same bus company			Participation rate: $70%. Adjusted for age, awkward posture, duration of exposure, BMI, mental load, education, smoking, sport activities, previous jobs at risk for back pain and duration of employment. Does not address sedentary nature of work (states sitting is poorly correlated with LBP unless in combination with WBV). Psychosocial: adjusted for “mental load” (no risk estimate provided). Results were similar after excluding those with WBV exposure in previous jobs from analyses.
				Univariate results: lifetime prevalence of LB symptoms, 83.8%;	66.4%	3.12	1.8-5.3	
				LBP, 36.3%;	15.2%	2.80	1.6-5.0	
				Previous 12 months: LB symptoms, 82.9%	65.6%	2.99	1.8-5.1	
				LBP, 39.7%;	20.0%	2.57	1.5-4.4	
				Dose-response for total vibration and lifetime LBP;		4.05	1.8-9.3	
				Dose-response for 12-mo. LBP.		3.25	1.5-7.0	

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

				MSD prevalence				
Study	Study design	Study population	Outcome and exposure	Exposed workers	Referent group	RR, OR, or PRR	95% CI	Comments
Bovenzi and Betta 1994	Cross-sectional	Tractor drivers, aged 25-65, working in Italy (n=1155) and male revenue officers engaged in inspection and administrative work (n=220).	Outcome: Survey questionnaire (modified Nordic) Exposure: Vibration levels were measured for a representative samples of tractors. Information on awkward postures gained from questionnaire. Number of hr operating yearly estimated from tractor maintenance records. Cumulative exposures estimated by combining the information.	Tractor drivers	Revenue officers			Participation rate: 91.2% for exposed and 92.2% for unexposed.
				Univariate: Back Pain: 86.1%	57.3%	1.83	1.1-3.0	Multivariate analyses adjusted for age, BMI, education, sport activity, car driving, marital status, mental stress, climatic conditions, back trauma, and postural load.
				LBP Lifetime: 81.3%	42.3%	3.22	2.1-5.2	
				12-month LBP, 71.7%	36.8%	2.39	1.6-3.7	
				Dose-response (highest categories)				Relationships reported between vibration exposure and back pain, with clearest dose-responses for chronic LBP outcome.
				Lifetime LBP and tot. vib. dose;		5.49	3.6-8.5	
				Chronic LBP and tot. vib. dose;		2.63	1.7-4.10	Independent effects observed for postural load and vibration.
				Lifetime prevalence LBP and duration of exposure:				Results were similar after excluding those with WBV exposure in previous jobs from analyses.
				5-15 years				
				16-25 years		3.08	1.88-5.07	
				>25 years		3.03	1.80-5.12	
						4.51	2.43-8.34	
				Lifetime prevalence LBP and total vibration dose (years m^2/s^4)				
				<15				
				15-30		2.79	1.70-4.58	
				>30		3.44	2.05-5.77	
						3.79	2.20-6.53	

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	RR, OR, or PRR	95% CI	Comments
Burdorf and Zondervan 1990	Cross-sectional	33 male crane operators and 30 male non-crane operator control subjects matched for age. Employed for $ one year.	Outcome: Back pain assessed by questionnaire (Nordic). Pain in lower back in the last 12 months. Exposure: Defined by job title and questionnaire items: heavy physical work, lifting, WBV, and sedentary postures (current and past).	61% of crane operators had back pain	27% of controls had back pain	3.6	1.2-10.6	Participation rate: 67% of crane operators and 100% of controls. Control workers carried out more moderate or heavy work, lifting, walking, and standing than crane operator in past.
				Risk Factors:				
				Heavy work		4.02	0.76-21.2	Physical demands are not significant in multivariate analyses.
				Frequent lifting		5.21	1.10-25.5	
				Whole body vibration		0.66	0.14-3.1	Controlled for age, height, and weight. Crane operators with long work absences over-represented among non-responders. Results indicate that the current job of crane operator is associated with reports of onset of back pain.

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

				MSD prevalence				
Study	Study design	Study population	Outcome and exposure	Exposed workers	Referent group	RR, OR, or PRR	95% CI	Comments
Burdorf et al. 1991	Cross-sectional prevalence study	114 concrete workers compared to 52 maintenance engineers (controls). All male.	Outcome: Back pain symptoms assessed by questionnaire. Back pain defined as pain which continued for $ a few hr during the past 12 months. Exposure: Assessed by task analysis and OVAKO working posture analysis system (OWAS) observation method. Eleven postures of importance for occupational strain on the back were used. For each job, two or three workers were chosen at random. Index for postural load constructed using ordinal scale for rating the average proportion of poor back postures. Six jobs were ranked by index.	59% of concrete workers had back pain	31% of controls had back pain	2.80 age adjusted and controlled for back pain from previous job Model 1 Postural index OR=1.23 Model 2 Whole body vibration OR=3.1	1.31-6.01 *p*=0.04 *p*=0.001	Participation rate: 95% concrete workers; 91% maintenance males. Workload related to prevalence of back pain. Postural load, bending and twisting, as well as whole body vibration causal factors. Questionnaire included previous employment history, risk factors in present and previous jobs. Univariate analysis controlled for confounders using Mantel-Haensel chisquare. Age, height, and weight not significant factors. Age controlled for in logistic regression. 30% with back pain had symptoms >30 days. Concrete workers spent significantly more time in bent and/or twisted postures. Postural index and whole body vibration significantly correlated (0.48, *p*<0.001). Therefore, authors designed two separate logistic regression models. Prolonged standing or sitting not found to be risk factors.

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Burdorf et al. 1993	Cross-sectional	Crane operators, saddle-carrier drivers and office workers aged 25-60, working in a large transport company (n=275).	Outcome: Back pain symptoms, by questionnaire. Exposure: Postures assessed with OWAS, WBV measured in sample of each group, and past work exposures estimated by questionnaire.	Crane operators (n=94) and saddle-carrier drivers (n=95) Multivariate analyses:	Office workers (n=86)			Participation rate: $70%. Adjusted for age and confounders (history of heavy work, exposure to WBV (y/n), history of work requiring prolonged sitting, cold and drafts, working under severe pressure, job satisfaction, height, weight, duration of total employment were considered). Risk estimates were not presented by exposure categories, despite quantitative assessment. Risk estimates reflect simultaneous exposure to WBV, static postures, and awkward postures. Only persons with no complaints of low back pain before starting their current jobs were included in analyses.
				Crane operators		3.29	1.52-7.12	
				Straddle-carrier drivers		2.51	1.2-5.4	

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Chaffin and Park 1973	Prospective with approx. 1 year follow-up	5 plants in large electronics company. n=411 individuals (279 males and 132 females).	Outcome: Visit medical department because of low back complaint. Exposure: 103 jobs evaluated for Lifting Strength Rating (LSR) and lifting frequency.	Overall back rate, annual 7.2/100 FTEs (25 total back injuries)				Participation rate: Not reported. Age, weight, stature not associated with low back injuries. A strong positive trend is indicated in the incidence rate data as the LSR increases.

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Clemmer et al. 1991	Retro-spective cohort	Offshore drilling workers. 14,518,845 worker-hr over 1979 to 1985 (7,259 FTEs), 4,765 total injuries.	Outcome: Back-injury cases reported on standard forms with mention of "rheumatogical crux" for which the agent of injury was mechanical energy excluding other body sites. Exposure: Based on job title.	543 cases of low back injuries. 7.5/100 Roustabouts, floorhands, and derrick workers, low-back strains rate: 6.92	Control room and maintenance 3.18	RR=2.2		Participation rate: Not reported. Workers performing the heaviest physical labor had highest number of injuries and highest rates. Controlling for "job," age significantly associated with back strain in workers performing heaviest length of employment work not associated with back pain. Job was best predictor of lost time. Back injuries largely from falls. 75% of back strains precipitated by pushing, pulling, or lifting.

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Deyo and Bass 1989	Cross-sectional	From the NHANES-II national survey of 27,801 individuals, 10,404 files of adults age 25 or older who had a physical examination were reviewed and 1,134 who met the case definition were selected for this study. The mean age of the subjects was 48.3 years and half (51.7) were females.	Outcome: Low-back pain within the past year with $ one episode of near daily pain for $ two weeks. Exposure: Smoking and obesity, personal characteristics.	Prevalence of LBP in current smokers: 10.7%.	Prevalence of LBP current non-smokers: 10.2%		Not significant	Participation rate: Not reported. Lifestyle factors, including smoking and obesity, are risk factors for low-back pain. The attributable risk for smoking was 1.3 cases/100 persons. Smoking risk increases steadily with cumulative exposure and with degree of maximal daily exposure. A stronger association exists between back pain and smoking in younger subjects than among those >age 45. There is a steady increase in back pain prevalence with increasing obesity, but this elevates most strikingly in the highest 20% of body mass index (levels over 29.0 kg/sq m). The association between obesity and LBP could be confounded by other unmeasured lifestyle differences between the obese and non-obese so that obesity is just a marker for a true causal factor or factors.
				Ever smoked vs. LBP: 10.9%	9.6%	1.13	Significant	
				50 pack years vs. LBP: 14.1%	9.6%	1.47	Significant	
				BMI vs LBP, Highest quintile: 14.8%	Lowest quintile: 8.5%	1.70	Significant	
						Odds ratio each increment		
				LOG REGRESSION:				
				Obesity		1.12	*p*<0.0006	
				Smoking		1.05	*p*<0.0006	
				Chronic cough		1.36	*p*<0.0006	
				Activity		1.22	*p*<0.0006	
				Education		0.84	*p*<0.0006	
				Age		1.01	*p*<0.0006	
				Working		0.8	NS	

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Heliövaara et al. 1991	Cross-sectional	2,727 males and 2,946 females (30 to 46 years) with history, symptoms, or findings indicating musculoskeletal disease.	Outcome: LBP interview and tests at medical mobile clinic with uniform criteria. Low-back syndrome: Symptoms during the preceding month and major pathologic finding on physical exam (fingertip-floor distance >25 cm at flexion, rotation restricted to 25 degrees or less, objective signs of scoliosis of 20 degrees or more, Lumbar Lordosis, Ladegue's test positive at 60 degrees or less, or severe abnormality. Sciatica: Symptoms radiating down leg and findings of Lumbar nerve root compression. Exposure: Based on self-administered questionnaire; index for occupational physical stress and occupational mental stress.	Prior traumatic injury increased risk of LBP and, sciatica and, low back syndrome Work load index and, sciatica and, low back syndrome Stress index and, sciatica and, low back syndrome	No prior injury	2.5 2.6 2.4 3.1 2.4 2.0	1.9-3.3 2.1-3.1 1.0-5.7 1.7-5.7 1.7-3.5 1.5-2.6	Participation rate: 93% in screening. Physical and mental stress loads related to both sciatica and LBP. Controlled for age and gender. Body mass index, alcohol consumption, work-related driving, parity, and height were not associated with LBP. Diabetes had a significantly decreased prevalence of LBP (OR=0.4 CI 0.3-0.8). There was no statistical difference in LBP between sexes; sciatica significantly more prevalent among males. No association between smoking and sciatica. Significant association between smoking and LBP in both older and younger males, but only older females. Significant association between LBP and osteoarthritis, mental disorders, and respiratory disease.

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Hildebrandt 1995	Cross-sectional	From the Dutch population; a sample of 8,748 workers from three surveys on successive years.	Outcome: Back pain cases defined by symptom questionnaire ("yes" to "back pain quite often") and responses to interviewer. Exposure: Based on job title classification of work demands; four categorical exposure variables: trade branch, trade class, professional branch, and professional class.	29.6% (2,327) of heavy workers reported back pain "quite often." Rates of LBP: Construction: 35%; Truckers: 31%; Plumbers: 31%.	23.9% of sedentary workers reported back pain "quite often."	*p*<0.05 OR=1.2	õ 1.33-1.55	Participation rate: "Population sampled was representative of Dutch population." Unable to calculate. Workers performing non-sedentary work at highest risk. Rates increase with age for males, to age 54, and for females to age 64. Controlled for age and gender by stratification. Professions with high prevalence of back pain on average were characterized by physically demanding work with dynamic components. Data originally collected for screening of health and medical consumption, therefore less specific exposure variables—only job titles. However, there may be less potential for information bias because respondents did not then focus exclusively on back pain and work-relatedness. Conclusion: In non-sedentary work, both males and females have higher prevalence rates than those who work in sedentary jobs.

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Hildebrandt et al. 1996	Cross-sectional	436 male workers in five maintenance departments of a steel company, compared to 396 non-sedentary workers also exposed to heavy workloads.	Outcome: Low back pain cases defined by symptom questionnaire ("yes" to low back pain in last 12 months). Exposure: Assessed by questionnaire. Workers placed into one of 18 groups based tasks performed "often" or "predominantly." Tasks assigned a score on four indices: (1) physical workload, (2) psychosocial workload, (3) poor climate, and (4) vibration.	Prevalence: 1-year; LBP: 53%	Reference group had high physical exposures.	õ	õ	Participation rate: Varied from 60% to 80% in different departments. Reference group characterized by high levels of exposure to adverse working conditions. Poor selection of referents. Prevalence rates adjusted for age differences between groups. Task groups with high prevalence rates of low back symptoms also associated with high exposures to unfavorable working conditions. Rates work groups (within units) according to self-reported exposures but does not cross-tab these with LBP.

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Holmström et al. 1992	Cross-sectional	1,773 randomly sampled construction workers (male).	Outcome: (1) LBP history from postal questionnaire. Back pain defined as pain, ache, or discomfort in lower back, including gluteal regions with or without radiating pain into leg/s experienced sometime, often, or very often during past year, (2) $ for 1 to 7 days, (3) with any degree of functional impairment. A sample of workers had clinical exam: Active spinal mobility test, springing test, straight leg raising, interspinal and paraspinal palpation from T11 to S1, combined extension and lateral flexion while standing and passive lumbar flexion and extension while lying on one's side. Exposure: Based on questionnaire data reporting of task activity.	1-year prevalence rate LBP 54%; 1-year prevalence for severe LBP 7%.				Participation rate: 76%. Examined medical records for nonrespondents; same as for respondents. Information included individual and employee-related factors, disorders in locomotor system, physical workload, and psychosocial factors. Examiners blinded to case and exposure status. Multiple logistic regression models used; separate models for individual, manual materials handling, and working postures. In univariate analysis, no relationship with daily traveling time, leisure activity, or height and weight. Construction tasks such as bricklaying or carpentry did not affect LBP. Stress index reflected a high achiever person. Longer duration of stooping and kneeling was associated with LBP in all age groups (dose-response). Only severe LBP related to smoking.
				Lifting freq: >1/5 min	<1/5	1.12	*p*<0.001	
				Stooping: >4 hr	seldom	1.29	1.1-1.5	
				Kneeling: > 4 hr	seldom	1.24	1.1-1.4	
				Stress: high		1.6	1.4-1.8	
				Anxiety: high		1.3	1.1-1.4	

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Huang et al. 1988	Cross-sectional	Subjects consisted of all 24 female full-time workers from school lunch center A and 20 female full-time workers from center B. All 42 workers completed a symptom, health and work history questionnaire and 20 from each center also participated in a physical examination. Six workers from center B declined to participate for personal reasons unrelated to the purpose of the study.	Outcome: Symptoms relating to upper limbs, trunk and lower limbs during the previous month were solicited from a questionnaire, while clinical findings of pain during movements, muscle tenderness, signs of CTS, signs of epicondylitis, and signs of tenosynovitis were documented in a physical examination. Exposure: Ergonomic risk factors included handling heavy objects, holding constrained postures, too much stooping, repetitive use of arms and hands, and poor equipment layout. NLE used to evaluate manual lifting tasks.	Consistently constrained postures: 17 workers (70.8%)	3 workers (15%)	N/A	*p*<0.05	Participation rate: All 42 workers completed a symptom, health, and work history questionnaire and 20 from each center also participated in a physical examination. Six workers from center B declined to participate for personal reasons unrelated to the purpose of the study.
				Poor equipment layout: 18 workers (75%)	3 workers (15%)		*p*<0.01	
				Consult physician: 17 workers (70.8%)	5 workers (25%)		*p*<0.01	Center A had a significantly higher prevalence of musculoskeletal complaints, more clinical findings, and greater medical treatment experience than those in center B.
				Muscle tenderness: 5.1 +/- 5.6	0.8 +/-2.3		*p*<0.01	The ratio of the actual lifting load to the Action Limit was also larger in center A than in center B.
				Signs of tenosynovitis: 6 workers (30%)	1 workers (5.0%)		*p*<0.05	No significant difference was found between the centers for low back pain.
				Upper back pain:			significant	Study design was ecologic. Health outcomes and exposures were examined separately for two centers. Information was not combined for individual participants.

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Johanning 1991; Johanning et al. 1991	Cross-sectional mail survey	Employees of the New York City transit system (n=584)	Outcome: Back-pain symptoms in past year, by questionnaire survey. Exposure: Job title. Although, WBV measures were taken for the exposed group, no analyses were presented.	Subway train operators (n=492) Any back pain, 41% Sciatic pain	Subway control tower operators (n=92) 25%	 PRR=1.11 3.9	 1.04-1.19 1.7-8.6	Participation rate: Not reported. Controlled for age, gender, job title, employment duration. Study groups are stable working populations with low turnover rates. Exposed and unexposed groups are similar with regard to demographics and job histories. Workers with a history of back problems or previous WBV exposure were excluded from the study. Duration of employment not associated with risk. Exposure data was not associated with outcome data in these articles. Vibration measures showed high lateral and vertical acceleration levels.

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Johansson and Rubenowitz 1994	Cross-sectional	Subjects were 241 blue-collar (39% females) and 209 white-collar (35% females) workers from eight diversified metal industry companies in Sweden. The participation rate was approximately 90%. Eighty-seven percent of the blue-collar and 95% of the white-collar workers had >2 years experience in their current jobs.	Outcome: Low-back symptoms during the past 12 months as self-reported on the Nordic Musculoskeletal Questionnaire (NMQ), which was supplemented with an additional question regarding the work-relatedness of the symptoms. Exposures: Individual and employee-related variables related to the psychosocial work environment and the physical workload (sitting, manual materials handling, lifting).	Prevalence of low-back symptoms =0.43 (CI 0.37-0.50) for blue-collar workers, which reduced to *p*=0.32 (CI 0.26-0.39) when solely work-related symptoms were considered.	Prevalence of LB symptoms =0.42 (CI 0.35-0.49) among wt. collar workers, which reduced to *p*=0.18 (CI 0.11-0.24) when solely work-related symptoms were considered.	PRR=1.76	1.25-2.47	Participation rate: The participation rate was approximately 90%. Eighty-seven percent of the blue-collar and 95% of the white-collar workers had >2 years experience in their current jobs. Among blue-collar workers 12 of 15 correlation tests regarding workload factors and work-related symptoms were not significant. Among blue-collar workers 10 of 15 partial correlation tests (adjusted for the effects of age and sex) regarding psychosocial job factors and work-related musculoskeletal symptoms were significant. Among blue-collar workers 7 of 15 partial correlation tests regarding psychosocial job factors and musculoskeletal symptoms, according to the NMQ, were significant. Among white-collar workers none of the relationships between the five psychosocial factors and low-back symptoms were significant, whether or not work-related. Calculations of associations based on the NMQ, without an effort to determine the work-relatedness of symptoms, could have a powerful effect-masking result.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	Referent group	RR, OR, or PRR	95% CI	Comments
Kelsey 1975b	Case-control	Cases were obtained from a population in the age range 20 to 64 years residing in the New Haven SMSA who had lumbar X-rays taken during the period June 1971 through May 1973 at the three hospitals in the area and at the office of two of the private radiologists in New Haven. A total of 217 pairs (89 females and 128 males) was obtained for the comparison of cases and matched controls. For the analysis of cases and unmatched controls, there were 223 cases (91 female and 132 males) and 494 controls (225 females and 269 males).	Outcome: Herniated lumbar intervertebral discs were the outcomes of interest in this study. Three levels of herniated disc were classified: Surgical cases, probable cases, and possible cases. Exposure: Occupation, years of employment, amount of time worked, amount of time spent sitting, type of chair, lifting, pushing, pulling, carrying, lifting frequency, and weight of objects lifted were the exposures of interest.	Sitting >half the time:				Participation rate: 79% cases; 77% controls.
				<35 years	Equal	RR=0.81		
				>35 years	Fewer	RR=2.40	p=0.01	Results were similar for two control groups (less strong for unmatched controls).
				Time driving: >half vs. herniation	Fewer	RR=2.75	p=0.02	Study design subject to nondifferential recall problems (with regard to case/control status).
				Occupation: Truck driver vs. herniation	Fewer	RR=4.67	p=0.02	The association between sedentary occupations, especially those which involve driving, and herniated lumbar discs exists in both sexes and in comparisons between cases and both control groups.
				Lifting vs. herniation	Equal	RR=0.94	p=0.10	The strength of this association in those aged 35 and older and the lack of association in those who are under that age suggest that a certain amount of time in sedentary occupations is necessary for an effect to be seen. This study gave no evidence of an increased risk for herniated lumbar discs among males who did lifting on their jobs, and little indication of this among the females. Chance could explain the slight tendency toward significance in the female subjects.

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Kelsey et al. 1984	Case-control	Persons in the age range of 20 to 64 years who had lumbar X-ray films or myelograms taken during 1979 to 1981, in one of three hospitals, one neurosurgical private practice, or two orthopaedic private practices in the New Haven and Hartford, CT areas. 232 matched case-control pairs.	Outcome: Status determined on the basis of an interview, diagnostic tests performed by interviewers, and data recorded in medical records. Cases classified as "surgical" cases, "probable" cases, and "possible" cases. Control group composed of persons without known prolapsed disc admitted to the same medical services for conditions not related to the spine. Cases and controls all with recent (within 1 year) disease onset. Exposure: Exposure to activities performed on the current job assessed by interview and questionnaire.	N/A	N/A	Lifting: >11.3 kg >25/day: OR=3.5 Lifting: > 11.3 kg >5/day and twisting the body half the time: OR=3.1 Lifting: >11.3 kg while twisting body with the knees almost straight: OR=6.1 Carrying: >11.3 kg 5 to 25/day: OR=2.1 Carrying: >11.3 kg >25 per/day: OR=2.7	1.5-8.5 1.3-7.5 1.3-27.9 1.0-4.3 1.2-5.8	Participation rate: 72% cases; 79% controls. All case categories combined in case-control analyses (same results observed for all categories). Controls matched with cases on sex, age and hospital service. Frequent twisting alone did not affect the risk of prolapsed disk, while twisting with lifting had a detrimental effect. Study design subject to nondifferential recall problems (with regard to case/control status).

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

				MSD prevalence				
Study	Study design	Study population	Outcome and exposure	Exposed workers	Referent group	RR, OR, or PRR	95% CI	Comments
Knibbe and Friele 1996	Cross-sectional (study intended to provide baseline data for longitudinal study).	355 females employed as community nurses or community nurse auxiliaries by the home care organization of the city of Rotterdam.	Outcome: Questionnaire, developed from Nordic questionnaire for musculoskeletal disorders, mailed to nurses. Exposure: Questionnaire asked (1) if nurses could describe any work tasks they considered physically demanding, and (2) whether the onset of back pain was related to a specific work situation. Also job title: Community nurses vs. Auxiliaries.	Lifetime LBP prevalence: 87% 1-year LBP prevalence: 66.8% Auxiliaries: 61.2 1-week LBP prevalence: 20.6% Prevalence of sick leave due to back pain in previous 3 months: 9.7%	N/A	õ Back pain in last 7 days, community nurses vs. community nurse auxiliary: OR=0.84 Backpain in previous 12 months; community nurses vs. community nurse auxiliary: OR=1.54	õ 0.49-1.45 0.97-2.47	Participation rate: 94%. Males and pregnant females excluded from sample. 89.9% of nurses described situations they considered physically demanding. 82.1% of tasks described involved patient transfers. Static load on the back was mentioned in 23.2% of descriptions. Prevalence appeared to decrease with age. Cross-sectional study design prevented investigators from determining whether observation was due to selection effect or due to experience. Rates for community nurses and auxiliaries do not reflect significant differences in hrs worked/week (30.7 vs. 26.2). Adjusted for hrs worked OR is 1.3 (auxiliaries higher). Authors state that auxiliaries are responsible for more lifting activities.

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Leigh and Sheetz 1989	Cross-sectional	959 working males and 455 working females in the United States employed >20 hr/week.	Outcome: LBP based on national survey of working conditions. Question: "Is the trouble with back or spine in past year?"	1-year LBP past prevalence: 19.4% males 20.7% female	Managers and Professional			Participation rate: Not reported. (Probably to national survey).
								Workers in jobs requiring "lots of physical effort and lots of repetitive work report more back pain.
		(U.S. Department of Labor QES Survey respondents.)	Exposure: Defined by job title and questionnaire on work conditions, including workload.	Occupations:				
				Farmers	Managers	5.17	1.57-17.0	
				Clerical	Managers	1.38	0.85-2.25	Exposure information based on self report and job title.
				Operator	Managers	2.39	1.09-5.25	
				Service	Managers	2.67	1.26-5.69	
								Health outcome did not distinguish between upper and lower back pain.
				Job demands:				
				High	Low	1.68	1.05-2.90	
								Gender, race, obesity, height, and repetitious work are not significantly associated with back pain.
				Smoker	Non smoker	1.48	1.00-2.19	

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	RR, OR, or PRR	95% CI	Comments
Liles and Deivanayagan 1984	Prospective	28 companies, 63 jobs in study 1, 38 in study 2. Selected jobs with frequent lifting requirements; manual handling requirements. Study 1: 220 males; 24 females. Study 2: 165 males; 44 females.	Outcome: Lifting injury to back, as recorded or reported. Exposure: Jobs rated by Job Severity Index for lifting (observation, use of records for calculation). Each individual followed until job change (up to 2 years). Total of 529 FTEs divided equally into 10 SI levels.	Total injuries: Injury rate for the highest job severity index category: 17.1 injuries/100 FTES	Total injuries: Injury rate for the lowest job severity index category: 3.8 injuries/ 100 FTES	RR=4.5		Participation rate: Not reported (all volunteers). Dose response for lifting injuries by JSI. No adjustment for confounders. Outcome defined as lifting injuries. Not distinct from exposure.
				Disability injury rate for the highest job severity index category: 11.4 lost time injuries/100 FTES	Disability injury rate for the lowest job severity index category 3.0 lost time injuries/100 FTES	RR=3.0		
				Severe injury rate for highest job severity index category: 120.8 days lost/number of lost time injuries	Severe injury rate for the lowest job severity index category 3.0 days lost/number of lost time injuries	RR=40		

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Magnusson et al. 1996	Cross-sectional	Bus drivers, truck drivers, and sedentary workers recruited in the state of Vermont and Gothenburg, Sweden	Outcome: Back pain symptoms, by questionnaire. Exposure: Ergonomic exposures, by questionnaire and vibration level measurements according to ISO standards. Long-term vibration exposure calculated as product of daily exposure and years driving.	Bus drivers (n=111) and truck drivers (n=117)	Sedentary workers (n=137)			Participation rate: Not reported. ORs do not appear to be from multivariate analyses including other covariates, except as stated. Quantitative exposure measures are not used in analyses that are presented.
				Driving		1.79	1.16-2.75	
				Freq. lifting		1.55	1.01-2.39	
				Heavy lifting		1.86	1.2-2.8	
				Long-term vibration exposure		2.0	0.98-4.1	
				Vibration and freq. lifting		2.1	0.8-5.7	
				Vibration and heavy lifting		2.06	1.3-3.3	

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	RR, OR, or PRR	95% CI	Comments
Magora 1972	Cross-sectional	A previous article (1970) described the process for selecting 3,316 individuals from 8 occupations for inclusion into this study.	Outcome: The outcome variable, low-back pain, was defined in a previous article [1970]. Symptoms by self-report. Exposure: The physical activities studied in this investigation were sitting, standing, weight lifting, and weight lifting technique.	The exposed group consisted of workers from 8 occupations. The selection process was described in an earlier article by the same author [1970].	The controls consisted of 2887 individuals from 8 occupations. The selection process was described in an earlier article by the same author [1970].		NR	Participation rate: Not reported. The use of two hands to lift a load, and especially holding the load away from the body, are related to a higher incidence of LBP. The lifting risk factors are magnified when completing unaccustomed tasks. Rarely sitting reported to be associated with LBP. Standing less than 4 hr daily reported to be associated with LBP. Variable sitting and standing reported to be protective.
				Sitting > 4 hr day:				
				Often:		0.95	0.8-1.14	
				Sometimes:		0.09	0.05-0.14	
				Rarely:		3.20	2.69-3.8	
				Standing Variable:				
				< 4 hr daily		2.38	1.99-2.85	

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

				MSD prevalence				
Study	**Study design**	**Study population**	**Outcome and exposure**	**Exposed workers**	**Referent group**	**RR, OR, or PRR**	**95% CI**	**Comments**
Magora 1973	Cross-sectional	A previous article (1970) described the process for selecting 3,316 individuals from 8 occupations for inclusion into this study by observation and interview.	Outcome: The outcome variable, low-back pain, was defined in a previous article (1970). Exposure: The physical activities studied in this investigation were bending, rotation, reaching, sudden maximal efforts, and the number and type of work breaks, by observation, and interview.	The exposed group consisted of workers from 8 occupations. The selection process was described in an earlier article by the same author (1970).	The controls consisted of individuals from 9 occupations. The selection process was described in an earlier article by the same author (1970).	Sudden maximal physical efforts were found to be related to a high incidence of LBP.	Not reported	Participation rate: Not reported. It appears that sudden maximal efforts, especially if unexpected, play an important role in the causation of LBP. Many of the physical causative factors, such as bending or rotation, found by other investigators to be related to a high incidence of LBP are actually sudden maximal efforts incidentally carried out at that moment in a certain position of the spine. While most bending, twisting, and reaching motions required by each occupation are knowingly carried out, sudden maximal physical efforts are characterized by their unexpectedness. This may actually trigger LBP through sudden strain of soft tissues, possibly caught in a condition or posture < optimal for this kind of effort.
				Among those with LBP:	Among controls:			
				Bending: Often: 14.5% Sometimes: 3.4% Rarely: 23.2%	Bending: Often: 85.5% Sometimes: 96.6% Rarely: 76.8%			
				Spine rotation: Often: 12.1% Sometimes: 22.0% Rarely: 10.3%	Spine rotation: Often: 87.9% Sometimes: 78% Rarely: 89.7%			
				Sudden maximal efforts: Often: 18.0% Sometimes: 11.3% Rarely: 10.9%	Sudden maximal efforts: Often: 82% Sometimes: 88.7% Rarely: 89%	Sudden maximal efforts and LBP: 1.65	1.3-2.1	

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Marras et al. 1993 Marras et al. 1995	Cross-sectional	403 industrial jobs from 48 manufacturing companies: e.g., automobile assembly, food processing, lumber and wood, construction, metal and paper production, printing, and rubber production. No data provided on the number of workers in study.	Outcome: Existing medical and injury records in each industry were examined for each job to determine if workers on those jobs had reported work-related low-back disorders. The result yielded an outcome measure of "LBD risk," which was a normalized rate of work-related LBD. Exposure: A triaxial electrogoniometer was worn by workers to record position, velocity and acceleration of the lumbar spine while workers lifted in either "high" or "low" risk jobs. Workplace and individual characteristics were recorded. High risk exposed was >12% injury rate, yielding 111 high risk jobs, while 124 jobs were low risk, serving as the control group.	Maximum load moment: 73.65 Nm Sagittal mean velocity: 11.74 E/sec Maximum weight: 104 N 23.3 lb	23.64 Nm 6.55 E/sec Maximum weight: 37 N 8.3 lb	5.17 3.33 3.17	3.19-8.38 2.17-5.11 2.19-4.58	Participation rate: Numbers and proportions of those sampled by job group. No information on number of individual participants. Study provides linkage between epidemiologic measures of injury (i.e., "probabilities of high-risk LBD group membership") and select biomechanical and task factors for repetitive lifting jobs. Study illustrates multi-factored nature of injury risk, but it does not indicate the risk of LBD. Quality and accuracy of injury and medical records are unknown. Inaccuracies or underreporting would affect the accuracy of the model. Exposure assessors may not have been blinded to risk status of jobs they were evaluating.

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Masset and Malchaire 1994	Cross-sectional	Steel workers (n=618). All male and all under 40 years of age.	Outcome: Interview-based checklist and questionnaire: Back pain defined for three periods: (1) during lifetime, (2) past 12 months, and (3) past 7 days by the question, “Did you have any problems in the lower back?” Exposure: Interview-based exposure assessment using checklist: postures and movements of the trunk, efforts, physical and psychosocial environment (monotony, responsibility), vehicular driving and exposure to whole body vibration.	Lifetime LBP prevalence for all workers: 66% 1-year LBP prevalence for all workers: 50% 1-week LBP prevalence: 25% Prevalence of sciatica was low: 2-3%	N/A	Õ Vehicle driving: 1.15 Heavy efforts of the shoulder: 1.62 Seated posture: 1.46	 <0.005 <0.01 0.09	Participation rate: 90%. Low back fatigue accounted for 25% LBP cases. No objective measure of workload. Stratified by age and exposure risk level. Ergonomic redesign prior to study, reduced ergonomic hazards. Physical workload, posture, movements of the trunk, repetition, negative perception of working environment, exposure to WBV, not associated with back pain. Information obtained included demographics, height, weight, medical history, personality, and social status (smoking, sports, satisfaction with family and occupation, abnormal fatigue, temper, headache, depressive tendency, present and past working environment. All long-lasting sick workers excluded from study; may cause survivor bias. Back “fatigue” separated from “back pain.” This cross-sectional study was first part of a prospective study. Heavy efforts with shoulders were strongly correlated with LBP.

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Partridge and Duthie 1968	Cross-sectional	206 male civil servants (clerical workers), age 15 to 64 years, and 171 male dock workers, age 25 to 64 years.	Outcome: Low-back pain (including lumbar disc disease, pelvic girdle pain, and leg pain). Participants attended an interview at which time a medical and social questionnaire was administered and a medical examination was performed. Complaints classified into 8 categories. Exposure: Based on job title (civil servant or docker).	Dockers: current rheumatic symptoms: 43.2% Low-back pain, 61 dockers (Standardized Ratio (SR) by age 106.1)	Civil servants: current rheumatic symptoms: 34.5% Low-back pain, 33 civil servants (SR 90.4)	RR=1.27	0.98-1.64	Participation rate: 95.7% for dockers and 91.0% for civil servants. Analyses corrected for age. Overall complaint rates did not differ between occupations, despite differences in physical effort requirements. Older civil servants complained of more neck/shoulder pain than dockers of a similar age. Difference attributed to static working postures involving the neck and shoulder. Among civil servants, only 5 weeks (16.1%) of sickness absence in previous year due to back pain. Among dockers, 75 weeks (68%) of work lost attributed to lumbar disc disease and backache. Authors conclude that there is a positive correlation between the heaviness of work and time lost due to back complaints, even if the complaint rate in different occupations does not vary significantly. Medical examiners probably not blinded to exposure status.

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

				MSD prevalence				
Study	Study design	Study population	Outcome and exposure	Exposed workers	Referent group	RR, OR, or PRR	95% CI	Comments
Punnett et al. 1991	Case-referent (retro-spective)	219 automotive assembly workers. 95 cases compared to 124 referents without back pain.	Outcome: Back pain cases: (interview and exam) defined as workers who filed new reports of back disorders at plant during a 10-month period. Back pain in interview defined as history of $ 3 episodes or $ one episode lasting $ one week within the year preceding the date of the interview. Physical exam consisted of active, passive, and resisted motions concentrating 11 ranges of motion of the back. Referents: No report of back disorders. Exposure: Based on video analysis of job postures and bio-mechanical data	84% (185)	20 workers unexposed	Non-neutral postures: 4.9 Mild flexion: 5.7 Severe flexion: 5.9 Time in non-neutral posture: 8.09 Lift 44.5N: 2.16 Age (years): 0.96 Back injury: 2.37	1.4-17.4 1.6-20.4 1.6-21.4 1.5-44.0 1.0-4.7 0.9-1.0 1.3-4.3	Participation rate: 84%. Healthy worker effect. Of the 124 referents, only 20 workers were unexposed to all awkward postures. Back disorders were found to be associated non-neutral trunk postures. 69% of subjects in job <5 years. Questionnaire involved demographics, work history, medical history, and non-occupational activities. Analyses controlled for gender, age, length of employment, recreational activity, medical history, and maximum weight lifted in study job. Exposure variable for non-neutral posture: The sum of the duration spent in non-neutral postures as a continuous variable. A strong trend found for increasing length of exposure and risk of back disorders to both mild and severe trunk flexion. Only current job analyzed: Assumes short-term relationship between outcome and exposure (however, also included duration of employment variables).

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Riihimäki et al. 1989a	Cross-sectional mail survey	Longshoremen, earth moving equipment operators (WBV), carpenters (heavy physical work), and office workers (sedentary work) (n=2,223)	Outcome: Back pain symptoms, by questionnaire. Exposure: Job title and questionnaire responses regarding work history, physical work factors, and work stress.	Longshoremen (n=542), earth movers (n=311), and carpenters (n=696)	Office workers (n=674)			Participation rate: $70%. Longshoremen and earthmovers combined in analysis (machine operators).
				Sciatic pain and machine operators		1.3	1.1-1.7	After adjustment for age, duration of employment was not associated with symptoms in any group.
				Sciatic pain and carpenters		1.0	0.8-1.3	Of the three back symptoms, sciatica, lumbago, and LBP, sciatica discriminated the best among occupational groups.
				Sciatica and twisted or bent postures		1.5	1.2-1.9	
				Sciatica and annual driving		1.1	0.9-1.4	All three exposed groups were exposed to $ one work-related risk factor for back disorder.

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Riihimäki et al. 1989b	Cross-sectional	216 concrete workers compared to 201 house painters (all male), age-matched. Restricted to workers with 5 years work experience and to workers <55 years.	Outcome: Radiographically detectable degenerative changes in lumbar region. Exposure: Based on job title (article refers to Wickström [1985] evaluation of concrete reinforcement workers).	Grade 2 to 3 disc problem: 27.8% concrete workers Back problems: 55% Sciatic: 53%	Grade 2 to 3 disc problem: 15.4% house painters Back problems: 45% Sciatic: 39%	N/A Occupa-tion effect of concrete work: OR=1.8 Age: OR=6.5 Spondy-lophytes Occupa-tion effect of concrete work: OR=1.6 Age: OR=14.9	*p*=0.001 1.2-2.5 1.7-26 1.2-2.3 2.3-95	Participation rate: 84% concrete workers and 86% house painters. Examiners (radiologists) blinded to case or exposure status. Age, self-reported back accidents, body mass index, height, and smoking controlled for in analysis. Height, weight, smoking no effect on degenerative X-ray changes. Negative bias for occupational factor due to healthy worker effect. Positive bias due to recall for identifying accidents as risk factors. Individual exposure data not available for workers. Radiographically detectable degenerative changes associated with sciatic pain (1.0, 1.4, 1.9) for three grades of degeneration (not for LBP or lumbage). No hypotheses regarding specific risk factors. Exposure assessed by job title only.

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Riihimäki et al. 1994 Pietri-Taleb et al. 1995	Prospective (3-years)	Machine (heavy equipment) operators (688), carpenters (533), and office workers (591). All males.	Outcome: Based on 2 Postal questionnaires; LBP=Low-back symptoms in preceding 7 days, 12 months, and lifetime. Sciatic pain = pain radiating to leg/s. Exposure: Based on specific occupation: Machine operators were exposed to static loads, low-level, whole body vibration. Carpenters exposed to dynamic physical work. Office workers were sedentary workers. Questionnaire asked amount of twisted or bent postures, pace of work, monotonous work, problems with co-workers or superiors, draft, cold, vibration.	22% machine operators 24% carpenters Physical exercise > once a week Smokers and ex-smokers History of lower back pain: Mild LBP; Severe LBP	14% office workers Maximum physical exercise once a week. Non-smokers None	1.4 1.5 1.26 1.29 2.7 4.5	0.99-1.87 1.1-2.1 1.0-1.6 (p<0.06) 0.98-1.7 p<0.06) 1.7-4.2 2.7-7.6 (p<0.001)	Participation rate: For follow-up: 81% machine operators, 79% carpenters, and 89% office workers. Questionnaire included age, level of education, annual car driving, weekly physical exercise, occupational exposure, and history of other back problems. Questionnaires administered in 1984 and 1987. Separate logistic regression models created for specific occupation. History of other types of low back pain predicted sciatica in all groups. Monotonous work, problems with co-workers or supervisors, and high-paced work were not associated with sciatica three-year cumulative Incident Rate. Article examines only sciatic pain.

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Ryden et al. 1989	Case-control	Cases consisted of 84 employees with back injuries and 168 controls (matched triplets). Mean age was 34 and 83.3% were female. Cases: Employees with injuries from job-related activities that occurred during the working day, not based on individual lost time from the job or workers' compensation. The incidence rate at the work site during the study period was 29/1,000 in 1983, 29/1,000 in 1984 and 33/1,000 in 1985. Controls selected from the same population by age, sex, and department. For each case, two controls were selected from a list of all employees, stratified by department. Matching for age was done within a 5-year span.	Outcome: Reported work-related low-back injuries while employed at the site of the study during the time period of 1983 through 1985. Exposures: History of previous back injury at work, work shift, heavy work, lifting, bending, slipping, self-reported low-back pain or "slipped disc," and individual risk factors.		Low-back pain: OR=2.27	Previous back injury: OR=2.13 Working day shift: OR=2.23 Low back pain: OR=2.27 Self-report slip disc: OR=6.20	1.07-4.24 1.28-3.89 1.25-4.12 2.64-14.57	Participation rate: Not reported. Disadvantages of the design include: a lack of detailed information that could have helped to focus on selected risk factors. For example, knowledge of pack-years rather than only number of cigarettes smoked/day would have been valuable, if available, as would more specific information on body build, including percent body fat and fitness level, rather than using height/weight and self-reported exercise level. Advantages of the design included economy, time savings, flexibility, and the analysis of a large group of risk factors simultaneously. Immediate reporting of injuries, including the nature of the injury and pertinent data regarding where and how the injuries occurred, is essential to efforts both to reduce injuries and to rehabilitate those who are injured. Cases and controls were (over) matched on occupation risk factors. Could not examine these effects. Those working day shift felt to have greater physical demands.

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Schibye et al. 1995	Longitudinal	Follow-up of 303 sewing machine operators at nine factories representing different technology levels who completed questionnaire in 1985. In April 1991, 241 of 279 traced workers responded to same questionnaire.	Outcome: Based on Nordic Questionnaire: pain in the last 12 months in the low back (last 7 days). Exposure: Assessed by questions regarding: (1) type of machine operated, (2) work organization, (3) workplace design, (4) units produced/day, (5) payment system, and (6) time of employment as a sewing machine operator.	Prevalences of LBP in Sewing jobs: 12-month: LBP: 1985=38% 1991=47% Prevalences 1-week: LBP: 1985=23% 1991=25%				Participation rate: 1985: 94%; 1991: 86%. All participants were females. 77 of 241 workers still operated a sewing machine in 1991. 82 workers had another job in 1991 among those 35 years or below, 77% had left job; among those above 35 years 57% left job. 20% reported musculoskeletal symptoms as the only reason for leaving job. Healthy worker effect. Another 13% said symptoms were part of the reason. No significant changes in prevalences among those employed as sewing machine operators from 1985 to 1991; significant decrease in those who changed employment. As many as 50% of respondents reported a change in the response to positive or negative symptoms from 1985 to 1991. This was due to a decrease in the risk factors: e.g., decreased in output and hrs worked/week. Article examines only neck/shoulder area in detail (no exposure analyses for back outcome).

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Skov et al. 1996	Cross-sectional	1,306 Danish salespersons	Outcome: Musculoskeletal symptoms, by questionnaire. Exposure: Self-reported driving distance, time in sedentary work, lifting of heavy loads, psychosocial job characteristics.	Danish salespersons (n=1,306)	No unexposed group included			Participation rate: Not reported. Covariates considered in multivariate analyses included age, sex, height, weight, smoking, work-related psychosocial variables, lifting, leisure time sports activities. No unexposed group was included.
				Annual driving distance		Annual driving distance, highest category: OR=2.79	1.5-5.1	
				Sedentary work (% of worktime)		Sedentary work (% of worktime) highest category: OR=2.45	1.2-4.9	

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Skovron et al. 1994	Cross-sectional	4,000 random-stratified sampled adults in Belgium; a bicultural country, uniform health care system; 48% male. Population-based telephone survey.	Outcome: Based on back pain symptom reporting from structured interviews. Back pain defined by question "Have you ever had back pain?" Cases restricted to those subjects currently working. Exposure: Based on interview data: occupation and working status, "Are you satisfied with work" question..	Point prevalence LBP: 33% Lifetime prevalence: 59% Among workers occupation: Work dissatisfaction: Female gender: Increasing age:		 NS 2.4 2.16 2.0	 *p*=0.02 *p*=0.001 *p*=0.001	Participation rate: 86%. Information included age, gender, social class, habitat, language, working status, occupation, work satisfaction, lifestyle factors, and family history. Logistic regression models controlled for age, and gender; interaction tested. First episode of back pain not associated with work satisfaction. Language influence reporting of first time occurrence and history of back pain but not severity of impairment as expressed as daily back pain. Uniform health care assured equal access and reporting. Results suggest that work satisfaction is not a cause of LBP, but it intervenes in the expression of LBP.

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	Referent group	RR, OR, or PRR	95% CI	Comments
Svensson and Andersson 1989	Cross-sectional	Random sample of 1,760 38 to 64-year-old females from Goteborg, Sweden. At the time of the investigation, 14 females could not be located. Approximately 80% of the final sample of 1,746 females participated in the study.	Outcome: Low-back pain (LBP) was defined as all conditions of pain, ache, stiffness, or fatigue localized to the lower back. All episodes of LBP were included in the study, as determined by questionnaire. Exposure: Variables included working hr, working hr/week, amount of overtime, lifting, frequency of forward bending and twisting, work posture, possibility to change work posture, need to concentrate, monotony, satisfaction with work tasks, possibility to take rest breaks, worried and tense after work, fatigued at the end of the work day, and education. Exposed and unexposed were determined by questionnaire responses.			Univariate analysis found significant correlations between LBP and 5 exposures in ages 50-64 years: More bending, lifting, standing, higher degree of worry, and exhaustion at the end of the work day.	 $p<0.05$ $p<0.01$ $p<0.01$ $p<0.01$ $p<0.0001$	Participation rate: Approximately 80% of the final sample of 1,746 females participated in the study. The analysis of correlations between the occurrence of LBP and the different variables describing work history, work environment, and stress was restricted to wage-earning females only (sick-listed included). No significant differences existed between the two age groups concerning the incidence and prevalence rates of LBP. However, several parameters indicated that the LBP in the older age group was more severe. Several of the correlations in the univariate analysis, when tested in the covariate analysis, were found to be dependent on other confounding factors. The findings in the present study stress the importance of psychological factors in relation to low-back pain. These factors are probably not only related to the individual's personality but also to the type of work and the environment at the workplace. Medical examiners discussed questionnaires with participants—not blinded.

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	RR, OR, or PRR	95% CI	Comments
Toroptsova et al. 1995	Cross-sectional	701 random-stratified sampled employees of a Russian machine building plant 47% male.	Outcome: LBP history from structured interviews. Back pain defined as pain lasting in area below 12th rib and above gluteal folds. All persons with LBP complaints examined by rheumatologist. Exposure: Based on interview data: Work, sports, and personal factors. 10 industrial factors examined: Lifting, standing, sitting, walking, vibration, static work, postures, repetitive work, and bending.	Frequent trunk flexion Frequent lifting required in job	No trunk flexion Occasional lifting (2 or less/day)	1.66 1.43	*p*<0.01 *p*<0.05	Participation rate: 88%. Analysis did not control for confounders. Information included personal data, family status, education, profession, anthropometric data, smoking, sport activity, and professional factors. Lifetime prevalence: 48%. Prevalence higher among older workers and smokers >10/day. Back pain decreased in group >55 years. The year of retirement for females. No association with sitting or standing postures, walking, vibration, static work postures, and repetitive work.

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Undeutsch et al. 1982	Cross-sectional	366 male cargo transport workers at a large airport. (Baggage handlers).	Outcome: Standardized interview administered to all workers to detect subjective previous and present back symptoms. Clinical orthopaedic examination administered to 134 workers to detect objective findings. Exposure: Data on work experience in the present occupation was collected. No other exposure data collected.	Prevalence of previous back complaints: 56% Prevalence of present back symptoms: 66% Prevalence of objective back findings at examination: 70%	N/A	N/A	N/A	Participation rate: Not reported (46% of target population included). Current back symptoms positively correlated with height, age, and length of experience in transport work. Among workers with present symptoms, symptoms occurred most frequently during lifting of loads (75%) and while in bended body positions (61%). Changing body position (71%) and absence of work for one or more days were relieving factors for back symptoms. Comparison of interview and clinical exam results show interview to be a suitable screening method for clinical back pain (sensitivity=86%, specificity=31%). Significant association between length of transport work and back symptoms (*p*=0.035) adjusted for age. No heterogeneity with regard to exposure.

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Videman et al. 1984	Cross-sectional	562 nurses and 318 nursing aides in Finland, all of them females.	Outcome: Based on results from a pre-tested questionnaire and from health information obtained from the local Pension Registers that were used to identify nurses who had been pensioned due to ill health during a 4-year period immediately preceding the mailing of the questionnaire. Exposure: Based on self-assessments from data obtained using a mailed questionnaire that included nine questions on physical loading factors at work and seven questions on work history and occupation. Jobs were reclassified as heavy, intermediate, and light based on results of questionnaire items dealing with workload.	85% of aides had $ one "life-time" episode of LBP and their point prevalence was 50% for LBP. Sciatica: 43% life-time prevalence. Aides had twice the lifting, bending and rotation.	79% of nurses had experienced $ one "life-time" episode of LBP; point prevalence was 41% for LBP Sciatica: 38% life-time prevalence	$ one "life-time" episode of LBP: 1.1	1.01-1.14	Participation rate: 88% nurses; 85% nurses aides. Workers with back pain were employed in heavy jobs on average 1 year longer than those with no previous LBP. Musculoskeletal disorders as a cause of disability increased with age; the 30-years risk for 25-years old aides was 3.4 times greater than for the nurses; similar results for sciatica with a risk of 4.5 times greater for the aides than nurses. The prevalence of LBP and sciatic symptoms in both nurses and in aides are high and similar to the results found in Britain. Physical workload related to patient handling was mainly responsible for the differences in LBP and sciatica rates between the aides and nurses. The finding was most evident under the age of 30 years. Non work-related factors, such as childbirth, also contributed to the adverse back conditions. Study lacks a good unexposed population since both nurses and aides were exposed to varying degrees of risk factors for LBP and sciatica. Workers with LBP were in heavier jobs for longer time than those without LBP.

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Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

				MSD prevalence				
Study	Study design	Study population	Outcome and exposure	Exposed workers	Referent group	RR, OR, or PRR	95% CI	Comments
Videman et al. 1990	Cross-sectional	From a Finnish workforce of 86 males who had worked in four distinct occupational groups: Sedentary, Mixed, Driving, and Heavy. Criteria for inclusion: Deceased below the age of 64 who had been employed before death and the subjects' family able to provide working information. Exclusion criteria were long illnesses or a diseased state, such as cancer or infectious disease.	Outcome: Objective radiologically and discography-based pathologic criteria from the cadaver spines of the study population. Degree of degeneration was outcome measure, i.e., annular ruptures. Information on symptoms was obtained from family members. Exposure: Type of work, based on work history reports from family; classification of work based on heaviness, driving, and sedentary jobs. Classification based on physically heaviest occupation held for $ 5 years.	54% of heavy workers had LBP often, and 36% had sciatica 50% of drivers had LBP often, and 29% of them had sciatica Heavy physical load vs. not: OR=2.8 Sedentary vs. not: OR=24.6 (symmetric disc degeneration)	10% of sedentary workers had LBP often, and 19% had sciatica 29% of mixed group had LBP often, and 10% had sciatica	Heavy vs. Mixed: 2.7 Driving vs. Mixed: 2.3 Sciatica: NS	1.1-6.2 0.8-6.2	Participation rate: Not reported. Strength: First study linking pathologic data with history of occupation and physical loading factors. Weakness: Do not know the temporal pattern in development of the pathologic changes. Possible selection bias due to potential differential rates between work groups in leaving jobs because of degenerative diseases. Two important findings: Sedentary or heavy work contribute to the development of pathologic findings in spine. Severity of back pain was related to the heaviness of work, i.e., work factors responsible for development of pathologic changes and for the production of pain. Back pain more common with physically more loading occupations; *p*<0.001. Similar but weaker trend between loading and sciatica; *p*=0.03. General: *p*<0.01 between groups for back pain; and *p*<0.07 for sciatica. Relationships were observed between report of symptoms and disc pathology; also, exposures and disc pathology.

(Continued)

Table 6-6 (Continued). Epidemiologic studies evaluating back musculoskeletal disorders

Study	Study design	Study population	Outcome and exposure	MSD prevalence: Exposed workers	MSD prevalence: Referent group	MSD prevalence: RR, OR, or PRR	MSD prevalence: 95% CI	Comments
Walsh et al. 1989	Cross-sectional	A postal questionnaire was sent to a random sample of 267 males and 268 females in the age range of 20 to 70 who lived in Whitchurch, England. Four hundred, thirty-six questionnaires were returned, giving an overall response rate of 81%.	Outcome: Self-reported low-back pain, by interview. Exposure: Standing or walking for > 2 hr; sitting for > 2 hr; driving a car or van for > 4 hr; driving a truck, tractor or digger; lifting or moving weights of 25kg or more by hand; or using hand held vibrating machinery were the exposures of interest. Lifetime occupational history obtained by interview.	Lifetime incidence of LBP was 63%.				Participation rate: 436 questionnaires were returned, giving an overall response rate of 81%. The association with use of vibrating machinery among females (repetitive risk=5.7) was based on only one exposed case. Cases of low-back pain were ascertained solely on the basis of reported symptoms. Successive birth cohorts reported the development of low-back pain at any given age with increasing frequency. Driving a car for >4 hr a day was associated with low-back pain in males but not with low-back pain in females. Authors believe the data give strong support for a role of regular heavy lifting in the etiology of low-back pain and add weight to the evidence implicating occupational driving as a risk factor. At the same time, however, they suggest that such activities account for only a small proportion of the total burden of low-back pain in the general population. Author's estimates of the fraction of disease attributable to heavy lifting and car driving are 14 and 4%, respectively, leaving a substantial proportion of cases unexplained. Authors attempted to recreate a retrospective cohort design; asked participants to remember dates and jobs and LBP. Questionable recall for temporal relationships.
				Recent Occup. Activity:				
				Males				
				Driving>4hr/d		RR=1.7	1.0-2.9	
				Lifting 25kg		RR=2.0	1.3-3.1	
				Females				
				Lifting 25kg		RR=2.0	1.1-3.7	
				Lifetime Occup. Activity:				
				Males				
				Lifting 25kg		RR=1.5	1.0-2.4	
				Females				
				Sit >2hr/d		RR=1.7	1.1-2.6	
				Vib. machine		RR=5.7	1.1-29.3	
				Risk of unremitting LBP:				
				Males				
				Lifting 25kg		RR=5.3	1.3-20.9	
				Females				
				Lifting 25kg		RR=2.9	0.8-10.2	

CHAPTER 7

Work-Related Musculoskeletal Disorders and Psychosocial Factors

SUMMARY

While the etiologic mechanisms are poorly understood, there is increasing evidence that psychosocial factors related to the job and work environment play a role in the development of work-related musculoskeletal disorders (MSDs) of the upper extremity and back. Though the findings of the studies reviewed are not entirely consistent, they suggest that perceptions of intensified workload, monotonous work, limited job control, low job clarity, and low social support are associated with various work-related musculoskeletal disorders.

As some of these factors are seemingly unrelated to physical demands, and a number of studies have found associations even after adjusting for physical demands, the effects of these factors on MSDs may be, in part or entirely, independent of physical factors. It is also evident that these associations are not limited to particular types of jobs (e.g., video display terminal work [VDT]) or work environments (e.g., offices) but, rather, seem to be found in a variety of work situations. This seems to suggest that psychosocial factors may represent generalized risk factors for work-related MSDs. These factors, while statistically significant in some studies, generally have only modest strength.

At present, two of the difficulties in determining the relative importance of the physical and psychosocial factors are: (1) psychosocial factors are usually measured at the individual level, while physical factors are more often measured at the group (e.g., job or task) level and often by methods with limited precision or accuracy and (2) “objective measures" of aspects of the psychosocial work environment are difficult to develop and are rarely used, while objective methods to measure the physical environment are more readily available. Until we can measure most workplace and individual variables with more comparable techniques, it will be hard to determine precisely their relative importance.

INTRODUCTION

There is considerable confusion regarding the contribution of psychosocial factors to musculoskeletal illness and injury. Because of this, it is examined in this separate section of the report. Unlike the more finite (and generally more familiar) range of physical factors (e.g., force, repetition, and posture), the concept of psychosocial factors includes a vast array of conditions. Indeed, the term “psychosocial” is commonly used in the occupational health arena as a catchall term to describe a very large number of factors that fall within three separate domains: (1) factors associated with the job and work environment, (2) factors associated with the extra-work environment, and (3) characteristics of the individual worker. Interactions among factors within each of these domains constitute what is referred to as a “stress process,” the results of which are thought to impact upon both health status and job performance [Bongers and deWinter 1992; ILO 1986; Sauter and Swanson 1996; WHO 1989].

Included in the domain of job and work environment are a host of conditions, sometimes referred to as "work organization factors," which include various aspects of job content (e.g., workload, repetitiveness, job control, mental demands, job clarity, etc.); organizational characteristics (e.g., tall versus flat organizational structures, communications issues); interpersonal relationships at work (e.g., supervisor-employee relationships, social support); temporal aspects of the work and task (e.g., cycle time and shift work); financial and economic aspects (e.g., pay, benefit, and equity issues); community aspects (e.g., occupational prestige and status). These work and job environment factors are often thought of as demands, or "risk factors," that may pose a threat to health [Hurrell and Murphy 1992]. Extra-work environment parameters typically include factors associated with demands arising from roles outside of work, such as responsibilities associated with a parent, spouse, or children. Finally, individual worker factors are generally of three types [Payne 1988] corresponding to: genetic factors (e.g., gender and intelligence); acquired aspects (e.g., social class, culture, educational status); and dispositional factors (e.g., personality traits, and characteristics and attitudes such as life and job satisfaction).

PSYCHOSOCIAL PATHWAYS

The purpose of this discussion is to summarize research evidence linking work-related psychosocial factors, as described above, to MSDs of the neck, shoulder, elbow, hand/wrist, and back. It should be recognized at the outset, however, that the linkages between work-related psychosocial factors and health outcomes of all varieties are often complex and influenced by a multitude of conditions. In particular, both personal and situational characteristics may lead to differences in the way individuals exposed to the same job and work environment perceive and/or react to the situation [Hurrell and Murphy 1992]. Recent theoretical models of the relationship between psychosocial factors and MSDs [Bongers et al. 1993; Sauter and Swanson 1996] clearly reflect the complexity and multifactorial nature of the problem.

In general, four plausible types of explanations have been suggested to account for associations between work-related psychosocial factors and MSDs [Bergqvist 1984; Bongers et al. 1993; Bernard et al. 1993; Sauter and Swanson 1996; Sauter et al. 1983; Ursin et al. 1988]. First, psychosocial demands may produce increased muscle tension and exacerbate task-related biomechanical strain. Second, psychosocial demands may affect awareness and reporting of musculoskeletal symptoms, and/or perceptions of their cause. Within this second explanation may fall the "perverse incentive" view, in which societies may provide workers with systems (such as workers' compensation) that may lead to overreporting of MSD symptoms [Frank et al. 1995]. Third, initial episodes of pain based on a physical insult may trigger a chronic nervous system dysfunction, physiological as well as psychological, which perpetuates a chronic pain process. Finally, in some work situations, changes in psychosocial demands may be associated with changes in physical demands and biomechanical stresses, and thus associations between psychosocial demands and MSDs occur through either a causal or effect-modifying relationship.

The research evidence reviewed in the following discussion is organized into two separate sections. The first section includes studies of disorders of the neck, shoulder, elbow, hand and wrist which are discussed under the rubric of “upper extremity disorders.” This convention was adopted because many of the studies utilize measures which combine symptoms associated with several upper extremity body areas (e.g., neck and shoulder), and it is therefore not possible in reviewing these studies to isolate the effects of the psychosocial variables under consideration on more specific areas. The second section examines studies of back disorders. Associations reported in this review are statistically significant in nearly all cases (at the $p<0.05$ level and frequently also at the $p<0.01$ level). Where possible, odds ratios (ORs) are also reported.

The studies examined in this review are summarized in Tables 7-1 and 7-2. In interpreting the studies reviewed, it is necessary to be aware that, in general, researchers have not used standardized methods for assessing psychosocial factors in relationship to MSDs. Thus, individual psychosocial factors assessed by investigators vary from study to study. Moreover, even when work-related psychosocial factors (e.g., workload , job control, social support, job satisfaction, etc.) included by various investigators are the same or similar, they may be measured by different methods and different kinds of scales which can vary in psychometric quality. These methodological limitations complicate the process of drawing definitive conclusions regarding the literature as a whole and when comparing results between studies, one must take these differences into account.

UPPER-EXTREMITY DISORDERS (NECK, SHOULDER, ELBOW, HAND AND WRIST)

Individual and Extra-Work Environment Factors

A variety of psychosocial factors associated with both the individual worker and extra-work environment have been linked to upper extremity MSDs [Sauter and Swanson 1996; Bongers and deWinter 1992; Bongers et al. 1993]. These factors have included such conditions as depression and anxiety [Helliwell et al. 1992], symptoms of psychological distress [Leino 1989], and home problems [Karasek et al. 1987]. The connection between factors of this nature and the job and work environment, however, is unclear. While affective problems (such as anxiety and depression) and symptoms of distress may certainly be a consequence of the work situation, they may also be causally related to non-work circumstances only. Likewise, while extra-work environment conditions (e.g., “home problems") may be exacerbated by the work situation (e.g., shift work) their “work-relatedness” remains unclear. Because of the uncertainty regarding the work-relatedness of these individual and extra-work environment factors (and because discussions can be found in other sources), only the individual psychosocial factor, job dissatisfaction, is examined here.

Job Dissatisfaction

A number of studies suggest associations between low levels of satisfaction with work and upper extremity musculoskeletal symptoms and disorders. Tola et al. [1988], for example, in a study of 1,174 machine operators, 1,054 carpenters, and 1,013 office workers, found an association (OR 1.2) between job dissatisfaction and neck and shoulder physical findings or symptoms, after adjusting for confounders. Likewise, Hopkins [1990] reported a positive association between job dissatisfaction and musculoskeletal symptoms. However, low job satisfaction was not found to predict neck and shoulder problems one year later in a study of 154 Finnish workers [Viikari-Juntura et al. 1991a]. Likewise, in a study of 273 nursing aids employed in a geriatric hospital [Dehlin and Berg 1977] job satisfaction was found to be unrelated to reports of ever having cervical pain.

Job and Work Environment Factors

Intensified Workload

One of the factors most consistently associated with upper extremity MSDs has been the perception of an intensified workload, as measured by indices of perceived time pressure, workload, work pressure, and workload variability. Pot et al. [1987], for example, in a cross-sectional study of 222 VDT operators, found high levels of perceived time pressure associated with the reporting of upper extremity musculoskeletal complaints. Kompier [1988] found perceived time pressure to be associated with upper extremity complaints (in the preceding 12 months) among some 158 male bus drivers. Likewise, Takala et al. [1991], in a longitudinal study of 351 female bank cashiers, reported a positive association between perceived time pressure and symptoms of the neck and shoulder after adjusting for postural load. Theorell et al. [1991], however, in a sample of some 206 workers from six occupations, found that perceived time pressure was not significantly correlated with neck or shoulder symptoms.

Positive associations with upper extremity disorders have also been found in studies using measures of perceived work pressure and workload. High levels of perceived workload, for example, were found to be positively associated with musculoskeletal symptoms in the Pot et al. [1987] and Theorell et al. [1991] studies (which adjusted for physical demands such as lifting and awkward postures) reported above. Kvarnström and Halden [1983], in a case control study of 112 cases and 112 age- and sex-matched controls from an engineering firm, found sick leave due to fatigue or shoulder muscle soreness to be positively associated with high perceived workload. Karasek et al. [1987], in a study of 8,700 full-time members of the Swedish white collar labor union federation, found perceived workload to be positively associated with musculoskeletal aches as measured by a combination of several questions (OR 1.1 for males, 1.2 for females). Likewise, Sauter et al. [1983], in a study of 248 VDT users, found perceived workload and demands for attention to be associated with neck, back, and shoulder discomfort after adjusting for a wide variety of variables denoting physical demands. Bernard et al. [1993], in a study of 1,050 newspaper employees, found perceived increased workload demands (increased time working under deadline and increased job pressure) to be positively associated with neck, shoulder, and hand-wrist symptoms. Similarly, Hales et al. [1994], in a study of 553 telecommunications workers, found increased work pressure to be associated with neck (OR 1.2) and upper extremity (OR 1.1) disorders, as defined by physical examination and questionnaire. Ryan and Bampton [1988], using a total sample of 143 data processors, compared 41 individuals reporting a number of neck symptoms to 28 reporting very few neck symptoms (middle group left out) and found a positive association between symptom reports and reports of having to push themselves (OR 3.9). Ekberg et al. [1994] compared 109 workers who consulted a physician for new musculoskeletal neck and shoulder disorders with 637 controls and found a positive association (OR 3.5) with rushed work pace. Houtman et al. [1994], in a representative sample of 5,865 workers in the Netherlands, found reported high work pace associated with muscle or joint symptoms (OR 1.3) after adjusting for physical stressors and modifying personal characteristics. However, Dehlin and Berg [1977] in the study described above, found no relationship between reports of high perceived physical and psychological demands and reports of ever having pain in the cervical region. Finally, Houtman et al. [1994], in a representative sample of 5,865 workers in the Netherlands, found reported high work pace associated with muscle or joint symptoms (OR 1.29) after adjusting for physical stressors and modifying personal characteristics.

Variability in workload (surges in workload) has also been linked to upper extremity disorders. The studies by Hales et al. [1994] of 553 telecommunication workers and Hoekstra et al. [1994] of some 108 teleservice representatives, found perceived workload variability to be associated with elbow (OR 1.2) and neck (OR 1.2) disorders, but not with shoulder or hand disorders.

Monotonous Work

Monotonous work has been positively linked to the prevalence of upper extremity symptoms in various studies. In a study of 143 data processors, Ryan and Bamptom [1988] found that self-reports of "being bored most of the time" were highly (OR 7.7) associated with neck symptoms. Likewise, Linton [1990], in a study of approximately 22,200 Swedish workers undergoing a screening examination by the occupational health care service, found that monotonous work was positively associated with neck/shoulder pain (OR 2.3) during the preceding year. Ekberg et al. [1994], in the study described above, found an association between "low quality work" (lacking stimulation and variation) and neck and shoulder problems (OR 2.6). Similarly, Kvarnström and Halden [1983] in the case control study described above, found monotonous work to be associated with sick leave due to fatigue or tenderness in the shoulder muscles. Finally, Hopkins [1990] in a study of around 280 clerical workers found high levels of boredom to be associated with musculoskeletal symptoms (in any part of the body) during work hours.

Job Control

Numerous studies have reported positive associations between limited job control or autonomy at work and upper extremity problems. These include neck symptoms [Ryan and Bamptom 1988, OR 3.9; Hales et al. 1994, OR 1.6], neck/back/shoulder symptoms [Sauter et al. 1983; Theorell et al. 1991], musculoskeletal aches [Karasek et al. 1987], and muscle/joint symptoms [Hopkins 1990; Houtman et al. 1994]. The study by Pot et al. [1987], however, failed to support this relationship.

Job Clarity

A number of studies, including those of Ryan and Bamptom [1988], Karasek et al. [1987], and Ekberg et al. [1994], have shown positive associations between reports of role ambiguity (uncertainty about job expectations) and upper extremity disorders (particularly neck disorders). Similarly, uncertainty regarding job future was found to be predictive of neck and shoulder discomfort [Sauter et al. 1983] and elbow, neck, and hand/wrist symptoms [Hales et al. 1994].

Social Support

Limited social support from supervisors and coworkers has been found to be positively associated with a variety of upper extremity symptoms. The studies by Pot et al. [1987], Kompier [1988], Hopkins [1990], Sauter et al. [1983], and Hales et al. [1994], all support a positive association. Linton [1990] reported a positive association between neck symptoms and limited support from supervisors. Ryan and Bampton [1988] reported an effect of limited support from coworkers (OR 6.7), but not supervisors, on neck symptoms, while Kvarnström and Hagberg [1983] reported an effect of limited support from supervisors but not coworkers on sick leave due to shoulder muscle symptoms. Dehlin and Berg [1977], however, found no effect of social support on neck/shoulder symptoms, while Theorell et al. [1991] found no effect of social support at work on neck and shoulder symptoms or symptoms of the other joints (with or without adjustment for physical load). Likewise, Karasek et al. [1987] found no significant association between musculoskeletal aches and social support at work.

Summary and Conclusions for Upper Extremities

Overall, the epidemiologic studies of upper extremity disorders suggest that certain psychosocial factors (including intensified workload, monotonous work, and low levels of social support) have a positive association with these disorders. Lack of control over the job and job dissatisfaction also appear to be positively associated with upper extremity MSDs, although the data are not as supportive.

The evidence for the relationship between psychosocial factors and upper extremity disorders appears to be stronger for neck/shoulder disorders or musculoskeletal symptoms in general than for hand/wrist disorders. This stronger association for neck/shoulder disorders may be due to the following reasons: the large number of studies performed in the Nordic countries which have focused more on the neck/shoulder MSD health outcome than a hand/wrist outcome; many of the neck/shoulder studies included numerous psychosocial variables in their models, whereas studies of hand/wrist MSDs have not, as a rule, included as extensive psychosocial variable testing (therefore the variables are absent from the risk factor models); and the fact that most of the studies with extensive psychosocial scales were in office settings, where physical factors may be less important than psychosocial factors in their relationship with MSDs. This finding can be contrasted with studies in heavy industrial settings, where higher exposure to physical factors may have played a greater role than psychosocial factors in the development of MSDs. Also, pathophysiologic processes resulting from adverse psychosocial and work organization factors may exert a greater effect on the neck/shoulder musculature to produce increased muscle tension and strain than on the hand/wrist region.

BACK DISORDERS

Individual and Extra-Work Environment Factors

As with upper extremity disorders, a host of psychosocial factors associated with the individual worker (e.g., personality and psychological status) and extra-work environment (e.g., living alone) have been linked to back pain and disability [Bongers et al. 1993]. As the "work-relatedness" of these factors is unclear and because they have been examined by others (e.g., Bongers [1993]), with the exception of job dissatisfaction discussed above, they will not be extensively reviewed in this report. In general, these studies show clear associations between measures of psychological distress or dysfunction and self-reported back pain. However, the temporal relationship between psychological factors and musculoskeletal symptoms/ disorders remains unclear. One possibility is that psychological distress is simply a consequence of chronic low back pain, with no etiologic role in the development of the disorder. Alternatively, it is possible that psychological factors may have some etiologic role in the transition from an employee with a history of back pain to the status of an unemployed patient with chronic back pain, due to fear of re-injury, or other factors which would make it impossible to perform the job [Feyer et al. 1992].

While there are a number of prospective studies of low back pain and individual physical factors, there appear to be only a few prospective studies that incorporate individual and extra-work environment psychosocial factors. Bigos et al. [1991b] defined, in a 4-year study of 3,020 hourly wage earners at an aircraft manufacturing plant, an outcome as reporting a back pain complaint to the company medical department, filing a back-related incident report, or filing an industrial insurance claim. The psychosocial assessment included personality traits, as measured by the Minnesota Multiphasic Personality Inventory (MMPI), and limited information on family support, health locus of control, and work social support. One question about enjoyment of tasks in the job was also included. Of the 37 variables used to evaluate the role of social support, health locus of control, and personality traits, three were found to be significant in a multivariate analysis. They were Scale 3 of the MMPI [tendencies towards somatic complaints or denial of emotional distress (relative risk [RR]=1.4), dissatisfaction with work (RR=1.7), and prior back pain (RR=1.7)]. Although significant, these variables explained only a small fraction of the back pain reports in this population. The number of back pain reports was three times higher in the group with the highest scores on these three variables compared with the group with the lowest scores, although only 9% of the work force was in the highest risk group. Because this study focused on the reporting of back pain complaint and not the actual development of back pain, it would be a mistake to generalize the results to workers developing back pain. This study suggests that individual premorbid personality traits only explain a small fraction of work-related lower back problems.

Job Dissatisfaction

Job dissatisfaction has been associated with back disorders in both longitudinal and cross-sectional investigations. Bergenudd and Nilsson [1988], studying some 575 residents of Malmo for over 19 years, found job dissatisfaction to be associated with self-reported back pain. As described above, Bigos et al. [1991b] found a positive association between job dissatisfaction and workers filing compensation claims for back injury. Here, subjects who stated that they "hardly ever" enjoyed their job tasks were 2.5 times more likely to report a back injury than those who "almost always" enjoyed their job tasks. However, as Frank et al. [1995] point out, some reviewers have argued that the airplane manufacturing jobs with the highest levels of dissatisfaction were also the most physically demanding. Frank et al. [1995] also noted that, unfortunately, the extent of the interaction is difficult to assess because of the limited measurement of workplace biomechanical exposures in the Bigos et al. studies [1986a,b; 1991a,b]. While psychosocial and psychological factors were assessed at the individual level, workplace biomechanical factors were assessed only at the group level. Biering-Sorensen et al. [1989], in a one-year follow-up mail survey study of some 928 inhabitants of Denmark (which adjusted for confounders such as previous back pain), also found no association of back pain with job dissatisfaction. Because information was limited to the use of mailed survey questionnaires, no workplace biomechanical factors were measured in this study either.

The cross-sectional study by Dehlin and Berg [1977] of nursing aids described earlier found an association between dissatisfaction and self-reported back symptoms. However, this study did not adjust for confounders. Likewise, Magora [1973] in a mailed survey study of Israeli workers in 8 occupational categories found job satisfaction to be associated with reports of sick leave due to low back pain. This study also did not adjust for potential confounders. Svensson and Anderson [1989], in a cross-sectional study of 1,746 Swedish residents, found an association after adjustment. However, in a cross-sectional study by Åstrand [1987] of 391 male Swedish paper company workers (clerks and manual workers), no association was found between dissatisfaction and back disorders, as assessed by symptoms and physical examination after confounder adjustment.

Job and Work Environment Factors

Intensified Workload

A number of studies have reported associations between perceptions of intensified workload, as measured by reports of time pressure and high work pace, and self-reports of back pain. Heliövaara et al. [1991] in a study of approximately 5,600 Finns, found a composite measure (containing items on perceived time pressure at work, monotony, and fear of mistakes) to be associated (OR 2.0) with back disorders (defined by interview and physical examination) after adjusting for potential confounders, including physical load and previous back pain. Lundberg et al. [1989] found perceived time pressure to be associated with perceived back load among 20 workers on a Swedish assembly line. In a similar vein, Houtman et al.

[1994], in the study of 5,865 Dutch workers across all occupations reported above, found an association (OR 1.21) between reporting high work pace and self-reported back pain (but not chronic back pain problems, defined as back pain for more than three months or at least three times in the study period) (OR 1.2). Magora [1973], in the study of Israeli workers described above, found high levels of concentration to be associated with reports of sick leave due to low back pain (OR 2.9). However, Åstrand [1987], found no association between "hustling" and "nerve wracking work" and back pain in male paper company workers.

Monotony

Several studies described above [Heliövaara et al. 1991; Houtman et al. 1994] have reported associations between perceived monotony and reports of back complaints. Svensson and Anderson [1983], in a study of 940 male residents of Goteborg, Sweden, between the ages of 40 and 47, similarly found monotonous work (rated "absolutely" or "unacceptably" boring) to be associated with back complaints. This relationship remained after adjusting for several physical factors. However, Svensson and Anderson [1989] found no relationship between monotony and back pain complaints among Swedish women in a multivariate analysis which included measures of job and task satisfaction. Similarly, in the Houtman et al. [1994] study, controlling for a combination of physical stressors (dangerous work, heavy physical load, noise at work, dirty work, and bad smell at work) reduced the magnitude of the relationship (for back complaints, the OR decreased from 3.90 to 3.46.) The authors suggest that this may be because monotonous work is often work which is also either short-cycled or involves a high static (postural) load.

Job Control

In the study of teleservice operators cited above, Hoekstra et al. [1994], after controlling for a number of individual and work-related factors, found perceived job control at work to be inversely associated with back disorders (OR 0.6), that is, the less perceived job control at work, the higher the odds of back disorders. Likewise, as noted above, Sauter et al. [1983] found that low job control was related to neck, back, and shoulder discomfort.

Social Support

Bigos et al. [1991b] found a significant univariate relationship between limited social support at work and back trouble. However, this association was found to be nonsignificant by the investigators when included in a multivariate analysis.

Summary and Conclusions for Back Disorders

In general, the studies reviewed suggest an association between back disorders and perceptions of intensified workload as measured by indices of both perceived time pressure and workload. Despite the considerable differences in the types of methods used to assess both the independent and dependent variables, four of the five studies that explicitly included measures of intensified workload found significant associations. It is also noteworthy that all four of these studies attempted to control or adjust for potential covariates. Five of the seven studies that assess job dissatisfaction also found positive associations with back disorders. While this evidence is clearly suggestive, Biering-Sorensen et al. [1989] found no association in a large-scale one-year follow-up study; while Åstrand [1987] likewise found no evidence of an association among 391 paper workers. Limited support for an association between back disorders and low job control is also evident, while the evidence for a relationship between monotonous work and back disorders is mixed. Only one study examined the relationship between social support and back disorders and found only weak evidence for an association.

Overall Conclusions

While the etiologic mechanisms are poorly understood, there is increasing evidence that psychosocial factors related to the job and work environment play a role in the development of work-related MSDs of the upper extremity and back. Though the findings of the studies reviewed are not entirely consistent, they suggest that perceptions of intensified workload, monotonous work, limited job control, low job clarity, and low social support are associated with various work-related MSDs. As some of these factors are seemingly unrelated to physical demands, and a number of studies have found associations even after adjusting for physical demands, the effects of these factors on MSDs may be, in part or entirely, independent of physical factors. It is also evident that these associations are not limited to particular types of jobs (e.g., VDT work) or work environments (e.g., offices) but, rather, seem to be found in a variety of work situations. This observation seems to suggest that psychosocial factors may represent generalized risk factors for work-related MSDs. These factors, while statistically significant in some studies, generally have only modest strength.

At present, two of the difficulties in determining the relative importance of the physical and psychosocial factors are the following: (1) psychosocial factors are usually measured at the individual level, while physical factors are more often measured at the group (e.g., job or task) level and often by methods with limited precision or accuracy, and (2) “objective measures” of aspects of the psychosocial work environment are difficult to develop and are rarely used, while objective methods to measure the physical environment are more readily available. Until we can measure most workplace and individual variables with more comparable techniques, it will be hard to determine precisely their relative importance in the causation of MSDs.

Table 7–1. Summary of studies examining psychosocial factors and upper extremity disorders (neck, shoulder, elbow, hand, and wrist)

	Methods					Associations with UE outcomes					
Study	**Worker group (particip. rate)**	**Design**	**Psychosocial factor assessment**	**MSD outcome assessment**	**Covariate adjust-ments**	**Job/task dissat.**	**Int. wkld.**	**Mono. work**	**Low job control**	**Low job clarity**	**Low social supp.**
Bernard et al. 1993	1,050 newspaper workers (93%)	Cross-sectional	Self-report questionnaire with job stress scales	MSD case definition based on questionnaire			+		+		
Dehlin and Berg 1977	233 nursing aides (85%)	Cross-sectional	Self-report questionnaire—7 scales	Interviews—pain/ache symptoms		o	o				o
Ekberg et al. 1994	109 workers vs. 637 controls	Cross-sectional (case-control)	Self-report—modified Nordic questionnaire	MD consults for MSD disorders			+			+	
Hales et al. 1994	553 telecom-munications workers	Cross-sectional	Self-report questionnaire with job stress scales	Disorders based on symptom questionnaire and MD exam	Controlled for extra job factors		+		+	+	
Hoekstra et al. 1994	108 teleservice workers (95%)	Cross-sectional	Self-report job stress questionnaire	MSD case definition based on self-report questionnaire			+				
Hopkins 1990	291 keyboard operators and other clerical groups	Cross-sectional	Self-report questionnaire—items from habits of living questionnaire	Questionnaire symptoms		+		+	+	+	

See footnotes at end of table.

(Continued)

Table 7–1(Continued). Summary of studies examining psychosocial factors and upper extremity disorders (neck, shoulder, elbow, hand, and wrist)

	Methods					Associations with UE outcomes					
Study	Worker group (particip. rate)	Design	Psychosocial factor assessment	MSD outcome assessment	Covariate adjust-ments	Job/task dissat.	Int. wkld.	Mono. work	Low job control	Low job clarity	Low social supp.
Houtman et al. 1994	5,865 workers—general population	Cross-sectional	Self-report work-living questionnaire	Symptoms questionnaire	Physical stressors—personal character-istics		+		+		
Karasek et al. 1987	8,700 white collar labor union members (87%)	Cross-sectional (random sample)	Self-report questionnaire	Questionnaire—musculoskeletal aches			+		+	+	+
Kompier 1988	158 male bus drivers (73%)	Cross-sectional	Self-report questionnaire	Self report questionnaire—complaints and sick leave			+				+
Kvarnstrom and Halden 1983	224 fabrication workers	Cross-sectional (case-control)	Structured interview questionnaire	Disorders from medical and sick absence records			+	+			+/o
Linton 1990	22,200 workers—general population	Cross-sectional	Self-report work environment questionnaire and habits of living questionnaire	Pain				+			+
Pot et al. 1987	222 VDT operators	Cross-sectional	Structured interview questionnaire	Complaints—structured interview			+/+		o		+

See footnotes at end of table.

(Continued)

Table 7–1(Continued). Summary of studies examining psychosocial factors and upper extremity disorders (neck, shoulder, elbow, hand, and wrist)

	Methods					Associations with UE outcomes					
Study	Worker group (particip. rate)	Design	Psychosocial factor assessment	MSD outcome assessment	Covariate adjust-ments	Job/task dissat.	Int. wkld.	Mono. work	Low job control	Low job clarity	Low social supp.
Ryan and Bampton 1988	143 data processors	Cross-sectional (high vs. low symptoms)	Self-report questionnaire—items from work environment scale	Symptoms based on MD interview and exam			+	+	+	+	+/o
Sauter et al. 1983	248 VDT users and 85 non-users (90%)	Cross-sectional	Self-report questionnaire—work environment scale items	Questionnaire—discomfort scale	Physical work demands (adj.)		+		+	+	+
Takala et al. 1991	351 bank cashiers	Longi-tudinal	Self-report questionnaire	Questionnaire—muscle symptoms	Postural load (adj.)		+				
Theorell et al. 1991	207 workers in 6 occupations	Cross-sectional	Self-report questionnaire	Questionnaire—muscle tension symptoms	Physical load (adj.)		+/o		+		o
Tola et al. 1988	1,174 machinists; 1,034 carpenters; 1,013 office workers (67% to 76%)	Cross-sectional	Mailed questionnaire—worker characteristics	Symptoms in last 12 months; questionnaire and interview		o					

+ = Significant association found.
o = No significant association found.
+/+ = Two different measures of factor (e.g., time pressure and workload) found significant.
+/o = Mixed results (on factor significantly associated; second factor not significantly associated).

Table 7–2. Summary of studies examining psychosocial factors and back disorders

	Methods					Associations with back disorders				
Study	Worker group (participation rate)	Design	Psychosocial factor assessment	MSD outcome assessment	Covariate adjust-ments	Job dissat.	Int. wkld.	Mono. work	Low job control	Low social supp.
Åstrand 1987	391 workers in paper-pulp industry	Cross-sectional	Questionnaire—questions on work conditions	Interview and MD exam—back pain abnormalities		o	o			
Bergenudd and Nilsson 1988	575 55-year-old city residents (96%)	Longi-tudinal	Interview and mailed questionnaire	Interview reports of back pain		+				
Biering-Sorenson et al. 1989	928 persons—general population (82%)	Longi-tudinal	Mail questionnaire	Questionnaire—back pain in last 12 months		o				
Bigos et al. 1991b	3,020 male aircraft plant employees (54% with all data)	Longi-tudinal	Questionnaire—Personality Inventory (MMPI), other questions	Back problems—medical reports, insurance claims	Control for prior back problems	+				o
Dehlin and Berg 1977	233 nursing aides (85%)	Cross-sectional	Questionnaire—7 scales, 52 items	Interview—reported pain/ache symptoms		+				
Heliövaraa et al. 1987	5,600 workers—general population (92%)	Cross-sectional	Questionnaire—scale assessing combined hurried work, monotonous work, tight work schedules	MD exam and interview—back disorders	Physical load, prior back problems	Combined +	+			

See footnotes at end of table.

(Continued)

Table 7–2 (Continued). Summary of studies examining psychosocial factor and back disorders

Study	Methods					Associations with back disorders				
	Worker group (participation rate)	Design	Psychosocial factor assessment	MSD outcome assessment	Covariate adjust-ments	Job dissat.	Int. wkld.	Mono. work	Low job control	Low social supp.
Hoekstra et al. 1994	108 teleservice workers (95%)	Cross-sectional	Job stress questionnaire	MSD case definition based on questionnaire data	Individual work factors				+	
Houtman et al. 1994	5,865 workers—general population	Cross-sectional	Questionnaire—work living questionnaire survey	Questionnaire symptoms	Physical stressors; personal character-istics		+	+		
Lundberg et al. 1989	20 male assembly line workers	Cross-sectional	Ratings of time pressure during 2-hr work period	Back load ratings during 2-hr work period			+			
Magora 1973	3,316 workers in 8 occupations	Cross-sectional (low pain vs. controls)	Questionnaire—ratings of job aspects and satisfaction	Questionnaire—reports of low-back pain and sick leave due to low-back pain	Analyses stratified by occupation	+	+			
Sauter et al. 1983	248 VDT users; 85 non-users (90%)	Cross-sectional	Questionnaire—work environment scale survey	Questionnaire—reports of discomfort	Physical work demands				+	
Svensson and Anderson 1983	940 males—general population	Cross-sectional	Questionnaire—perceptions of stress, boredom	Interview report of back pain	Physical work demands—life and job satisfaction			+		

See footnotes at end of table.

(Continued)

Table 7–2 (Continued). Summary of studies examining psychosocial factor and back disorders

	Methods					Associations with back disorders				
Study	Worker group (participation rate)	Design	Psychosocial factor assessment	MSD outcome assessment	Covariate adjust-ments	Job dissat.	Int. wkld.	Mono. work	Low job control	Low social supp.
Svensson and Anderson 1989	1,746 females ages 38–64—general population	Cross-sectional	Questionnaire—items on job and task satisfaction	Interview—reports of back pain	Physical workload	+		o		

\+ = Significant association found.
o = No significant association found.

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APPENDIX A
Epidemiologic Review

Various investigators have used different occupational epidemiologic methods to identify the patterns of work-related MSD occurrence in different working groups, as well as the factors that influence these disease patterns. The following section briefly summarizes these study designs and then addresses the most common biases (such as misclassification or selection) that can affect the results of these studies.

TYPES OF EPIDEMIOLOGIC STUDY DESIGNS REVIEWED

The NIOSH reviewers have first addressed studies that use a prospective approach. **Prospective cohort studies**, identify groups of subjects (exposed and nonexposed) and observe them over a period of time to compare the number of new work-related MSD cases in the two groups. All subjects are initially disease-free. The rate (or risk) of new cases (the incidence) is calculated for both groups, and the ratio of these two incidences (the relative risk or rate ratio, RR) can be used to assess the association of the exposure with the occurrence of the MSD. A RR greater than 1.0 implies that the incidence of cases was higher in the exposed group than in the nonexposed group and that an association has been observed between the exposure and the disease. A confidence interval (CI) is derived, which is an estimated range of values within which the true RR is likely to fall. The CI reflects the precision of the effect observed in the study. Ordinarily, if the CI includes 1.0, the association between the exposure and the MSD could be due to chance alone and the elevated odds ratio (OR) is not considered statistically significant.

The cohort study ensures that the exposure to work-related factors occurs before the observation of the MSD, thereby allowing a causal interpretation of the observed association. Cohort studies are often done prospectively; they follow a group of current workers forward in time. The length of time required for a prospective study depends on the problem studied. With adverse health conditions that occur as a result of long-term exposure to some factor in the workplace, many years may be needed. Extended time periods make prospective studies costly. Arguing causation is more difficult with extended time periods because other events may affect outcome. Prospective studies that require long periods of time are especially vulnerable to problems associated with worker follow-up, particularly worker attrition (workers discontinue participation in the study) and worker migration (diseased workers move to other employment before investigators ascertain their disease).

The second type of epidemiologic study evaluated for this document is the **case-control study**, which is retrospective and examines differences in exposures among workers with (cases) and without (controls) MSDs. In such studies, cases should be all incident (new) cases in a given population over a defined period or a representative sample of the cases. Controls should be a representative sample of non-cases from the same population. The ratio of the odds of exposed cases to the odds of exposed controls is called the OR. An OR above 1.0 indicates an association between the exposure and the work-related MSD, and a 95% CI indicates the probable range of the true OR. Case control studies are useful for evaluating rarely occurring conditions or small numbers of cases. One limitation of case control studies is the difficulty of obtaining accurate information about past exposures. In occupational studies of MSDs, a further limitation of case-control studies is the difficulty of identifying cases who are representative of all cases that occurred in a defined period (many of these workers will have left the workforce). Another problem with case-control studies is the selection of an inappropriate control group.

Third, the reviewers considered **cross-sectional studies**. Cross-sectional studies provide a "snapshot in time" of a disease process; that is, they measure both health outcomes and exposures at a single point in time. These studies usually identify occupations with differing levels of exposure and compare the prevalences of MSDs in each group. Cross-sectional studies are most useful for identifying risk factors of a relatively frequent disease with a long duration that is often undiagnosed or unreported [Kleinbaum et al. 1982]. Typically, cross-sectional studies do not provide the evidence of the correct temporal relationship between exposure and disease inherent in prospective studies, but they nevertheless can be valuable. Some cross-sectional studies discussed here had inclusion criteria such as working at a specific job for a defined period of time before onset of symptoms. This condition adds a dimension of temporality to the studies. A common problem with cross-sectional studies that use surveys is obtaining sufficiently large response rates; many people who are asked to participate decline because they are busy, not interested, etc. The conclusions are therefore based on a subset of workers who agree to participate, and these workers may not be representative of or similar to the entire population of workers. Furthermore, cross-sectional studies are often confined to current workers who may not be representative of true prevalence rates if workers with disease have left the workforce. (The problem of representativeness is not confined to cross-sectional studies and may occur in the other study designs mentioned whenever subjects are selected, decline, or drop out.) Either ORs or prevalence ratios (PRs) (proportion of diseased in exposed divided by the proportion of diseased in unexposed) may be used to report results in cross-sectional studies.

The last type of observational study used is the **case-series study**, in which certain characteristics of a group (or series) of cases (or patients) are described. The simplest design is a set of case reports for which the author describes some interesting or intriguing observations that occurred in a small number of patients. Cases included in case series have usually been drawn from a single patient population, whose makeup may have influenced the observations noted because of selection bias. Case-series studies frequently lead to a generation of hypotheses that are subsequently investigated in a cross-sectional, case-control, or prospective study. Because case-series do not involve comparison groups (who do not have the condition or exposure to the risk factors being studied), some investigators would not consider them epidemiologic studies because they are generally not planned studies and do not involve any research hypotheses.

BIASES AND OTHER ISSUES IN EPIDEMIOLOGIC STUDIES

In interpreting the validity of epidemiologic studies to provide evidence for work-relatedness of MSDs, several assumptions and sources of bias must be considered when analyzing the findings from such studies.

1. Selection bias (internal validity). In occupational health studies, at least two types of selection bias may occur: (a) a selection of "healthy workers" in the work population studied, and (b) an exclusion of "sick" workers who leave the active workforce. Both of these biases tend to cause an underestimate of the true relationship between a workplace risk factor and an observed health effect because the workers who are in better health tend to be those in the workforce and available for study.

   A basic assumption underlying the analysis of these studies is that the selected cases of work-related MSDs in the specific studies are representative of all workers at that worksite with work-related MSDs. In a single study, representativeness generally increases with increasing population size and participation rate. A parallel assumption is that the nondiseased groups are representative of the entire nondiseased population. The fact that some cases leave the workforce causes the disease prevalence among currently employed workers to be underestimated. However, if cases are missing from the current workforce in equal proportion for both nonexposed and exposed workers, the underestimate of prevalence will not affect the internal validity of the study.

2. Generalizability (external validity). Some studies are based on a single population, occupation, or restricted data base (individual insurance companies, specific industrial settings) and, therefore, the sample may not be representative of the general population. Another assumption is that MSD cases in one study are comparable to cases in another study. This assumption needs particular scrutiny in work-related MSD studies because no standardized case definitions may exist for the particular illnesses.

3. Misclassification bias. Misclassification bias may be introduced during selection of cases and determination of their exposure. Erroneous diagnoses may result in work-related MSD cases misclassified as noncases, and similarly, noncases may be misclassified as cases. The calculated RR or OR would usually underestimate the true association because of a dilutional effect if both exposed and nonexposed cases are equally misclassified. Similarly, misclassification can occur when determining the exposure factor of interest. Again, such misclassification will create a bias towards finding no association if equal misclassification is assumed for cases and noncases.

4. Confounding and effect modification. Other factors may explain the supposed relationship between work and disease. Confounding is a situation in which the relationship (in this case with MSDs) appears stronger or weaker than it truly is as a result of something (the confounder) being associated with both the outcome and the apparent causal factor. In other words, the risk estimate is distorted because symptoms of exposed and nonexposed workers differ because of some other factors that cause disease. For example, diabetes might result in abnormal nerve conduction testing, a sign of CTS. If a higher proportion of exposed workers than nonexposed workers were diabetic, diabetes would act as a positive confounder, causing an apparent exposure-disease association.

   An effect modifier is a factor that alters the effect of exposure on disease. For example, it is possible that repetitive motion causes tendinitis only in older workers; in this case, age would be an effect modifier. Although effect modification is not a bias per se, if an investigator has failed to analyze old and young workers separately, the investigator might have missed a true work/disease association.

5. Sample size, precision, and CIs. The CI around an estimated measure of effect (such as a RR) is an estimated range of values in which the true effect is likely to fall. It reflects the precision of the effect observed in the study. Large studies generally have smaller CIs and can estimate effects more precisely. In studies that are “statistically significant” the CI excludes the null value for no effect (for example, a RR of 1.0). Small studies are generally less precise, lead to wider CIs, and less likely to be “statistically significant” even if the exposed have a greater prevalence of disease than the nonexposed.

APPENDIX B
Individual Factors Associated with Work-Related Musculoskeletal Disorders (MSDs)

Although the purpose of this document is to examine the weight of evidence for the contribution of work factors to MSDs, the multifactorial nature of MSDs requires a discussion of individual factors that have been studied to determine their association with the incidence and prevalence of work-related MSDs. These factors include age [Guo et al. 1995; Biering-Sorensen 1983; English et al. 1995; Ohlsson et al. 1994]; gender [Hales et al. 1994; Johansson 1994; Chiang et al. 1993; Armstrong et al. 1987a]; anthropometry [Werner et al. 1994b; Nathan et al. 1993, Heliövaara 1987]; and cigarette smoking [Finkelstein 1995; Owen and Damron 1984; Svensson and Andersson 1983; Kelsey et al. 1990; Hildebrandt 1987], among others. Nonoccupational physical activities, such as nonoccupational VDT use, hobbies, second jobs, and household activities that might increase risk for MSDs are described in the detailed tables for those studies in which they were analyzed as risk factors.

A worker's ability to respond to external work factors may be modified by his/her own capacity, such as tissue resistance to deformation when exposed to high force demands. The level, duration, and frequency of the loads imposed on tissues, as well as adequacy of recovery time, are critical components in whether increased tolerance (a training or conditioning effect) occurs, or whether reduced capacity occurs which can lead to MSDs. The capacity to perform work varies with gender and age, among workers, and for any worker over time. The relationship of these factors and the resulting risk of injury to the worker is complex and not fully understood.

Certain epidemiologic studies have used statistical methods to take into account the effects of these individual factors (e.g., gender, age, body mass index), that is, to control for their confounding or modifying effects when looking at the strength of work-related factors. Studies that fail to control for the influence of individual factors may either mask or amplify the effects of work-related factors. The comments column of the detailed tables notes whether studies have adjusted for potential confounders.

A number of factors can influence a person's response to risk factors for MSDs in the workplace and elsewhere. Among these are the following:

AGE

The prevalence of MSDs increases as people enter their working years. By the age of 35, most people have had their first episode of back pain [Guo et al. 1995; Chaffin 1979]. Once in their working years (ages 25 to 65), however, the prevalence is relatively consistent [Guo et al. 1995; Biering-Sorensen 1983]. Musculoskeletal impairments are among the most prevalent and symptomatic health problems of middle and old age [Buckwalter et al. 1993]. Nonetheless, age groups with the highest rates of compensable back pain and strains are the 20–24 age group for men, and 30–34 age group for women. In addition to decreases in musculoskeletal function due to the development of age-related degenerative disorders, loss of tissue strength with age may increase the probability or severity of soft tissue damage from a given insult.

Another problem is that advancing age and increasing number of years on the job are usually highly correlated. Age is a true confounder with years of employment, so that these factors must be adjusted for when determining relationship to work. Many of the epidemiologic studies that looked at populations with a wide age variance have controlled for age by statistical methods. Several studies found age to be an important factor associated with MSDs [Guo et al. 1995; Biering-Sorensen 1983; English et al. 1995; Ohlsson et al. 1994; Riihimäki et al. 1989a; Toomingas et al. 1991] others have not [Herberts et al. 1981; Punnett et al. 1985]. Although older workers have been found to have less strength than younger workers, Mathiowetz et al. [1985] demonstrated that hand strength did not decline with aging; average hand pinch and grip scores remained relatively stable in their population with a range of 29 to 59 years. Torell et al. [1988] found no correlation between age and the prevalence of MSDs in a population of shipyard workers. They found a strong relationship between workload (categorized as low, medium, or heavy) and symptoms or diagnosis of MSDs.

Other studies have also reported a lack of increased risk associated with aging. For example, Wilson and Wilson [1957] reported that the age and gender distribution of 88 patients with tenosynovitis from an ironworks closely corresponded to that of the general population of that plant. Similarly, Wisseman and Badger [1976] reported that the median age of workers with chronic hand and wrist injuries in their study was 23 years, while the median age of the unaffected workers was 24 years. Riihimäki et al. [1989a] found a significant relationship between sciatica and age in machine operators, carpenters, and sedentary workers. Age was also a strong risk factor for neck and shoulder symptoms in carpenters, machine operators and sedentary workers [Riihimäki et al. 1989a]. Some authors may have incorrectly attributed age as the sole cause of their findings in their analysis, when data presented suggested a relationship with work [Schottland et al. 1991].

An explanation for the lack of an observed relationship between an increased risk for MSDs and aging may be “survivor bias” (this is different from the “healthy worker effect”). If workers who have health problems leave their jobs, or change jobs to one with less exposure, the remaining population includes only those workers whose health has not been adversely affected by their jobs. As an example, in a study of female plastics assembly workers, Ohlsson et al. [1989] reported that the degree of increase in the odds of neck and shoulder pain with the duration of employment depended on the age of the worker. For the younger subjects, the odds increased significantly as the duration of employment increased (p=0.01), but for the older ones no statistical change was found with length of employment. The older women who had been employed for shorter periods of time had more reported symptoms than the younger ones, while older workers with longer employment times reported fewer symptoms than younger workers. Ohlsson et al. [1989] interviewed 76 former assembly workers and found that 26% reported pain as the cause of leaving work. This finding supports the likely role of a survivor bias in this study, the effect of which is to underestimate the true risk of developing MSDS, in this case in the older workers.

GENDER

Some studies have found a higher prevalence of some MSDs in women [Bernard et al. 1994; Hales et al. 1994; Johansson 1994; Chiang et al. 1993]. A male to female ratio of 1:3 was described for carpal tunnel syndrome (CTS) in a population study in which occupation was not evaluated [Stevens et al. 1988]. However, in the Silverstein [1985] study of CTS among industrial workers, no gender difference could be seen after controlling for work exposure. Franklin et al. [1991] found no gender difference in workers compensation claims for CTS. Burt et al. [1990] found no gender difference in reporting of neck or upper extremity MSD symptoms among newspaper employees using video display terminals (VDTs). Nathan et al. [1988, 1992a] found no gender differences for CTS. In contrast, Hagberg and Wegman [1987] reported that neck and shoulder muscular pain is more common among females than males, both in the general population and among industrial workers. Whether the gender difference seen with some MSDs in some studies is due to physiological differences or differences in exposure is unclear. One laboratory study, Lindman et al. [1991], found that women have more type I muscle fibers in the trapezius muscle than men, and have hypothesized that myofascial pain originates in these Type I muscle fibers. Ulin et al. [1993] noted that significant gender differences in work posture were related to stature and concluded that the lack of workplace accommodation to the range of workers' height and reach may, in part, account for the apparent gender differences. The reporting bias may exist because women may be more likely to report pain and seek medical treatment than men [Armstrong et al. 1993; Hales et al. 1994]. The fact that more women are employed in hand-intensive jobs and industries may account for the greater number of reported work-related MSDs among women. Byström et al. [1995] reported that men were more likely to have deQuervain’s disease than women; they attributed this to more frequent use of hand tools. Some studies have reported that workplace risk factors account for increased prevalence of MSDs among women more than personal factors (e.g., Armstrong et al. [1987a], McCormack et al. [1990]). In a recent evaluation of Ontario workers compensation claims for “RSI,” Asbury [1995] reported a RR for female to male claims ranging from 1.3 to 1.6 across industries. Within 5 different broad occupational categories, females were approximately 2–5 times as likely to have a lost-time RSI claim. No information on gender differences in hand intensive jobs was reported. May researchers have noted that men and women tend to be employed in different jobs.

In order to separate the effect of work risk factors from potential effects that might be attributable to biological differences, researchers must study jobs that men and women perform relatively equally.

SMOKING

Several papers have presented evidence that a positive smoking history is associated with low back pain, sciatica, or intervertebral herniated disc [Finkelstein 1995; Owen and Damron 1984; Frymoyer et al. 1983; Svensson and Anderson 1983; Kelsey et al. 1984]; whereas in others, the relationship was negative [Kelsey et al. 1990; Riihimäki et al. 1989b; Frymoyer 1993; Hildebrandt 1987]. Boshuizen et al. [1993] found a relationship between smoking and back pain only in those occupations that required physical exertion. In their study, smoking was more clearly related to pain in the extremities than to pain in the neck or the back. Deyo and Bass [1989] observed that the prevalence of back pain increased with the number of pack-years of cigarette smoking and with the heaviest smoking level. Heliövaara et al. [1991] only observed a relationship in men and women older than 50 years. Two studies did not find a relationship between sciatica and smoking among concrete reinforcement workers and house painters [Heliövaara et al. 1991; Riihimäki et al. 1989b].

In the Viikari-Juntura et al. [1994] prospective study of machine operators, carpenters, and office workers, current smoking (OR 1.9 1.0–3.5), was among the predictors for change from "no neck trouble" to "severe neck trouble." In a study of Finnish adults ages 30–64, [Mäkelä et al. 1991], neck pain was found to be significantly associated with current smoking (OR 1.3, 95% CI 1–1.61) when the logistic model was adjusted for age and gender. However, when the model included mental and physical stress at work, obesity, and parity, then smoking (OR 1.25, 95% CI 0.99–1.57) was no longer statistically significant [Mäkelä et al. 1991]. With univariate analysis, Holmström [1992] found a PRR of 1.2 (95% CI 1.1–1.3) for neck-shoulder trouble in "current" smokers versus "never" smokers. But using multiple logistic regression, when age, individual and employment factors were in the model, only "never smoked" contributed significantly to neck-shoulder trouble. Toomingas et al. [1991] found no associations between multiple health outcomes (including tension neck, rotator cuff tendinitis, CTS or problems in the neck/scapula or shoulder/upper arm) and nicotine habits among platers, assemblers and white collar workers. In a case/referent study, Wieslander et al. [1989] found that smoking or using snuff was not related to CTS among men operated on for CTS .

Several explanations for the relationship have been postulated. One hypothesis is that back pain is caused by coughing from smoking. Coughing increases the abdominal pressure and intradiscal pressure and puts strain on the spine. A few studies have observed this relationship [Deyo and Bass 1989; Frymoyer et al. 1980; Troup et al. 1987]. The other mechanisms proposed include nicotine-induced diminished blood flow to vulnerable tissues [Frymoyer et al. 1983], and smoking-induced diminished mineral content of bone causing microfractures
[Svensson and Andersson 1983]. Similar associations with diminished blood flow to vulnerable tissues have been found between smoking and Raynaud's disease.

PHYSICAL ACTIVITY

The relationship of physical activity and MSDs is more complicated than just "cause and effect." Physical activity may cause injury. However, the lack of physical activity may increase susceptibility to injury, and after injury, the threshold for further injury is reduced. In construction workers, more frequent leisure time was related to healthy lower backs [Holmström et al. 1993] and severe low back pain was related to less leisure time activity [Holmström et al. 1992]. On the other hand, some standard treatment regimes have found that musculoskeletal symptoms are often relieved by physical activity. Having good physical condition may not protect workers from risk of MSDs. NIOSH [1991] stated that persons with high aerobic capacity may be fit for jobs that require high oxygen uptake, but will not necessarily be fit for jobs that require high static and dynamic strengths and vice versa.

When physical fitness is examined as a risk factor for MSDs, results are mixed. For example, some early case series reported an increased risk of MSDs associated with playing professional sports [Bennet 1946; Nirschl 1993], or with physical fitness and exercise [Kelsey 1975b; Dehlin et al. 1978, 1981] while other studies indicate a protective effect and reduced risk [Cady et al. 1979; Mayer et al. 1985; Åstrand et al. 1987; Biering-Sorensen 1984]. Boyce et al. [1991] reported that only 7% of absenteeism could be explained by age, sex, and physical fitness among 514 police officers 35 years or older. Cady et al. [1979, 1985], on the other hand, found that physical capacity was related to musculoskeletal fitness. Cady defined fitness for most physical activities as combinations of strength, endurance, flexibility, musculoskeletal timing and coordination. Cady et al. [1979] evaluated male fire fighters and concluded that physical fitness and conditioning had significant preventive effects on back injuries (least fit 7.1% injured, moderately fit 3.2% injured and most fit 0.8% injured). However, the most fit group had the most severe back injuries. Low cardiovascular fitness level was a risk factor for disabling back pain in a prospective longitudinal study among aerospace manufacturing workers by Battie et al. [1989]. Good endurance of back muscles was found to be associated with low occurrence of low back pain [Biering-Sorensen 1984].

Few occupational epidemiologic studies have looked at non-work-related physical activity in the upper extremities. Most NIOSH studies [Hales and Fine 1989; Kiken et al. 1990; Burt et al. 1990; Baron et al. 1991; Hales et al. 1994; Bernard et al. 1994] have excluded MSDs due to sports injury or other nonwork-related activity or injury and have not included these factors in analyses. However, many of the risk factors that are important in occupational studies occur in sports activities—forceful, repetitive movements with awkward postures. A combination of high exposure to load lifting and high exposure to sports activities that engage the arm was a risk factor for shoulder tendinitis, as well as osteoarthritis of the acromioclavicular joint [Stenlund et al. 1993]. Kennedy et al. [1978] found that 15% of competitive swimmers with repetitive overhead arm movements had significant shoulder disability primarily due to impingement from executing butterfly and freestyle strokes. Epicondylitis in professional athletes has been well documented, and many of the biomechanical and physiological studies of epicondylitis have been conducted in professional tennis players and baseball pitchers [King et al. 1969; Nirschl 1993]. One prospective study of healthy baseball players has found slowing of the suprascapular nerve function as the season progresses [Ringel et al. 1990]. Scott and Gijsbers [1981] found an association between athletic performance and pain tolerance, and suggested that physically fit persons may have a higher threshold for injury.

In summary, although physical fitness and activity is generally accepted as a way of reducing work-related MSDs, the present epidemiologic literature does not give such a clear indication. The sports medicine literature, however, does give a better indication that sports involving activities of a forceful, repetitive nature (such as tennis and baseball pitching) are related to MSDs. It is important to note that professional sports activities usually provide players (i.e., workers) with more substantial breaks for recovery and shorter durations for intense tasks as compared with more traditional work settings in which workers are required to perform repetitive, forceful work for 8 hours per day, 5 days per week.

STRENGTH

Some epidemiologic support exists for the relationship between back injury and a mismatch of physical strength and job tasks. Chaffin and Park [1973] found a sharp increase in back injury rates in subjects performing jobs requiring strength that was greater or equal to their isometric strength-test values. The risk was three times greater in the weaker subjects. In a second longitudinal study, Chaffin et al. [1977] evaluated the risk of back injuries and strength and found the risk to be three times greater in the weaker subjects. Keyserling et al. [1980] strength-tested subjects, biomechanically analyzed jobs, and assigned subjects to either stressed or non-stressed jobs. Following medical records for a year, they found that job matching based on strength criteria appeared to be beneficial. In another prospective study, Troup et al. [1981] found that reduced strength of back flexor muscles was a consistent predictor of recurrent or persistent back pain, but this association was not found for first time occurrence of back pain.

Other studies have not found the same relationship with physical strength. Two prospective studies of low back pain reports (or claims) of large populations of blue collar workers [Battie et al. 1989; Leino 1987] failed to demonstrate that stronger (defined by isometric lifting strength) workers are at lower risk for low back pain claims or episodes. One study followed workers for ten years after strength testing and the other followed workers for a few years. Neither of these studies included precise measurement of exposure level for each worker, so the authors could not estimate the degree of mismatch between workers' strength and tasks demands. Battie et al. [1990] compared workers with back pain with other workers on the same job (by isometric strength testing) and did not find that workers with back pain were weaker. In two studies of nurses [Videman et al. 1989; Mostardi et al. 1992] lifting strength was not a reliable predictor of back pain.

When examined together, these studies reveal the following: The studies that found a significant relationship between strength/job task and back pain used more thorough job assessment or analysis and have focused on manual lifting jobs. However, these studies only followed workers for a period of one year, and whether this same relationship would hold over a much longer working period remains unclear. Studies that did not find a relationship, although they followed workers for a longer period of time, did not include precise measurements of exposure level for each worker, so they could not assess the strength capabilities that were important in the individual jobs. Therefore, they could not estimate the degree of mismatch between workers' strength and task demands.

ANTHROPOMETRY

Weight, height, body mass index (BMI) (a ratio of weight to height squared), and obesity have all been identified in studies as potential risk factors for certain MSDs, especially CTS and lumbar disc herniation.

Few studies examining anthropometric risk factors in relationship to CTS have been occupational epidemiologic studies; most have used hospital-based populations who may differ substantially from working populations. Nathan et al. [1989, 1992, 1994] have published several papers on the basis of a single industrial population and have reported an association between CTS and obesity; however, the methods employed in their studies have been questioned in a number of subsequent publications [Gerr and Letz 1992; Stock 1991; Werner et al. 1994b]. Several investigators have reported that their industrial study subjects with CTS were shorter and heavier than the general population [Cannon et al. 1981; Dieck and Kelsey 1985; Falk and Aarnio 1983; Nathan et al. 1992; Werner et al. 1994b; Wieslander et al. 1989]. In the Werner et al. [1994b] study of a clinical population requiring electrodiagnostic evaluation of the right upper extremity, patients classified as obese (BMI>29) were 2.5 times more likely than slender patients (BMI<20) to be diagnosed with CTS. Werner et al. [1994b] developed a multiple linear regression CTS model (with the difference between median and ulnar sensory latencies as the dependent variable) that demonstrated that BMI was the most influential variable, but still only accounted for 5% of the variance in the model. In Nathan's [1994a] logistic model, body mass index accounted for 8.6% of the total risk; however, this analysis used both hands from each study subject as separate observations, although they are not independent of each other. Falck and Aarnio [1983] found no difference in BMI among 17 butchers with (53%) and without (47%) CTS. Vessey et al. [1990] found that the risk for CTS among obese women was double for that of slender women. 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 persons compared with slender persons [Werner 1994b].

Carpal tunnel canal size and wrist size has been suggested as a risk factor for CTS, however, some studies have linked both small and large canal areas to CTS [Bleecker et al. 1985; Winn and Habes 1990].

For back MSDs, Hrubec and Nashold [1975] found that height and weight were predictive of herniated disc disease among World War II U.S. army recruits compared with age-matched controls. Some studies have reported that people with back pain, are, on the average, taller than those without it [Rowe 1965; Tauber 1970; Merriam et al. 1980; Biering-Sorensen 1983]. Heliövaara et al. [1987], in a Finnish population study, found that height was a significant predictor of herniated lumber disc in both sexes, but a moderately increased BMI was predictive only in men. Severe obesity (exceeding 30 kg/m^2) involved less risk than moderate obesity. Kelsey [1975a] and Kelsey et al. [1984] failed to reveal any such relationships between height or BMI among patients with herniated lumber discs and control subjects. Magora and Schwartz [1978] found an association between obesity and radiological disc degeneration, but Kellgren and Lawrence [1958] did not. A study of Finnish white collar and blue collar workers found no association between overweight (relative weight (>120%) and lumbosacral disorders either cross-sectionally or in a 10-year follow-up [Aro and Leino 1985].

Schierhout et al. [1995] found that short stature was significantly associated with pain in the neck and shoulder among workers in 11 factories, but not in the back, forearm, hand and wrist. Height was not a factor for neck, shoulder or hand and wrist MSDs among newspaper employees [Bernard et al. 1994]. Kvarnström [1983a] found no relationship between neck/shoulder MSDs and body height in a Swedish engineering company with over 11,000 workers.

Anthropometric data are conflicting, but in general indicate that there is no strong correlation between stature, body weight, body build and low back pain. Obesity seems to play a small but significant role in the occurrence of CTS.

APPENDIX C
Summary Tables

Appendix C contains summary tables of articles reviewed in this document. These tables provide a concise overview of the studies reviewed relative to the evaluation criteria, risk factors addressed, and other issues.

Appendix C Table C-1. Summary table for epidemiologic studies evaluating work-related neck musculoskeletal disorders

Components of study	Andersen 1993a	Andersen 1993b	Baron 1991	Bergqvist 1995a	Bergqvist 1995b	Bernard 1994	Ferguson 1976	Hales 1989
Study type	CS	CS	CS	CS	CS	CS	CS	CS
Participation rate $70%	Y	Y	N	Y	Y	Y	Y	Y
Outcome	S	S and PE	S and PE	S and PE	S and PE	S	S	S and PE
Exposure	Job title categorization	Categorization by job duration	Observation, video analysis, measurement of items, (assessment was for hand/wrist, not neck)	Questionnaire, observation	Questionnaire, observation	Observation, questionnaire	Measurements, observation, questionnaire	Observation, video taping, job categorization, (assessment was for hand/wrist, not neck)
Covariates considered	Age, having children, not exercising, smoking, SES, marital status	Age, having children, not exercising, smoking, SES	Age, gender, duration of work environment	Age, gender	Adjustments made for confounders	Age, gender, height, psychosocial factors	Height, weight	Age, duration of employment
Investigators blinded	Y	Y	Y	Y	Y	Y	NR	Y
Repetition	Combined	Combined	Combined	Repeated work movements: 3.6 (0.4-29.6)	Combined	Time spent typing: NS	Õ	Combined
Force	Combined	Combined	Combined	Õ	Õ	Õ	Õ	Combined
Extreme posture	Combined	Õ	Combined	Too highly placed keyboard: 4.4 (1.1-17.0)	Õ	Time spent on telephone: 1.4 (1.0-1.8)	NR, sig.	Õ
Vibration	Õ	Õ	Õ	Õ	Õ	Õ	Õ	Õ

See footnotes at end of table. (Continued)

Appendix C Table C-1. Summary table for epidemiologic studies evaluating work-related neck musculoskeletal disorders

Components of study	Andersen 1993a	Andersen 1993b	Baron 1991	Bergqvist 1995a	Bergqvist 1995b	Bernard 1994	Ferguson 1976	Hales 1989
Risk factors (combined)	Sewing operators vs. referents: 4.9 (2.0-12.8)	Current high exposure: 1.6 (0.7-3.6) 8 to 15 years: 6.8 (1.6-28.5)	Checkers vs. noncheckers: 2.0 (0.6-6.7)	Õ	VDT work >20 hr and eye glasses at VDT: 6.9 (1.1-42)	Õ		High exposure vs. Low exposure jobs (estimated crude OR): 3.7 (0.4-164) Outcome, neck symptoms: RR=1.64 (0.4-3.9)
Duration of employment	0 to 7 years: 1.9 (1.3-2.9) 8 to 15 years: 3.8 (2.3-6.4) >15 years: 5.0 (2.9-8.7)	0 to 7 years: 2.3 (0.5-11) 8 to 15 years: 6.8 (1.6-28.5) >15 years: 16.7 (4.1-67.5)	NS	Õ	Õ	NS	Õ	Adjusted for in analysis
Physical workload	Õ	Õ	Õ	Õ	Õ	Õ	Õ	Õ
Psychosocial factors	Õ	Õ	Job satisfaction: NS	Limited break opportunity: 7.4 (3.1-17.4)		Deadline hr: 1.7 work variance: 1.7 management issues: 1.9	Õ	Õ
Individual/other factors considered	Age at least 40 years: 1.5 (1.1-2.2); having children: 1.3 (0.8-2.0); SES: 1.29 (0.7-2.3); smoking: 1.39 (0.99-1.9)	Age $ 40 years: 1.9 (0.9-4.1); having children: 0.5 (0.1-1.7); exercise: 1.4 (0.6-2.9); smoking: 1.5 (0.7-3.3)	Age, gender, hobbies controlled for in analysis	Females with children: 6.4; smoking, stress reaction, stomach-related stress, use of spectacles, peer contacts, rest breaks, work task flexibility, overtime, static work position, nonuse of lower arm support, hand in non-neutral posture, high visual angle to VDT, glare on VDT	Smoking, stress reaction, stomach-related stress, use of spectacles, peer contacts, rest breaks, work task flexibility, overtime, static work position, nonuse of lower arm support, hand in non-neutral posture, high visual angle to VDT, glare on VDT	Age, gender, height, psychosocial factors; VDT use outside of work	Õ	Age
Dose/response	Years worked: Sig.	Õ	Õ	Õ	Õ	Õ	Õ	Õ

See footnotes at end of table.

(Continued)

Appendix C Table C-1. Summary table for epidemiologic studies evaluating work-related neck musculoskeletal disorders

Components of study	Hales 1994	Hunting 1994	Kamwendo 1991	Kiken 1990	Knave 1985	Kukkonen 1983	Kuorinka 1979	Linton 1990
Study type	CS	CS	CS	CS	CS	Prospective, intervention	CS	CS
Participation rate $70%	Y	Y	Y	Y	Y	NR	Y	Y
Outcome	S and PE	S	S	S and PE	S	S and PE	S and PE	S
Exposure	Observation, questionnaire	Questionnaire	Questionnaire	Observation, (assessment was for hand/wrist, not neck)	Observation, gaze direction instrument, job title or self-report	Observation, interview	Observation, job analysis, video taping (assessment was for hand/wrist, not neck)	Questionnaire
Covariates considered	demographics, work practices, age, gender, hobbies	Years worked, age, current work as electrician, gender	Age, length of employment, psychosocial work environment	Age, gender	Age, gender, smoking, educational status, drinking	Gender, prospective design	Age, duration of employment, BMI, metabolic disease, hobbies, "extra work"	Age, gender, exercise, eating regularly, smoking, alcohol consumption, psychosocial variables
Investigators blinded	Y	NR	NR	Y	NR	Y	NR	NR
Repetition	Õ	Õ	Combined	Combined	Combined	Combined	Scissor makers vs. Referents: 4.1 (2.3-7.5) Short cycle tasks vs. long cycle tasks: 1.64 (0.7-3.8)	Õ
Force	Õ	Õ	Õ	Combined	Õ	Õ	Combined	Õ
Extreme posture	Use of bifocals: 3.8 (1.5-9.4)	Õ	Combined	Combined	Combined	Combined	Combined	Uncomfortable posture and poor psychosocial environment: 3.5 (2.7-4.5)
Vibration	Õ	Õ	Õ	Õ	Õ	Õ	Õ	Univariate analysis showed elevated OR for vibration

See footnotes at end of table. (Continued)

Appendix C Table C-1. Summary table for epidemiologic studies evaluating work-related neck musculoskeletal disorders

Components of study	Hales 1994	Hunting 1994	Kamwendo 1991	Kiken 1990	Knave 1985	Kukkonen 1983	Kuorinka 1979	Linton 1990
Risk factors (combined)	Õ	Õ	Work with office machines >5 hr/day: 1.65 (1.02-2.67)	High exposure vs. low exposure jobs: 1.3 (0.2-11)	Typing hr: Sig.	Intervention group: PRR=3.6 (2.2-5.9) No intervention 1.0	Scissor-makers vs. department store shop assistants: OR=4.1 (2.3-7.5)	Õ
Duration of employment	NS	1 to 3 years: 1 4 to 5 years: 1.3 6 to 10 years: 1.6 >10 years: 1.3	Length of employment: Sig.	Õ	Õ	Õ	Controlled for	Õ
Physical workload	Õ	Õ	Being given too much to do: Sig.	Õ	Õ	Õ	Õ	Õ
Psychosocial factors	Decision making: 4.2; productivity standard: 3.5; fear of replacement by computer: 3.0; higher information processing demands: 3.0; job task variety: 2.9; work pressure: 2.4		Ability to influence work, cooperative spirit between co-workers: sig.	Õ	Interest in work, positive attitude	Õ		Monotonous work SS, work content, work load, social support
Individual/other factors considered	Electronic performance monitoring, keystrokes, hobbies, recreational activities: NS	Age group, current work as electrician: NS	Sitting 5 or more hr/day: 1.6 (0.9-2.8); age: Sig.	Õ	Õ	Õ	Extra work, hobbies, outside activities: NS	Exercise, eating, smoking, alcohol consumption
Dose/response	Õ	Õ	Õ	Õ	Between registered work duration and musculoskeletal complaints	Õ	Õ	Õ

See footnotes at end of table.

(Continued)

Appendix C Table C-1. Summary table for epidemiologic studies evaluating work-related neck musculoskeletal disorders

Components of study	Liss 1995	Luopajärvi 1979	Milerad 1990	Ohlsson 1989	Ohlsson 1995	Onishi 1976	Ryan 1988	Sakakibara 1987
Study type	CS	CS	CS	CS	CS	CS	CS	CS
Participation rate $70%	N	Y	Y	NR	Y	NR	Y	Y
Outcome	S	S and PE	S	S	S and PE	S and PE	S and PE	S
Exposure	Questionnaire	Observation, video analysis, interviews	Questionnaire	Questionnaire	Videotaping, observation, analysis of posture, flexion of neck, questionnaire	Observation, then job categorization	Observation measurements at work stations	Observation job analysis and neck angle measurements
Covariates considered	N	Age, gender, social background, hobbies, amount of housework	Gender, age, leisure-time exposure, systemic disease	Age, gender, duration of employment	Age , gender, psychosocial scales	Õ	Age, height, length of training time	Õ
Investigators blinded	N	Y	NR	NR	Blinded to exposure information but "Not possible to completely blind the examiners."	NR	Y	NR
Repetition	Combined	Combined	Combined	Combined	Combined	Combined	Õ	Combined
Force	Combined	Combined	Õ	Õ	Industrial workers exposed to repetitive tasks vs. referents: 3.6 (1.5-8.80)	Combined	Õ	Õ
Extreme posture	Combined	Combined	Combined	Combined	Õ	Combined	Significant difference in mean elbow angle and shoulder flexion of left arm	Combined
Vibration	Õ	Õ	NS for exposure to vibration	Õ	Õ	Õ	Õ	Õ

See footnotes at end of table. (Continued)

Appendix C Table C-1. Summary table for epidemiologic studies evaluating work-related neck musculoskeletal disorders

Components of study	Liss 1995	Luopajärvi 1979	Milerad 1990	Ohlsson 1989	Ohlsson 1995	Onishi 1976	Ryan 1988	Sakakibara 1987
Risk Factors (Combined)	Dental hygienists vs. dental assistants: 1.7 (1.1-2.6)	Assembly workers vs. shop assistants: 1.6 (0.9-2.7)	Dentists compared to pharmacists: 2.1 (1.4-3.1)	Assemblers vs. referents pain in last 12 months: 1.9 (0.9-3.7)	Õ	Film rolling workers: 3.8 Lamp assemblers: 3.8 (2.1-6.6) Teachers and nurses: 1.5 (0.7-3.2)	Õ	Pear work vs. apple work right side: $p<0.05$ Pear work vs. Apple work at left side: $p<0.01$
Duration of employment	NS	Õ	NS	Employees <35 years: Sig.	Õ	Õ	NS	Õ
Physical workload	Õ	Õ	Õ	Õ	Õ	Õ	Õ	Õ
Psychosocial factors	Õ	Õ	Õ	Increased OR for medium and fast paced work compared to slow paced but OR lower for very fast paced work		Õ	Insufficient rest, break time, more boredom, more stress, lower peer cohesion, lower antonomy, lower job clarity, higher staff support, higher work pressure	Õ
Individual/other factors considered	Gender (99% females in study group); had to modify work or unable to work at some point: 2.4 (1.1-5.4)	Õ	Leisure time exposure, smoking systemic disease		Õ	Õ	Age, height, marital and parental status, handedness, length of training time	Õ
Dose/response	Õ	Õ	Õ	Õ	Õ	Õ	Õ	Õ

See footnotes at end of table. (Continued)

Appendix C Table C-1. Summary table for epidemiologic studies evaluating work-related neck musculoskeletal disorders

Components of study	Sakakibara 1995	Schibye 1995	Veiersted 1994	Viikari-Juntuna 1994	Welch 1995	Wells 1983	Yu 1996
Study type	CS	Cohort	Cohort	Cohort	CS	CS	CS
Participation rate $70%	Y	Y	N (55%)	Y	Y (83%)	Y	Y
Outcome	S and PE	S	S and PE/ pain diaries	S	S	S	S
Exposure	Observation, measurements	Questionnaire	EMG, interviews every 10 weeks	Questionnaire, observation	Questionnaire	Questionnaire, interview	Questionnaire
Covariates considered	Õ	Subjects served as their own controls	Metabolic or other diseases, gender	All male, smoking, age, physical exercise, occupation, duration of work, car driving	Smoking, years of employment	Age, gender, number of years on job, previous work experience, education, marital status, quetelet ratio	Age, gender, "other covariates"
Investigators blinded	NR	NR	NR	Y	N	NR	NR
Repetition	Õ	Combined	Õ	Õ	Combined	Õ	Frequent VDT use: 28.9 (2.8-291.8)
Force	Õ	Combined	Strenuous previous work: 6.7 (1.6-28.5)	Combined	Õ	Combined	Õ
Extreme posture	Combined	Combined	Strenuous postures: 7.2 (2.1-25.3)	No neck pain to severe, machine operators vs. office workers: 3.9 (2.3-6.9) Persistently severe: 4.2 (2.0-9.0)	Percent of time hanging duct: 7.5 (0.8-68)	Combined	Inclining neck at work: 784.4 (33.2-18,630)
Vibration	Õ	Õ	Vibration (floor or machine)	Combined (machine operators)	Õ	Õ	Õ

See footnotes at end of table. (Continued)

Appendix C Table C-1. Summary table for epidemiologic studies evaluating work-related neck musculoskeletal disorders

Components of study	Sakakibara 1995	Schibye 1995	Veiersted 1994	Viikari-Juntuna 1994	Welch 1995	Wells 1983	Yu 1996
Risk factors (combined)	Pear vs. Apple bagging: 1.5 (0.99-2.35)	Other employment group vs. garment workers: 3.3 (1.4-7.7)	Physical environment: 0.9 (0.5-1.7)	Occupation Sig. from no neck trouble to moderate neck trouble; occupation Sig. from no neck to severe neck trouble Carpenters vs. Office workers persistently severe: 3.0 (1.4-6.4)	Õ	All letter carriers vs. Clerks and readers: 2.57 (1.13-6.2)	Frequent video display terminal use: 28.9 (2.8-291.8)
Duration of employment	Õ	NS	Õ	Õ	Õ	Controlled for in analysis	Õ
Physical workload			Õ	Õ	Õ	Õ	Õ
Psychosocial factors`	Õ	Õ	Psychosocial factors: 3.3 (0.8-14.2)	Job satisfaction: NS	Õ	Õ	Õ
Individual/other factors considered	Õ	Age	Anthropometrics, general health, previous employment variables, draft, noise, personality	Current smoking and age Sig. in model of "no neck trouble to severe neck trouble"	Õ	Education, marital status, quetelet ratio	General health
Dose/response	Õ	Õ	Õ	Õ	Õ	Õ	Õ

Õ Not studied.
BMI Body mass index.
CS Cross-sectional.
EMG Electromyography.
hrs Hours.
MSD Musculoskeletal disorders
MVC Maximum voluntary contraction.
N No.
NR Not reported.
NS Not statistically significant.
OR Odds ratio.
PE Physical examination.
PRR Prevalence rate ratio.
S Symptoms.
SES Socioeconomic status.
Sig. Statistically significant.
VDT Video display terminal.
vs. Versus.
Y Considered (yes).

Appendix C Table C-2. Summary table for evaluating work-related neck/shoulder disorders

Components of study	Åaras 1994	Andersen 1993a	Andersen 1993b	Bergqvist 1995a	Bergqvist 1995b	Bjelle 1981	Blåder 1991	Ekberg 1994
Study type	Prospective	CS	CS	CS	CS	Case Control	CS	Case Control
Participation rate $70%	NR	Y	Y	Y	Y	NR	Y	Y
Outcome	S and Records	S	S and PE	S	S and PE	S and PE	S and PE	S
Exposure	Observation and EMG	Job title categorization	Categorization by job duration	Observation, measurements	Job title and questionnaire	Observation, videotape analysis	Questionnaire	Questionnaire
Covariates considered	ð	Age, having children, education, marital status, smoking, not exercising	Age, having children, education, marital status, smoking, not exercising	Age, gender, smoking, rest breaks, stress	Age, gender, smoking	Age, anthropometric data	Age, nationality, employment time, working hr/week	Age, gender, smoking, having preschool children
Investigators blinded	NR	Y	Y	Y	Y	Y; Videotape analysis blinded to case status	N	NR
Repetition	ð	Combined	Combined	For intensive neck/shoulder discomfort: 3.6 (0.4-29.6)	<20 hr/week VDT use: 1.2 (0.4-3.7) >20 hr/week VDT use: 0.7 (0.3-1.5)	No sig difference in cycle time	Combined	Precise repetitive movements High: 15.6 (2.2-113.0)
Force	Static trapezius load dropped from 4.1 to 1.4% NR, Sig.	Combined	Combined	ð	ð	Cases had significantly higher shoulder loads than controls	ð	ð
Extreme posture	Intervention consisted of equipment and tool adjustment to create relaxed position of shoulders and neck: NR, Sig.	ð	ð	For tension neck syndrome: too highly placed VDT: 4.4 (1.1-17.6)	ð	Cases with longer duration and higher frequency of abduction or forward flexion than referents: NR, Sig.	Combined	Work with lifted arms 4.8 (1.3-18); uncomfortable sitting posture: 3.6 (1.4-9.3)
Vibration	ð	ð	ð	ð	ð	ð	ð	ð

See footnotes at end of table. (Continued)

Appendix C Table C-2. Summary table for evaluating work-related neck/shoulder disorders

Components of study	Åaras 1994	Andersen 1993a	Andersen 1993b	Bergqvist 1995a	Bergqvist 1995b	Bjelle 1981	Blåder 1991	Ekberg 1994
Risk factors (combined)	ō	Sewing machine operators vs. referents: 4.6 (2.2-10.2)	Current high exposure (yes vs. no): 1.6 (0.7-3.6)	ō	VDT work >20 hr and stressful stomach reactions: 3.9 (1.1-13.8) VDT work $ 20 hr and bifocals or progressive glasses: 6.9 (1.1-42.1)	ō	Working >30 hr per week: *p*<0.05	ō
Duration of employment	ō	Years as sewing machine operators 0 to 7 years: 3.2 (0.6-16.1) 8 to 15 years: 11.2 (2.4-52) >15 years: 36.7 (7.1-189)	Years as sewing machine operators 0 to 7 years: 2.3 (0.5-11) 8 to 15 years: 6.8 (1.6-28.5) >15 years: 16.7 (4.1-67.5)	ō	ō	ō	Working >30 hr/week and tension neck syndrome: *p*<0.05	ō
Physical workload	ō	ō	ō	ō	ō	ō	ō	ō
Psychosocial factors	ō	ō	ō	For cervical diagnoses: Stressful stomach reactions: 5.4 (1.6-17.6)	Combined	ō	Smaller randomized study group interviewed by sociologist and psychologist for psychosocial history	High work pace: 3.5 (1.3-9.4); Low work content: 2.6 (0.7-9.4); Work role ambiguity: 16.5 (6.0-46); Demands on attention: 3.8 (1.4-11)
Individual/ other factors considered	Median sick days decreased from 22.9 to 1.8	Age >40 yrs: 1.96 (0.8-5); exercise: 1.28 (0.5-3.4); smoking: 2.3 (0.9-6.1); children: 0.35 (0.1-1.9)	Age $ 40 years: 1.9 (0.9-4.1); children: 0.5 (0.1-1.7); exercise: 1.4 (0.6-2.96); smoking: 1.5 (0.7-3.3)	Children at home, negative, affectivity, peer contacts, overtime, work task flexibility, visual angle to VDT	Children at home, negative, affectivity, peer contacts, overtime, work task flexibility, visual angle to VDT	Age-isometric testing	Cervical syndrome correlated with age	Female: 11.4 (4.7-28); immigrant status: 4.9 (1.8-14); current smoker: 8.2 (2.3-29)
Dose/response	ō	Duration of employment as sewing machine operator	Duration of employment	ō	ō	ō	ō	Repetitive precision movements, work pace

See footnotes at end of table. (Continued)

Appendix C Table C-2. Summary table for evaluating work-related neck/shoulder disorders

Components of study	Ekberg 1995	Holmström 1992	Hünting 1981	Jonsson 1988	Kilbom 1986, 1987	Linton 1989	Maeda 1982	Milerad 1990
Study type	CS	CS	CS	Cohort	CS	CS	CS	CS
Participation rate $70%	Y	Y	NR	Y	Y	Y	NR	Y
Outcome	S	S	S and PE	S and PE	S and PE	S	S	S
Exposure	Questionnaire	Questionnaire	Observation, questionnaire	Observation, video taping, job analysis, MVC of forearm	Observation, video taping, job analysis, MVC of forearm	Questionnaire dealing with psychosocial issues	Observation, measurement	Questionnaire
Covariates considered	Age, smoking, exercise habits, family situations with preschool children, immigrant status, gender	Age, physical factors, psychosocial stress scales	Psychosocial factors	Used prospective cohort design with same study sample	Age, spare time physical activities, hobbies, psychosocial stress, muscle strength	ð		Gender, leisure time, smoking, systemic disease
Investigators blinded	NR	Y	NR	Y	Y	NR	NR	NR
Repetition	Repetitive movements demanding precision: 1.2 (1.0-1.3)	ð	Combined	Combined	Combined	ð	ð	Combined
Force	ð	ð	ð	Combined	Combined	ð	ð	ð
Extreme posture		Hand above shoulder: <1 hr/day: 1.1 (0.8-1.5) 1 to 4 hr/day: 1.5 (1.2-1.9) >4 hr/day: 2.0 (1.4-2.7)	Combined/head inclination >56E Sig. for neck/shoulder MSDs	Combined	Combined	ð	Constrained tilted head posture: p<0.05	Combined
Vibration	ð	ð	ð	ð	ð	ð	ð	NS

See footnotes at end of table. (Continued)

Appendix C Table C-2. Summary table for evaluating work-related neck/shoulder disorders

Components of study	Ekberg 1995	Holmström 1992	Hünting 1981	Jonsson 1988	Kilbom 1986, 1987	Linton 1989	Maeda 1982	Milerad 1990
Risk factors (combined)	õ	Roofers: 1.6 Plumbers: 1.5 Floor workers: 1.3	Data entry workers vs. non-keyboard-using office workers: 9.9 (3.7-26.9)	At third year, 38 workers reallocated had improved, 26% with unchanged conditions deteriorated further: NR, Sig.	Average time/work cycle in neck flexion sig, Upper arm abducted 0-30E: NR, Sig.	õ	õ	Dentists vs. pharmacists: 2.1 (1.3-3.0); males: 2.6 (1.2-5.0); females 2.0 (1.3-3.1)
Duration of employment	õ	õ	õ	õ	NS	õ	õ	NS
Physical workload	õ	õ	õ	õ	õ	õ	õ	õ
Psychosocial factors	õ	Qualitative demands: 1.4 (1,2) Quantitative demands: 3.0 (2.1-4) Solitary work: 1.5 (1.2-1.8) Anxiety: 3.2 (2.5-4)	Job satisfaction; relationship with supervisors, colleagues; decision making, use of skills all NS	Job satisfaction, productivity	Productivity, work satisfaction, perceived stress: NS	Poor work content: 2.5 (1.3-4.9) Lack of social support: 1.6 (0.9-2.8) Work demand social support at work	õ	õ
Individual/ other factors considered	Immigrant status: 1.3 (1.1-1.5) Social work climate, work planning, job security, job constraints	Psychosomatic: 5.0 (3.6-6.9) Psychological: 4.7 (3.6-6) Stress: 3.4 (2.6-4.2) Discretion, support, under stimulation, anxiety, job satisfaction, quality of life	Medical findings in neck and shoulder significant for typists with head rotation >20E compared to < 20E	õ	Age, muscle strength, rest pauses: NS	õ	Age	Leisure time, smoking NS
Dose/response	õ	Stress index and neck-shoulder MSDs	õ	õ	õ	õ	õ	õ

See footnotes at end of table. (Continued)

Appendix C Table C-2. Summary table for evaluating work-related neck/shoulder disorders

Components of study	Ohara 1976	Ohlsson 1995	Punnett 1991	Rossignol 1987	Ryan 1988	Tola 1988	Vihma 1982	Viikari-Juntura 1991a
Study type	CS and Cohort	CS	CS	CS	CS	CS	CS	Cohort
Participation rate $70%	CS study: NR; Cohort: Y	Y	Y	N to Y (6 industries)	Y	Y overall: 67% carpenters 67% office workers	NR	Y
Outcome	S and PE	S and PE	S	S	S	S	S	S and PE
Exposure	Observation	Observation, video, analysis, muscle strength testing	Observation, questionnaire	Questionnaire	Observation, workstation measurement, questionnaire	Occupation title	Observation, interview	Questionnaire
Covariates considered	Used prospective cohort design with same study sample	Age, gender, psychosocial scales	Age, gender	Age, cigarette smoking, industry, education, VDT training	Height, weight, gender, age, marital status, parental status	Years in occupation, age, leisure time activities, car driving, general health	Age, duration of employment	Physical hobbies, creative hobbies
Investigators blinded	NR	Y to exposure information, no for physical	NR	NR	Y	NR	NR	NR
Repetition	Combined	Repetitive work: 4.6 (1.9-12)	Combined	Combined	õ	õ	Combined	õ
Force	õ	õ	Combined	õ	õ	õ	õ	õ
Extreme posture	Combined	Significant time spent in neck flexion <60°: NR	Associated with extended duration of and lifting weight in abduction/flexion and extension of the shoulder	Combined	More non-cases trained in adjustment of furniture than cases: NR, Sig.	Use of twisted or bent postures during work: Little (referent): 1.0 Moderate: 1.2 (1.0-1.5) Rather much: 1.6 (1.4-1.9) Very much: 1.8 (1.5-2.2)	Combined Sewing machine operator with significantly greater static work compared to seamstresses	Sitting in a forward posture 1-3 hr/day: 10.7 (0.4-291); >3 hr/day: 1.5 (0.7-29.5)
Vibration	õ	õ	õ	õ	õ	õ	õ	õ

See footnotes at end of table.

(continued)

Appendix C Table C-2. Summary table for evaluating work-related neck/shoulder disorders

Components of study	Ohara 1976	Ohlsson 1995	Punnett 1991	Rossignol 1987	Ryan 1988	Tola 1988	Vihma 1982	Viikari-Juntura 1991a
Risk factors (combined)	Operators hired post-intervention had less reports of MSDs	Industrial workers vs. referents: 2.7 (1.2-6.3)	Male: 1.8 (1.0-3.2) Female: 0.9 (0.5-1.9)	½ to 3 hr of VDT use: 1.8 (0.5-6.8) 4 to 6 hr of VDT use: 4.0 (1.1-14.8) 7 $ hr of VDT use: 4.6 (1.7-13.2)	ô	Machine operators vs. office workers: 1.7 (1.5-2.0) Carpenters vs. office workers: 1.4 (1.1-1.6)	Sewing machine operators vs. seamstresses: 1.6 (1.1-2.3)	ô
Duration of employment	ô		ô	ô	ô	ô	ô	ô
Physical workload	ô	ô	ô	ô	ô	ô	Cases had significantly higher shoulder loads	ô
Psychosocial factors	ô	Stress/worry tendency: 1.9 (1.1-3.5)	ô	ô	Adequate rest breaks, boredom, work stress job pressure, autonomy, peer cohesion, role ambiguity, staff support	Job satisfaction, poor vs. very good: 1.2 (1.1-1.4)	ô	Social confidence, much fear vs. none: 1.4 (0.05-42.2); Sense of coherence: 0.95 (0.9-0.99)
Individual/other factors considered	ô	Muscle tension tendency: 2.3 (1.3-4.9)	ô	Smoking, industry, education	ô	Working in a draft: 1.1 (1.0-1.3)	ô	Alexithymia 1.02 (0.97-1.1)
Dose/response	ô	ô	ô	Hours of VDT use	ô	Use of twisted or bent posture	ô	ô

ô Not studied
CI Confidence interval
CS Cross-sectional
EMG Electromyography
hr Hours
Med. Medium
MSDS Musculoskeletal disorders
MVC Maximum voluntary contraction
N No
NR Not reported
NS Not statistically significant
OR Odds ratio
PE Physical examination
S Symptoms
Sig. Statistically significant
VDT Video display terminal
vs. Versus
Y Considered (yes)

Appendix C Table C-3. Summary table for evaluating work-related shoulder musculoskeletal disorders

Components of study	Andersen 1993a	Andersen 1993b	Baron 1991	Bergenudd 1988	Bernard 1994	Bjelle 1979	Bjelle 1981	Burdorf 1991
Study type	CS	CS	CS	CS	CS	Case control	Case control	CS
Participation rate $70%	Y	Y	N	N	Y	NR	NR	Y for riveters; N for referents
Outcome	S	S and PE	S and PE	S and PE	S	S and PE	PE	S
Exposure	Job title, categorization by job duration	Job title, categorization by job duration	Observation and videotape analysis, weight of scanned items, job category	Questionnaire, job classification (light, moderate, heavy physical demands)	Questionnaire and observation	Observation, measurement, EMG on 15 cases, open muscle biopsies on 11 cases	Measurement, videotape analysis, observation, EMG on 3 subjects and 2 healthy volunteers	Observation, measurement of vibration
Covariates considered	Age, having children, not exercising, duration of employment, socioeconomic status, smoking status, current neck/shoulder exposure	None for the shoulder analysis	Age, gender, hobbies, duration of work, second job, metabolic disease, duration of employment	Gender	Age, race, gender, height, medical conditions, psychosocial factors, typing hr away from work	Age, gender, and workshop	Age, gender, and place of work	Height, weight, smoking status
Investigators blinded	Y	Y	Y	NR	N	N	Y	NR
Repetition for shoulder	Combined	Combined	Combined	õ	R no surrogate for hand used: number of hr typing	Combined	Combined	õ
Force	Combined	Combined	Combined	õ	õ	Combined	Cases had Sig. higher shoulder loads than controls	õ
Extreme posture	Combined	Combined	Combined	õ	õ	Combined	Combined	õ

See footnotes at end of table. (Continued)

Appendix C Table C-3. Summary table for evaluating work-related shoulder musculoskeletal disorders

Components of study	Andersen 1993a	Andersen 1993b	Baron 1991	Bergenudd 1988	Bernard 1994	Bjelle 1979	Bjelle 1981	Burdorf 1991
Vibration	ð	ð	ð	ð	ð	ð	ð	1.5 (no confidence limits)
Risk factors (combined)	Increasing years of experience: 1.38-10.25 (Sig.)	Chi sq test for trend using exposure time in years for rotator cuff syndrome: 9.51; $p<0.01$	Checkers vs. others 3.9 (1.4-11.0) Checkers using scanners vs. others 8.6 (1.0-72.2)	ð	ð	Work at or above shoulders, cases (65%) vs. referents (15%): 10.6 (2.3-54.9)	Cases had Sig. longer duration and higher frequency of abduction or forward flexion than controls, $p<0.001$	ð
Duration of employment	See under "Physical workload"	See under "Risk factors combined"	Number of hr per week as a checker Sig.	ð	Years at newspaper: 1.4 (1.2-1.8)	ð	ð	Years of riveting: 0.05# $p<0.10$
Physical workload	0 to 7 years: 1.56 (0.76-3.75) 8 to 15 years: 4.28 (2.14-10.0) >15 years: 7.27 (3.82-16.3)	ð	ð	Prevalence of occupational workload in subjects with shoulder pain: Heavy, 11%; Moderate, 49%; Light, 40%	ð	ð	ð	ð
Psychosocial factors	ð	ð	ð	Females showed Sig. association with shoulder pain and dissatisfaction	Lack of decision making participation: 1.6 (1.2-2.1) job pressure: 1.5 (1.0-2.2)	ð	ð	ð
Individual/other factors considered	Age-matched controls	Age-matched controls	Age, gender, metabolic disease	Gender	Gender, race, height	Age, gender	Age, gender; median number of sick-leave days Sig. different between cases and controls, $p=0.01$	Age
Dose/response	Y with years of employment	Y with years of exposure	ð	ð		ð	ð	ð

See footnotes at end of table. (Continued)

Appendix C Table C-3. Summary table for evaluating work-related shoulder musculoskeletal disorders

Components of study	Burt 1990	Chiang 1993	English 1995	Flodmark 1992	Hales 1989	Hales 1994	Herberts 1981	Herberts 1984
Study type	CS	CS	Case control	CS	CS	CS	CS	CS
Participation rate $70%	Y	Y	Y	Y	Y	Y	NR	NR
Outcome	S	S and PE	S and PE	S	S and PE	S and PE	S and PE	S and PE
Exposure	Observation, questionnaire, job sampling	Observation and recording of representative jobs, hand F estimation	Self-reports	ô	Observation walk-through, job categorization High vs. low exposure (hand/wrist exposure)	Observation and questionnaire	Analyses by job title	Analyses by job title
Covariates considered	Age, gender, psychosocial factors, metabolic disease duration of employment	Age, gender, metabolic diseases	Age, height, gender, weight, injury, study center, hobbies, sporting activities, average hr of driving, compensation claim made	Age, headache, tiredness, medical problems, sleeping problems or lack of concentration, sleep	Age and duration of employment	Age, race, gender, work practices, work organization factors, individual factors, electronic performance monitoring, recreational activities, hobbies	Age, job duration	Controls matched for age and gender
Investigators blinded	ô	Y	Y	ô	Y	Y	NR	NR
Repetition for shoulder	Typing speed fast compared to slow: 4.1 (1.8-9.4)	Repetitive movement of upper limb: 1.6 (1.1-2.5)	Combined	ô	Combined	No	Combined	Combined
Force	ô	Sustained forceful movement of upper limb: 1.8 (1.2-2.5)	ô	ô	Combined	ô	Welders vs. office workers: 15-18	Welders vs. office workers: 15-18
Extreme posture	ô	ô	Combined	ô	Combined	Number of times arising from chair: 1.9 (1.2-15.5)	Combined	Combined

See footnotes at end of table. (Continued)

Appendix C Table C-3. Summary table for evaluating work-related shoulder musculoskeletal disorders

Components of study	Burt 1990	Chiang 1993	English 1995	Flodmark 1992	Hales 1989	Hales 1994	Herberts 1981	Herberts 1984
Vibration	ð	ð	ð	ð	ð	ð	ð	ð
Risk factors (combined)	ð	Repetition multiplied by force: 1.4 (1.0-2.0)	Repeated shoulder rotation with elevated arm: 2.3, *p*<0.05	ð	Any symptom of shoulder: 49% vs. 43%; 1.2 (0.7-2.0) Period prevalence: 19% vs. 4%; 3.8 (0.6-22.8) Point prevalence: 7% vs. 4%;0.9 (0.1-7.3)	ð	Welders vs. office workers: shoulder symptoms: 15.2 (2.1-108) Shoulder Tendinitis: 8.3 (NS)	ST results of 23 welders called back for clinical follow-up exams: 16 had ST; 18.3 (13.7-22.1) (90% CI) ST results of 30 plate-workers called back for clinical follow-up exams: 15 plate-workers had ST: 16.2 (10.9-21.5) (90% CI)
Duration of employment	NS	ð	ð	ð	ð	ð	ð	ð
Physical workload	ð	ð	ð	ð	ð	ð	NS	ð
Psychosocial factors	Job dissatisfaction: 2.3 (1.2-4.3)	ð	ð	Type A Behavior: *p*<0.001	ð	Fear of replacement by computers: 1.5 (1.1-2.0)	ð	ð
Individual/other factors considered	Pre-existing arthritis: 2.3 (1.2-4.4)	Plant effect age: 1.0 (0.9-1.1) Gender: 1.1 (0.7-1.7)	Per 5 years of age: 1.4 (1.2-1.5)	ð	ð	Typing outside of work	ð	ð
Dose/response	ð	Dose response found for shoulder diagnosis as exposure status increased from Group 1 to Group 3	ð	ð	ð	ð	ð	ð

See footnotes at end of table. (Continued)

Appendix C Table C-3. Summary table for evaluating work-related shoulder musculoskeletal disorders

Component of study	Hoekstra 1994	Hughes 1997	Ignatius 1993	Jonsson 1988	Kiken 1990	Kilbom 1986, 1987	Kvarnström 1983	McCormack 1990
Study type	CS	CS	CS	Prospective	CS	CS	CS and Case control	CS
Participation rate $70%	Y	N	N	Y	Y	Y	NR	Y
Outcome	S	S and PE	S	S and PE	S and PE	S and PE	S and PE	S and PE
Exposure	Analyses based on questionnaire, self-reports	Observation and job analysis	Observation, questionnaire, weight of mail bags	Observation, measurement of exertion, videotaping	Observation (exposure based on repetitive and forceful hand motions, not shoulder)	Observation, measurement, videotaping, observation	Observation, interview, questionnaire	Observation
Covariates considered	Age, seniority, gender	Controlled for age, smoking status, sports, hobbies	Age, duration of employment, bag weight, walking time	Age, hobbies, spare time, physical action, psychosocial factors, breaks, rest pauses	Age and gender	Age, years of employment, productivity, muscle strength	ð	Age, gender, race, job category, duration of employment, general health history
Investigators blinded	Y	NR	NR	Y	Y	Y	N	N
Repetition for shoulder	ð	ð	Combined	Combined	Combined	Fewer total number of upper arm flexions/hr. (*p*<0.05)	Combined	Combined
Force	ð	ð	Combined	ð	Combined	ð	Combined	ð
Extreme posture	Non-optimally adjusted desk height work: 5.1 (1.7-15.5)	Years of forearm twist: 46.0 (3.8-550)	Combined	Relative time spent with shoulder elevated negatively related to 'remaining healthy ' after both 1 and 2 years: Sig.	Combined	Greater percentage of work cycle time with upper arm abducted 0-30° (*p*<0.05)	Combined	Combined
Vibration	ð	ð	ð	ð	ð	ð	ð	ð

See footnotes at end of table. (Continued)

Appendix C Table C-3. Summary table for evaluating work-related shoulder musculoskeletal disorders

Component of study	Hoekstra 1994	Hughes 1997	Ignatius 1993	Jonsson 1988	Kiken 1990	Kilbom 1986, 1987	Kvarnström 1983	McCormack 1990
Risk factors (combined)	Center B compared to Center A: 4.0 (1.2-13.1)	õ	Letter delivery postal workers compared to other postal workers Recurrent: 1.8 (1.5-2.2) Severe joint pain: 2.2 (1.5-3.1)	38 subjects who were reallocated to more varied tasks improved	Plant #1 Any symptom for shoulder: 46% vs. 28%; 1.6 (0.9-2.9) Period prevalence: 13% vs. 3%; 4.0 (0.6-29) Plant #2 Any symptom for shoulder: 50% vs. 30%; 1.7 (0.8-3.3) Period prevalence: 14%vs. 5%; 2.8 (0.4-19.6)	õ	Die casting machine operators: 5.4; plastic workers: 2.2; spray painters: 3.7; surface treatment operators: 4.7; assembly line workers: 5.2	Boarding workers vs. knitting workers: 2.1 (0.6-7.3)
Duration of employment	õ	õ	õ	õ	õ	Years of employment in electronics: p<0.05	õ	NS
Physical workload	õ	õ	õ	Low muscle strength no a predictor for shoulder MSD	õ	õ	õ	õ
Psychosocial factors	Job dissatisfaction, exhaustion (not for shoulder)	Low decision latitude: 4.0 (0.8-19)	õ	Strong negative relationship between remaining health and satisfaction with colleagues	õ	õ	9 cases and 1 control reported poor relationship with supervisor. Sig. differences in group piece rate, shift work, heavy work, monotonous work, stressful work,	õ
Individual/other factors considered	Location	Age: 0.93 (0.8-1.0); good health: 0.35 (0.1-0.87)	Age, work experience, bag weight, walking time	Predictors of deterioration, previously physically heavy job, high productivity, and sick leave	õ	Shorter stature: p<0.05, productivity: NS, muscle strength: NS	Sig. differences in heavy lifting and unsuitable working conditions	õ
Dose/response	õ	õ	õ	õ	õ	õ	õ	õ

See footnotes at end of table. (Continued)

Appendix C Table C-3. Summary table for evaluating work-related shoulder musculoskeletal disorders

Components of study	Milerad 1990	Ohara 1976	Ohlsson 1989	Ohlsson 1994	Ohlsson 1995	Onishi 1976	Punnett 1985	Rossignol 1987
Study type	CS	CS and Prospective	CS	CS	CS	CS	CS	CS
Participation rate ≥70%	Y	NR (CS), Y (Prospective)	NR	Y	Y	NR	Y	Y: clerical workers N: industry groups
Outcome	S	S and PE	S	S and PE	S and PE	S, PE, and measurement	S and PE	S
Exposure	Questionnaire	Observation	Job categorization	Observation, questionnaire, video analysis	Observation, video analysis, measurement	Observation	Observation and questionnaire	Observation and questionnaire
Covariates considered	Age, gender, leisure time exposure, smoking, systemic disease, duration of employment	ð	Age, gender (females only)	Sports activities, age, gender (females only) psychosocial factors	Age, employment status	Body height, weight, grip strength	Age, number of years employed, native language	Age, cigarette smoking, industry, VDT educational training
Investigators blinded	NR	NR	NR	Y	Yes, to exposure information	NR	NR	ð
Repetition for shoulder	Combined	Combined	Combined	Combined	Combined	Combined	Combined	4-6 hrs. VDT use: 4.0 (1.0-16.9) >7 hrs. VDT use: 4.8 (1.6-17.2)
Force	Combined	Combined	Combined	Combined	Combined	Combined	Combined	ð
Extreme posture	Combined	Combined	Combined	Combined	Combined	Combined	Combined	ð
Vibration	NS	ð	ð	ð	ð	ð	ð	ð

See footnotes at end of table. (Continued)

Appendix C Table C-3. Summary table for evaluating work-related shoulder musculoskeletal disorders

Components of study	Milerad 1990	Ohara 1976	Ohlsson 1989	Ohlsson 1994	Ohlsson 1995	Onishi 1976	Punnett 1985	Rossignol 1987
Risk factors (combined)	Dentists vs. pharmacists: males: 2.4 (1.0-5.4), females: 2.4 (1.5-3.7)	Shoulder stiffness: cashiers (81% vs. office workers (72%), 1.7 (1.0-2.8) Shoulder dullness and pain: cashiers (49%) vs. other workers (68%), 2.0 (1.4-2.8); vs. office workers (30%), 2.2 (1.4-3.5)	Assemblers vs. referents shoulder pain last 7 days: 3.4 (1.6-7.1)	Supraspinatus, infraspinatus, or bicipital tendinitis working in the fish industry: OR=3.03 (2.5-7.2) Shoulder tendinitis alone: PRR=3.5 (2.0-5.9)	Assembly work compared to referent 5.0 (2.2-11.0)	Shoulder tenderness: assemblers vs. ref.: 1.1 (0.6-1.9); film rollers vs. ref.: 6.0 (3.0-12.2); teachers vs. ref.: 1.6 (0.7-3.3) Shoulder stiffness: reservationists vs. ref: 2.5 (1.1-5.6); assemblers vs. ref.: 3.7 (2.0-7.0); film rollers vs. ref.: 2.7 (1.5-4.9); teachers vs. ref.: 2.1 (0.9-4.6)	Garment workers vs. hospital employees 2.2 (1.0-4.9)	ð
Duration of employment	NS	ð	Sig. with duration of employment (*p*=0.03) for younger workers but not older workers	For age <45 years, duration of employment showed dose-response with shoulder MSDs	<10 years: 9.6 (2.8-33.0) 10-19 years: 4.4 (1.5-13.0) >20 years: 3.8 (1.4-10.0)	ð	NS	ð
Physical workload	ð	ð	ð	ð	ð	ð	ð	ð
Psychosocial factors	ð	ð	Increasing work pace	Stress, worry factors, tendencies towards muscle tension Sig.	Control, stimulation, psychosocial climate, work strain, social support, psychosomatic symptoms	ð	ð	ð
Individual/other factors considered		ð		Sports activities: 4-9	Employment status	Body height and weight: NS		ð
Dose/response	ð	ð	Reported pain increased with increasing work pace except for very high paces	For age <45 years, duration of employment and shoulder MSDs	ð	ð	ð	As VDT use increased, shoulder symptoms increased

See footnotes at end of table. (Continued)

Appendix C Table C-3. Summary table for evaluating work-related shoulder musculoskeletal disorders

Components of study	Sakakibara 1987	Sakakibara 1995	Schibye 1995	Stenlund 1992	Stenlund 1993	Sweeney 1994	Wells 1983
Study type	CS	CS	Cohort	CS	CS	CS	CS
Participation rate $70%	Y	Y	Y (But there was a significant dropout of work as a sewing machine operator in those >35 years	Y	Y	N	Y
Outcome	S	S and PE	S	S and PE	S and PE	S and PE	S
Exposure	Observation and measurement of postures	Observation and measurement of representative workers or job titles	Questionnaire	Questionnaire, self-reports, weight of tools job title, duration of employment	Questionnaire and self-reports	Questionnaire	Questionnaire, job categorization
Covariates considered	Gender, age	ð	Cohort study: followed same workers over time	Age, smoking, dexterity, ethnicity	Age, handedness, smoking, sports activities, duration of employment	ð	Age, number of years on job, quetelet ratio, previous work experience, education
Investigators blinded	ð	NR	NR	Y	Y	Yes	NR
Repetition for shoulder	ð	Combined	Combined	ð	ð	Combined	ð
Force	ð	ð	Combined	Combined	Manual work: right side: 1.1 (0.7-1.8) left side: 1.9 (1.0-3.4)	ð	Combined
Extreme posture	Thinning out, bagging pears had significantly more forward shoulder flexion than bagging apples	Combined	Combined	ð	ð	Combined	Combined
Vibration	ð	ð	ð	Right side: 2.2 (1.0-4.6) Left side: 3.1 (1.4-6.9)	Right side 1.7 (1.1-2.6) left side 1.8 (1.1-3.1)	ð	ð

See footnotes at end of table. (Continued)

Appendix C Table C-3. Summary table for evaluating work-related shoulder musculoskeletal disorders

Components of study	Sakakibara 1987	Sakakibara 1995	Schibye 1995	Stenlund 1992	Stenlund 1993	Sweeney 1994	Wells 1983
Risk factors (combined)	ð	Pear baggers compared to apple baggers: 1.7 (1.1-2.9) Posture: NR, Sig.	Development of shoulder symptoms not related to work exposure but significant dropout of workers >35 years	Rockblasters vs. Foremen: 4.0 (1.8-9.2) Bricklayers compared to foremen: right side: 2.2 (1.0-4.7)	Rock blasters compared to foremen: right side: 1.7 (0.7-4.0) left side: 3.3 (1.2-9.3)	>20 hrs./ week signing: 2.5 (0.8-8.2)	Letter carriers with increased shoulder load vs. postal clerks: 5.7 (2.1-17.8)
Physical workload	ð	ð	ð		Right side: 1.0 (0.6-1.8) left side: 1.8 (0.9-3.4)	ð	ð
Psychosocial factors	ð	ð	ð		ð	ð	ð
Individual/other factors considered	ð	ð	ð	Rock blasters compared to foremen: Right side: 2.1 (0.9-4.6) Left side: 4.0 (1.8-9.2)	ð	ð	
Duration of employment	ð	ð	ð	Right side: 2.9 (1.2-7.4) Left side: 2.5 (1.0-5.9)		ð	NS
Dose/response	ð	ð	None for increasing piece work in previous years	As length of employment and exposure to vibration and amount lifted increased, osteoarthritis of shoulder increased	High vibration compared to low vibration	ð	ð

ð Not studied.
EMG Electromyography.
F Force.
MSD Musculoskeletal disorders.
N Considered (no).
NR Not reported.
NS Not statistically significant.
R Repetition.
Ref. Referents.
S Symptoms.
Sig. Significant.
ST Supraspinatus tendinitis.
PE Physical examination.
VDT Video display terminals.
Y Considered (yes).

Appendix C Table C-4. Summary table for evaluating elbow musculoskeletal disorders

Components of study	Andersen 1993a	Baron 1991	Bovenzi 1991	Burt 1990	Byström 1995	Chiang 1993	Dimberg 1987	Dimberg 1989
Study type	CS	CS	CS	CS	CS	CS	CS	CS
Participation rate ≥70%	Y	N	NR	Y	Y	Y	Y	Y
Outcome	S	S and PE	S and PE	S	S and PE	S and PE	S and PE	S and PE
Exposure	Job categorization by job duration	Observation videotape, questionnaire	Observation, checklist, vibration measured	Questionnaire	Observation, videotape analysis, EMG of forearm muscle load collected, however, job title used for analysis	Observation videotape analysis, EMG	Observation job analysis categorization	Observation, job analysis, categorization
Covariates considered	Age, number of children, smoking, socioeconomic status	Age, gender, hobbies, second jobs, height, systemic disease	Age, ponderal index	Age gender, years on job, psychosocial factors	Gender, age >40 years, psycho-social variables and potential confounders addressed by Fransson-Hall et al. 1995	Age, gender, metabolic disease	Gender, age, employee category, degree of stress, tennis playing	Ponderal index, gender, age, time in present job, height, weight, smoking, house ownership, racquet sports
Investigators blinded	Y	Y	Y	Y	Y to questionnaire responses, No to exposure status	Y	NR	NR
Repetition	Combined	Combined	ô	80% of time reported typing vs. 0-19% of time: 2.8 (1.4-5.7)	Combined	Combined	ô	ô
Force	Combined	Combined	ô	Combined	Combined	Combined	Combined	Combined
Extreme posture	Combined	Combined	ô	Combined	Combined	Combined	Combined	Combined

See footnotes at end of table. (Continued)

Appendix C Table C-4. Summary table for evaluating elbow musculoskeletal disorders

Components of study	Andersen 1993a	Baron 1991	Bovenzi 1991	Burt 1990	Byström 1995	Chiang 1993	Dimberg 1987	Dimberg 1989
Vibration	ô	ô	Vibration-exposed forestry workers vs. referents: 4.9 (1.27-56.0)	ô	ô	ô	ô	*p*<0.01
Risk factors (combined)	Sewing machine operators vs. general population 1.7 (0.9-3.3)	Checkers vs. Noncheckers: 2.3 (0.5-11.0)	ô	Reporters compared to others: 2.5 (1.5-4.0)	Assembly line workers vs. population referen ts: 0.74 (0.04-1.7)	Group III vs. Group I (females): 1.44 (0.3-5.6) High force/high repetition vs. low force/low repetition: (males) 6.75 (1.6-32.7)	Force and posture: NR, Sig.	Force and posture: NR, NS
Physical workload	ô	ô	ô	ô	ô	ô	ô	ô
Psychosocial factors	ô	Job satisfaction: NS	ô	Job control and satisfaction: NS	Addressed by Fransson-Hall et al. 1995	ô	ô	Mental stress at the onset of symptoms: *p*<0.001
Individual/other factors considered	ô	ô	ô	Sick leave more common among strenuous jobs than nonstrenuous jobs	ô	ô	"Work" the cause in 35% of elbow problems, most white collar	Ponderal index associated with elbow symptoms
Duration of employment	ô	NS	ô	ô	ô	ô	ô	ô
Dose/response	ô	ô	ô	Y for time spent typing	ô	Y for males with increasing force/repetition	ô	ô

See footnotes at end of table.

(Continued)

Appendix C Table C-4. Summary table for evaluating elbow musculoskeletal disorders

Components of study	Fishbein 1988	Hales 1994	Hoekstra 1994	Hughes 1997	Kopf 1988	Kurppa 1991	Luopajärvi 1979	McCormack 1990
Study type	CS	CS	CS	CS	CS	Cohort	CS	CS
Participation rate $70%	N	Y	Y	N	N	Y	Y	Y
Outcome	S	S and PE	S	S and PE	S	S and PE	S and PE	S and PE
Exposure	Questionnaire	Observation and Questionnaire	Observation and Questionnaire	Observation, checklist, formal job analysis	Questionnaire, job categories	Observation, measurements, categorized by job titles	Observation, interviews, videotape analysis	Observation, job categories based on manual exposure
Confounders considered	Age, gender stratification, smoking status, alcohol, beta blockers, other drugs	Age, gender, metabolic disorder, hobbies, recreation	Age, gender, location, seniority	Age, smoking status, sports, hobbies, metabolic diseases, acute traumatic injuries, smoking	Age, job satisfaction, job security, moistness, vibration, Scheuerman's Disease	Workers used as their own controls; age, gender, duration of employment (with exceptions)	Age, gender, social background, hobbies, amount of housework, length of employment	Gender, age, race, job category, years of employment
Investigators blinded	NR	Y	Y	NR	NR	NR	Y	NR
Repetition	Combined	Number of key-strokes per day: NS	ð	ð	Combined	Combined	Combined	Combined
Force	ð	ð	ð	Number of years handling >2.5 kg/hand: NS	Combined	Combined	Combined	Combined
Extreme posture	Combined	ð	Non optimally adjusted chair: 4.0 (1.2-13.1)	Wrist flexion/ extension: NS; years of ulnar deviation: NS; years of forearm twisting: 37 (3.0-470.0)	Combined	Combined	Combined	ð
Vibration	ð	ð	ð	ð	ð	ð	ð	ð

See footnotes at end of table.

(Continued)

Appendix C Table C-4. Summary table for evaluating elbow musculoskeletal disorders

Components of study	Fishbein 1988	Hales 1994	Hoekstra 1994	Hughes 1997	Kopf 1988	Kurppa 1991	Luopajärvi 1979	McCormack 1990
Risk factors (combined)	Female musicians compared to males: 2.04 (1.6-2.6)	ð	ð	ð	Bricklayers compared to manual workers: 2.8; Increasing job demands OR increased from 1.8 to 3.4	Workers in strenuous vs. nonstrenuous jobs: 6.7 (3.3-13.9)	Assembly workers vs. shop assistants: for epicondylitis: 2.7 (0.66-15.9)	Boarding vs. Non-office workers: 0.5 (0.09-2.1) Knitting vs. Non-office workers: 1.2 (0.5-3.4)
Physical workload	ð	ð	ð	Push/pull; lift carry: NS	Sig	ð	ð	ð
Psychosocial factors	ð	Fear of replacement by computers: 2.9 (1.4-6.1); decision making: 2.8 (1.4-5.7); surge in workload: 2.4 (1.2-5.0)	Job dissatisfaction; exhaustion	Low decision latitude: 3.5 (0.6-19.0)	ð	ð	ð	ð
Individual/other factors considered	ð	Race (non-white): 2.4 (1.2-5.0)	ð	Age: 0.96 (0.9, 1.2)	ð	ð	ð	Age, race Sig
Duration of employment	ð	ð	ð	ð	ð	ð	ð	Y, Sig, with <6 months and >13 years
Dose/response	ð	ð	ð	ð	Yes, increasing levels of job demands	ð	ð	No

See footnotes at end of table.

(Continued)

Appendix C Table C-4. Summary table for evaluating elbow musculoskeletal disorders

Components of study	Moore 1994	Ohlsson 1989	Punnett 1985	Ritz 1995	Roto 1984	Viikari-Juntura 1991b
Study type	CS	CS	CS	CS	CS	CS
Participation rate $70%	Y	NR	Y for cases N for referents	NR	Y	Y
Outcome	PE records	S	S	S and PE	S and PE	S and PE
Exposure	Observation, videotape analysis, job strain index	Questionnaire, job categorization	Questionnaire, job category	Observation and record review and employee interviews	Job categorization	Observation, job analysis; weights of items
Confounders considered	Age, gender, duration of employment	Age, gender, duration of employment	Age, number of years employed, native language	Age, age-squared, and "history of cervical spine symptoms". Having ever played tennis, squash, other racquet sports, rowing, bowling,	Gender, other work tasks	Age, gender, duration of employment, leaving the company, changing the task, being on sick leave
Investigators blinded	Y	NR	NR	Y	Y	NR
Repetition	õ	Combined	Combined	õ	Combined	Combined
Force	5.5 (1.5-62)	õ	Combined	10 years of high exposure to elbow straining work: 1.7 (1.0-2.7)	Combined	Combined
Extreme posture	NR: was not found to be sig. associated with "hazardous" jobs.	Combined	Combined	õ	Combined	õ
Vibration	õ	õ	-	õ	õ	õ
Risk factors (combined)	õ	Non significant pain in last year assembly vs. referents: 1.5 (0.6-3.4) Work inability in last year assembly vs. Referents: 2.8 (0.8-10.7)	Garment workers vs. hospital employees: 2.4 (1.2-4.2)	õ	Meatcutters vs. construction workers: 6.4 (0.99-40.9), *p*=0.05	Strenuous vs. nonstrenuous: NS; difference: 0.88 (0.27-2.8)

See footnotes at end of table. (Continued)

Appendix C Table C-4. Summary table for evaluating elbow musculoskeletal disorders

Components of study	Moore 1994	Ohlsson 1989	Punnett 1985	Ritz 1995	Roto 1984	Viikari-Juntura 1991b
Physical workload	ô	ô	ô	ô	ô	ô
Psychosocial factors	ô	ô	ô	ô	ô	ô
Individual/other factors considered	ô	Not associated with work pace	Age; Non-English speakers sig. less likely to report symptoms	ô	ô	ô
Duration of employment	ô	No association	ô	Increased duration of current exposure increased risk of epicondylitis	All with epicondylitis had >15 years of employment	ô
Dose/response	ô	ô	ô	ô	ô	ô

ô Not studied.
CS Cross-sectional.
EMG Electromyography.
F force.
Hrs Hours.
MSD Musculoskeletal disorders.
N no.
NR Not reported.
NS Not statistically significant.
PE Physical examination.
R Repetition.
Sig. Statistically significant.
S Symptoms.
Y Considered (yes).

Appendix C Table C-5a. Summary table for evaluating work-related carpal tunnel syndrome (CTS)

Components of study	Armstrong 1979	Barnhart 1991	Baron 1991	Bovenzi 1991	Bovenzi 1994	Cannon 1981	Chatterjee 1982	Chiang 1990
Study type	CS	CS	CS	CS	CS	Case control	Case control	CS
Participation rate $70%	NR	N	N	NR	Y	NR	Y	Y
Outcome	S or surgery or PE findings	PE and NCS	S and PE	S and PE	S and PE	Industry medical records	S and PE and NCS	S and PE and NCS
Exposure	Observation, video, EMG	Observation	Observation, videotape analysis, job category	Observation, measurement	Observation, vibration, measurement	Medical records, job category	Observation, Measurement	Observation
Covariates considered	Gender, metabolic or soft tissue disease	Age, gender	Age, gender, hobbies, past employment, years on job	Age, gender, weight	Age, smoking, alcohol, upper limb injuries	Age, gender, race, weight, occupation, years employed, workers compensation status, history of metabolic disease, hormonal status, gynecologic surgery	Age, gender	Age, gender, length of employment, history of metabolic disease
Investigators blinded	N	Y, but clothing may have biased observation	Y	Y	N	NR	Y	Y
Repetition	ô	Repetitive ski manufacturing vs. others NCS: 1.9 (1.0-3.6) PE+NCS: 4.0 (1.0-15.8) S+PE+NCS: 1.6 (0.8-3.2)	Combined	ô	ô	2.1 (0.7-5.3)	ô	1.87 (*p*<0.018)

See footnotes at end of table. (Continued)

Appendix C Table C-5a. Summary table for evaluating work-related carpal tunnel syndrome (CTS)

Components of study	Armstrong 1979	Barnhart 1991	Baron 1991	Bovenzi 1991	Bovenzi 1994	Cannon 1981	Chatterjee 1982	Chiang 1990
Force	Pinch F: 2.0 (1.6-2.5) Hand F: 1.05 (1.0-1.2)	ð	Combined	ð	ð	ð	ð	ð
Extreme posture	Pinch force exertion: 2.0 (1.6-2.5)	ð	ð	ð	ð	ð	ð	ð
Vibration	ð	ð	ð	23.1 (no confidence limits) *p*=0.002	Quarry drillers and stone carvers vs. polishers and machine operators: 3.4 (1.4-8.3)	7.0 (3.0-170.0)	10.89 (1.02-524.0)	ð
Risk factors (combined)	ð	ð	Grocery checkers vs. other grocery workers: 3.7 (0.7-16.7)	Chain saw operators vs. maintenance workers: 18.8 (2.7-795)	ð	ð	ð	High cold/ high repetition: 11.66 (2.92-46.6)
Duration of employment	ð	ð	Y, Sig.	ð	ð	0.09 (0.8-10)	ð	NS
Physical workload	ð	ð	ð	ð	ð	ð	ð	ð
Psychosocial factors	ð	ð	ð	ð	ð	ð	ð	ð
Individual/other factors considered	ð	ð	ð	ð	ð	ð	ð	ð
Dose/response	ð	ð	Y, Sig.	ð	Y, NS	ð	ð	ð

See footnotes at end of table.

(Continued)

Appendix C Table C-5a. Summary table for evaluating work-related carpal tunnel syndrome (CTS)

Components of study	Chiang 1993	deKrom 1990	English 1995	Färkkilä 1988	Feldman 1987	Franklin 1991	Koskimies 1990	Liss 1995
Study type	CS	CS	Case control	CS	CS for symptoms and cohort for NCS	Retrospective cohort	CS	CS
Participation rate $70%	Y	Y	Y	NR	Y	Y	NR	No
Outcome	S and PE	S and PE and NCS	S and PE	S and PE and NCS	S and in some PE and NCS	Records review of workers' compensation cases	S and PE and NCS	Mailed survey
Exposure	Observation, measurement, EMG	Questionnaire	Questionnaire	Interview	Observation, biomechanical analysis, videotaping	Job title and industry	Records of vibration exposure	Mailed survey
Covariates considered	Age, gender, metabolic disease, hormonal status	Age, gender, weight, slimming courses	Gender, height, weight	Alcohol	Gender, past medical history, cigarette smoking, hobbies (No analyses performed to take these into account)	None	NR	Gender, age
Investigator blinded	Y	NR, participants blinded	Y	NR	NR	Y	NR	N
Repetition	Repetitive fish processing vs. other: 1.1 (0.7-1.8)	ð	CTS patients vs. other patients: 0.4 (0.2-0.7)	ð	Combined	Combined	ð	Combined
Force	Repetitive fish processing vs. other: 1.8 (1.1-2.9)	ð	ð	ð	Combined	Combined	ð	ð
Extreme posture	ð	Reported 20 to 40 hrs./week Flexed wrist: 8.7 (3.1-24.1) Extended 5.4 (1.1-27.4)	CTS patients vs. other patients: 1.8 (1.2-2.8)	ð	ð	Combined	ð	Combined

See footnotes at end of table. (Continued)

Appendix C Table C-5a. Summary table for evaluating work-related carpal tunnel syndrome (CTS)

Components of study	Chiang 1993	deKrom 1990	English 1995	Färkkilä 1988	Feldman 1987	Franklin 1991	Koskimies 1990	Liss 1995
Vibration	õ	õ	õ	Vibration: p< 0.05	õ	õ	Vibration exposure time and NCS Sig. Right hand: r=-0.27; *p*=0.01 Left hand r=-0.12 *p*=NS	õ
Risk factors (combined)	Repetitive and forceful fish processing vs. others: 1.1 (0.7-1.8) Female poultry workers hi R/hi F vs. low R F: 2.6 (1.0-7.3)	õ	õ	õ	Year 2 vs. Year 1, numbness and tingling in fingers: 2.26 (1.14-4.46)	Oyster and crab packers vs. industry-wide rates: 14.8 (11.2-19.5)	õ	CTS symptoms, dental hygienists vs. dental assistants: 3.7 (1.1-11.9) Responder told that they had CTS: 5.2 (0.9-32.0)
Duration of employment	Y,<12 months; No for 12 to 60 months and >60 months	õ	õ	õ	õ	õ	Exposure time Sig.	õ
Physical workload	Y	õ	õ	õ	õ	õ	õ	õ
Psychosocial factors	õ	õ	õ	õ	õ	õ	õ	õ
Individual/other factors considered	õ	õ	õ	õ	õ	õ	õ	õ
Dose/response	Y, Sig.	Y, Sig.	õ	õ	õ	õ	õ	õ

See footnotes at end of table. (Continued)

Appendix C Table C-5a. Summary table for evaluating work-related carpal tunnel syndrome (CTS)

Components of study	Loslever 1993	Marras 1991	McCormack 1990	Morgenstern 1991	Moore 1994	Nathan 1988	Nathan 1992a	Nathan 1992b
Study type	CS	CS	CS	CS	Retrospective cohort	CS	Cohort	Longitudinal
Participation rate $70%	Jobs selected due to CTS occurrence	NR	Y	Y	Y	NR	N	Y=Japanese N=Overall
Outcome	S	Records and medical records	S and PE	S	PE and NCS from records	NCS	S and NCS	S and NCS
Exposure	Observation; measurements, videotaping	Observation; measurements	Observation, job title	Survey	Observation, videotape, measurement	Observation	Observation	Questionnaire
Covariates considered	Gender, age, years on the job, hand orientation	Age, gender, handedness, job satisfaction	Age, gender, race, job category, years of employment	Age, gender, pregnancy status, work history job tasks, use of selected drugs, history of wrist injury	None	Age, gender	Age, gender, hand dominance, duration of employment and industry	Gender, hand dominance, occupational hand use, duration of employment, industry, leisure exercise, heavy lifting, keyboard use, coffee, tea, alcohol
Investigator blinded	N	NR	NR	N	Y	NR	NR	NR
Repetition	õ	Number of wrist movements: NS	Combined	1.88 (0.9-3.8)	Combined	Group II vs. Group 1:1.0 (0.05-2.0)	Combined	Found to be "protective"
Force	Combined	Grip forces three times as great in high-risk jobs	Combined	õ	Combined	Combined	Combined	
Extreme posture	Combined	Radial/ulnar ROM: 1.52 (1.1-2.1); Flexion/extension ROM: 1.3 (1.0-1.7); Pronation/supination ROM: 1.2 (0.9-1.6)	õ	õ	Combined	õ	õ	õ

See footnotes at end of table. (Continued)

Appendix C Table C-5a. Summary table for evaluating work-related carpal tunnel syndrome (CTS)

Components of study	Loslever 1993	Marras 1991	McCormack 1990	Morgenstern 1991	Moore 1994	Nathan 1988	Nathan 1992a	Nathan 1992b
Vibration	ð	ð	ð	ð	ð	ð	ð	ð
Risk factors (combined)	High force with high flexion: r=0.62; high force and high extension: r=0.29	Flexion/extension velocity: 3.8 (1.5-9.6) Flexion/extension acceleration: 6.1 (1.7-22)	Boarding vs. non-office: 0.5 (0.05-2.9) Packing vs. Non-office 0.4 (0.04-2.4) Sewing vs. Non-office 0.9 (0.3-2.9)	ð	Meat processors in hazardous vs. safe jobs: 2.8 (0.2-36.7)	Group I vs. Group III: 1.7 (1.3-2.3) Group I vs. Group V: 2.2 (1.3-3.3)	Group V vs. Group I: 1.0 (0.5-2.2) Group IV vs. Group I: 1.4 (0.9-2.1) Group III vs. Group I: 1.5 (1.0-2.2)	Americans with significantly greater prevalence of CTS compared to Japanese
Duration of employment	ð	Sig.	Prevalence higher in workers with <3 years employment	>34 hrs./week: 1.9 (1.1-3.1) >9 years: 1.7 (1.0-3.2)	ð	ð	ð	Duration of employment found to be protective
Physical workload	ð	ð	ð	ð	ð	ð	ð	ð
Psychosocial factors	ð	Job satisfaction: NS	ð	ð	ð	ð	ð	ð
Individual/other factors considered	ð	trunk depth: Sig.	ð	ð	ð	ð	Age, hand dominance sig.	Mean age, body mass index and leisure exercise Sig., cigarettes Sig .
Dose/response	ð	ð	ð	ð	ð	Y, Sig.	ð	ð

See footnotes at end of table.

(Continued)

Appendix C Table C-5a. Summary table for evaluating work-related carpal tunnel syndrome (CTS)

Components of study	Osorio 1994	Punnett 1985	Schottland 1991	Silverstein 1987	Stetson 1993	Tanaka (*In Press*)	Weislander 1989
Study type	CS	CS	CS	CS	CS	CS	Case control
Participation rate $70%	Y	Y for cases; N for comparison group	NR	Y	Y	Y	Y
Outcome	S and PE, NCS	S and PE	NCS	S and PE	S and PE and NCS	S	S and PE and NCS
Exposure	Job title, observation	Observation, questionnaire	Job title	Observation, videotape analysis, EMG	Observation, questionnaire, job analysis	Questionnaire	Telephone interview
Covariates considered	Age, gender, alcohol, medical history	Age, gender, hormonal status, native language, history of metabolic disease	Age, gender	Age, gender, plant, years on job	Age, height, skin temperature, dominant index finger circumference	Age, gender, race, cigarettes, income, education, BMI	Age, gender, year of operation
Investigator blinded	Y	NR	NR	Y	NR	No	No
Repetition	Combined	Combined	Combined	Repetition: 5.5 $p<0.05$	NS	ð	2.7 (1.3-5.4)
Force	Combined	Combined	Combined	Combined	Y, Sig. combined	ð	ð
Extreme posture	ð	ð	Combined	Ulnar deviation and pinching, elevated but NS	Combined (pinch grip)	Bending/twisting of the wrist: 5.9 (3.4-10.2)	ð
Vibration	ð	ð	ð	5.3 (no confidence limits)	ð	Vibration: 1.85 (1.2-2.8)	Vibrating tool use 3.3 (1.6-6.8)
Risk factors (combined)	NCS: 6.7 (0.8-52.9) Super-market workers, high vs. low exposure symptoms: 8.3 (2.6-26.4)	Force, repetition, posture: 2.7 (1.2-7.6)	Workers vs. applicants: females, right hand: 2.86 (1.1-7.9); males, right hand: 1.87 (0.6-9.8)	High force/high repetition vs. low force/low repetition: 15.5 (1.7-142.0)	Y, Sig. median sensory amplitudes Sig. smaller ($p < 0.01$) and latencies longer ($p<0.05$) with exposure to high pinch grip forces	ð	ð

See footnotes at end of table. (Continued)

Appendix C Table C-5a. Summary table for evaluating work-related carpal tunnel syndrome (CTS)

Components of study	Osorio 1994	Punnett 1985	Schottland 1991	Silverstein 1987	Stetson 1993	Tanaka (*In Press*)	Weislander 1989
Duration of employment	Y	NS	ò	0.9 *p*>0.09	ò	ò	ò
Physical workload	Y	ò	ò	ò	ò	ò	Loads on wrist 1.8 (1.0-3.5)
Psychosocial factors	ò	ò	ò	ò	ò	ò	ò
Individual/other factors considered	ò	ò	ò	ò	ò	Female gender: 2.4 (1.6-3.8); BMI $25: 2.1 (1.4-3.1); white race: 4.2 (1.9-15.6) Cigarettes: 1.6 (1-2.5); annual income $$20,000: 1.5 (1-2.4)	ò
Dose/response	Y, Sig.	ò	ò	Y, Sig.	ò	ò	ò

ò Not studied
BMI Body Mass Index
CS Cross-sectional
CTS Carpal tunnel syndrome
EMG Electromyography
F Force
hrs Hours
NCS Nerve conduction studies
NR Not reported
NS Not statistically significant
PE Physical examination
R Repetition
Sig. Statistically significant
S Symptoms
Y Considered (yes)

See footnotes at end of table.

(Continued)

Appendix C Table C-5b. Summary table for evaluating work-related hand/wrist tendinitis

Components of study	Amano 1988	Armstrong 1987a	Byström 1995	Kuorinka 1979	Kurppa 1991	Luopajärvi 1979	McCormack 1990	Roto 1984
Study type	CS	CS	CS	CS	Cohort	CS	CS	CS
Participation rate $70%	NR	Y	Y	Y	Y	Y	Y	Y
Outcome	S and PE	S and PE	S and PE	S and PE	S and PE	S and PE	S and PE	S and PE
Exposure	Job titles or self-reports	Observation, measurements, video analysis, EMG	Questionnaire, observation, measurements, videotape analysis, EMG	Records, observation, measurements, videotape analysis	Observation, measurements, video analysis. Reader referred to methods found in previous publications	Observation, measurements, video analysis	Observation, job category	Job title
Covariates considered	Age, gender	Age, gender, years on job, and industrial plant	Age, gender, psychosocial factors (addressed by Fransson-Hall et al. 1995)	Age, gender, body mass index, "muscle-tendon" syndrome	Age, gender	Gender (only females in study groups), age, hobbies, housework, medical conditions	Race, age, gender	Rheumatoid arthritis
Investigators blinded	NR	Y	No	NR	NR No=occupation of subjects	Y	NR	Y=occupation meat processing No=construction foremen (referent)
Repetition	Combined	Combined	Combined	Combined	Combined	Combined	Combined	Combined
Force	Combined	Combined	Combined	Combined	Combined	Combined	Combined	Combined
Extreme posture	Combined	Significant differences between males and females	Combined	Combined	Combined	Combined	Combined	Õ
Vibration	Õ	Õ	Õ	Õ	Õ	Õ	Õ	Õ

See footnotes at end of table

(Continued)

Appendix C Table C-5b. Summary table for evaluating work-related hand/wrist tendinitis

Components of study	Amano 1988	Armstrong 1987a	Byström 1995	Kuorinka 1979	Kurppa 1991	Luopajärvi 1979	McCormack 1990	Roto 1984
Risk factors (combined)	Right index finger flexor: 3.67 (1.85-7.27) Left index finger flexor: 6.17 (2.72-13.97)	Comparison between low R/low F and high R/high F: 4.8 (0.6-39.7) 5.5 (0.7-46.3) 17.0 (2.3-126.2)	De Quervain's tendinitis among among auto assembly workers vs. general population: 2.5 (1.00-6.23)	Scissor makers vs. shop assistants: 1.38 (0.76-2.51)	Meat cutter compared to office workers: risk ratio: 14.0 (5.7-34.4); Meat packers compared to office workers: risk ratio: 38.5 (11.7-56.1); sausage makers compared to office workers: risk ratio: 25.6 (19.2-77.5)	Assembly line workers vs. shop assistants: 4.13 (2.63-6.49)	Textile workers compared to non-office workers: 3.0 (1.4-6.4) Overall group exposed: 1.75 (0.9-3.39)	Meat cutters vs. construction workers: 3.09 (1.43-6.67)
Physical workload	õ	õ	õ	õ	õ	õ	õ	õ
Psychosocial factors	õ		Analyzed by Fransson-Hall et al. 1995		õ	õ	õ	õ
Individual/ other factors considered	õ	õ	õ	Pieces handled over the years: a nonsignificant trend with increasing number of pieces handled	õ	NS for age, hobbies, or housework	Female gender significant for tendinitis at p=0.01; job category significant at p=0.001	Rheumatoid arthritis found not to be a confounder
Duration of employment	õ	õ	õ	õ	õ	No association	õ	õ
Dose/response	õ	With increasing combination of R and F	õ	õ	õ	õ	õ	õ

õ Not studied.
CS Cross-sectional
EMG Electromyography.
F Force.
HAVS Hand-arm vibration syndrome
NR Not reported.
NS Not statistically significant.
PE Physical examination.
R Repetition.
S Symptoms.
Y Considered (yes).

Appendix C Table 5c. Summary table for evaluating hand-arm vibration syndrome

Components of study	Bovenzi 1988	Bovenzi 1994	Bovenzi 1995	Brubaker 1983	Brubaker 1987	Dimberg 1991	Kivekäs 1994	Koskimies 1992	Letz 1992	McKenna 1993
Study type	CS	CS	CS	CS	Cohort	CS	Cohort	Cohort	CS	CS
Participation rate $70%	NR	Y	Y	Y	N	Y	Y	Y	Y	NR
Outcome	S and PE; cold provocation	S and PE	S and PE; cold provocation	S and PE; cold provocation	S and PE; cold provocation	S	S and PE	S and PE	S	S and PE; cold provocation
Exposure	Observation; measurements of the tool	Observation, interview, measurements of the tool	Questionnaire, observation, measurements of the tool	Question-naire data	Observation; measurements of the tool	Questionnaire	Questionnaire	Measurement of the tools	Questionnaire, measurements of the tool used from previous studies	Questionnaire
Covariates considered	ö	Age, smoking, alcohol consumption, upper limb injuries; leisure activities, systemic diseases	Age, smoking, drinking habits, cardiovascular, neurologic, previous musculoskeletal injuries, use of medicines	Smoking, age, height, weight	Age, gender, psychosocial scales	ö	Age	ö	Age, race, smoking, alcohol, medical conditions	Age, smoking, only males studied, those with injury to the neck, upper limbs excluded.
Investigators blinded	NR	N	Y	NR	NR	NR	Y	NR	No	N
Repetition	ö	ö	ö	ö	ö	ö	ö	ö	ö	ö
Force	ö	ö	ö	ö	ö	ö	ö	ö	ö	ö
Extreme posture	ö	ö	ö	ö	ö		ö	ö	ö	ö

See footnotes at end of table

(Continued)

Appendix C Table 5c. Summary table for evaluating hand-arm vibration syndrome

Components of study	Bovenzi 1988	Bovenzi 1994	Bovenzi 1995	Brubaker 1983	Brubaker 1987	Dimberg 1991	Kivekäs 1994	Koskimies 1992	Letz 1992	McKenna 1993
Vibration	Stone drillers and cutters vs. quarry and mill workers: 6.06 (2.0-19.6)	Stone workers vs. polishers and machine operators: 9.33 (4.9-17.8)	Forestry workers and 2.6% in ship-yard referents: OR = 11.8 (4.5-31.1) For workers only using antivibration saws: OR = 6.2 (2.3-17.1) For those using non-antivibration saws: OR = 32.3 (11.2-93)	NR	15% of fellers reported new symptoms of VWF from 1979 to 1985; 28% increase in prevalence of VWF in workers using antivibration chain-saws	Vibrating tool use sig. Correlated with HAVS symptom prevalance	Lumberjackes vs. referents: for 1978: 3.4, (1.7-6.9) Cumulative incidence HAVs (7-years) 14.7% vs. 2.3%: 6.5 (2.4-17.5)	Decrease in prevalence in forest workers from 1972 to 1990, attributed to reduction in weight of saws, increase in vibration frequency, reduction in acceleration	Full-time vibration workers vs. referents: 5.0 (2.1-12.1) Full-time vibration workers vs. Controls: 40.6 (11-177)	Riveters vs. referents: 24 (3.1-510)
Risk factors (combined)	ō	ō	ō	ō	ō	ō	ō	ō	ō	ō
Physical workload	ō	ō	ō	ō	ō	ō	ō	ō	ō	ō
Psychosocial factors	ō	ō	ō	ō	ō	ō	ō	ō	ō	ō
Individual/ other factors considered	ō	See "Covariates considered" above	See "Covariates considered" above	Age significantly different between cases and controls, height and weight were not.	ō	Vibrating tool use significantly correlated with HAVS symptoms prevalence	ō	ō	Smoking Sig.	ō
Duration of employment	ō	ō	ō	ō	ō	ō	No differece in lumberjacks with <15 years of exposure, but then increased with duration of exposure	ō	ō	ō
Dose/response	ō	ō	Y, between increasing vibration exposure and "vibration white finger"	ō	ō		Increased HAVS with duration of exposure	ō	Sig. for reported exposure to vibratory tools in workers with <17,000 hours of exposure	ō

See footnotes at end of table. (Continued)

Appendix C Table 5c. Summary table for evaluating hand-arm vibration syndrome

Components of study	Mirbod 1992a, 1994	Mirbod 1992b	Miyashita 1992	Musson 1989	Nagata 1993	Nilsson 1989	Saito 1987	Shinev 1992	Starck 1990	Virokannas 1995
Study type	CS	CS	CS	CS	CS	CS	Cohort	CS	CS	CS
Participation rate $70%	NR	NR	NR	N	NR	Y for platers; NR for office workers	N	NR	NR	NR
Outcome	S	S and PE	S	S	S and PE	S and PE	S and PE	S and PE	S	S and PE
Exposure	Questionnaire; interviews, measurements of the workers and the tools	Questionnaire; measurements of the workers and the tools	Job Title	Postal questionnaire, measurement of representative tools	Based on years of exposure since employment	Questionnaire, measurement of tool, exposure time	Questionnaire	Measurement of tool	Measurement of tools	Interview
Covariates considered	Age	ŏ	ŏ	Age, height, weight, smoking, time pressure, working posture	Age	Age	Follow-up of cohort	Age, cigarette smoking, industry, education VDT training	N	Age, duration of employment
Investigators blinded	NR	N	N	NR	N	NR	NR	NR	N	NR
Repetition	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
Force	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
Extreme posture	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
Vibration	Male chain saw operators vs. referents: 3.77 (2.1-6.8)	Symptom severity positively correlated with exposure duration	Male Construction workers compared to male office workers: 0.5 (0.1-11.8)	Exposure duration not related to HAVS symptoms	For >20 years vibration exposure: 7.1 (2.5-19.9)	Office workers with no vibration exposure to former exposure: 14 (5-38) Office workers with no exposure: 85 (15-486)	NR	Percussive vibration had a greater effect on muscle and bone pathology than constant high-frequency vibration	High prevalence of HAVS among workers using vibrating tools	NR

See footnotes at end of table (Continued)

Appendix C Table 5c. Summary table for evaluating hand-arm vibration syndrome

Components of study	Mirbod 1992a, 1994	Mirbod 1992b	Miyashita 1992	Musson 1989	Nagata 1993	Nilsson 1989	Saito 1987	Shinev 1992	Starck 1990	Virokannas 1995
Risk factors (combined)	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
Physical workload	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
Psychosocial factors	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
Individual/ other factors considered	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	Age Sig. Correlated to recovery rates from 1978 to 1983	ŏ	Poor correlation between vibration exposure and HAVS when tools were highly impulsive	ŏ
Duration of employment	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
Dose/response	ŏ	HAVS symptom severity positively correlated with exposure duration	ŏ	ŏ	ŏ	OR increased by 11% for each year of exposure	ŏ	ŏ	ŏ	ŏ

ŏ Not studied.
CS Cross-sectional.
CTS Carpal tunnel syndrome.
EMG Electromyography.
F Force.
Hrs Hours.
NCS Nerve conduction studies.
NR Not reported.
NS Not statistically significant.
OR Odds ratio.
PE Physical examination.
R Repetition.
S Symptoms.
Sig Statistically significant.
VPT Vibration perception threshold.
Y considered (yes).

Appendix C Table C-6. Summary table for evaluating back musculoskeletal disorders

Components of study	Åstrand 1987, 1988	Bergenudd 1988	Bigos 1991b	Bongers 1988	Bongers 1990	Boshuizen 1990a, 1990b
Study type	1987: CS; 1988: Cohort	Cohort	Cohort	Retrospective cohort	CS	CS Cohort
Participation rate $ 70%	Y	N	N	Y	Y	Y
Outcome	S and PE	S	S	Physical exam from disability records	S	CS: S Cohort: records
Exposure	Questionnaire	Questionnaire	Questionnaire; For jobs with >19 workers: job analysis	Job title and records; vibration measurements obtained but not used	Questionnaire; vibration measurements	Questionnaire; vibration measurements
Covariates considered	Education level, psychosocial factors (including neuroticism)	Years of education, psychosocial factors	Medical history, previous episodes of back pain, "individual" factors, psychosocial factors (from MMPI)	Nationality, shift-work, age, and calendar time	Age, height, weight, climate, bending forward, twisted postures and feeling tense at work	Duration of exposure, age, height, smoking, awkward postures, and mental workload
Investigators blinded	N	NR	NR	NR	NR	NR
Heavy physical work	Combined	Workers in moderate and heavy physical demand work groups vs. light physical demand group: 1.8 (1.2-2.7)	No association	ð	ð	ð
Lifting and forceful movements	Combined	ð	ð	ð	ð	ð

See footnotes at end of table. (Continued)

Appendix C Table C-6. Summary table for evaluating back musculoskeletal disorders

Components of study	Åstrand 1987, 1988	Bergenudd 1988	Bigos 1991b	Bongers 1988	Bongers 1990	Boshuizen 1990a, 1990b
Awkward postures	ð	ð	ð	ð	ð	ð
Whole body vibration	ð	ð	ð	All back disorders: 1.32 (0.84-2.1); Intervertebral disc disorders: 2.00 (1.1-3.7); Disc degeneration by years of exposure: 5.7 (for highest exposure category)	LBP in exposed vs. referents: 9.0 (4.9-16.4), Sciatica: 3.3 (1.3-8.5); LBP by total vibration dose: ORs=12.0, 5.6, 6.6, 39.5 LBP by hours of flight time per day: 5.6, 10.3, 14.4;	LBP by vibration dose category: ORs=19.1, 29.4, 28.0, 38.1; By vibration dose: ORs=1.80, 1.78, 2.8; years of exposure: 3.6 (1.2-11)
Static work postures	ð	ð	ð	ð	ð	ð
Risk factors (combined)	Mill workers vs. clerical workers: 2.3 *p*=0.002	ð	ð	ð	ð	ð
Psychosocial factors	Neuroticism and back pain: 2.8 (1.4-5.4)	Those with back pain less satisfied with working conditions; no difference in social support	MMPI: tend towards somatic complaint or denial of emotional distress and reporting injury: 1.37 (1.1-1.7)	ð	ð	ð
Individual/other factors considered	ð	ð	Does not enjoy job tasks and reporting injury: 1.7 (1.3-2.2)	ð	ð	ð
Duration of employment	Duration of employment and back pain: 1.2 (1.0-1.5)	ð	Prior back pain and reporting injury: 1.7 (1.2-2.5)	ð	ð	ð
Dose/response	ð	ð	ð	ð	ð	ð

See footnotes at end of table. (Continued)

Appendix C Table C-6. Summary table for evaluating back musculoskeletal disorders

Components of study	Boshuizen 1992	Bovenzi 1992	Bovenzi 1994	Burdorf 1990	Burdorf 1991	Burdorf 1993
Study type	CS	CS mail survey	CS	CS	CS	CS
Participation rate $70%	Y	Y	Y	N	Y	Y
Outcome	S	S	S	S	S	S
Exposure	Questionnaire; vibration measurements	Questionnaire, measurement of WBV	Questionnaire, measurement of vibration levels	Questionnaire, job title, and expert knowledge	Questionnaire, task analysis and OWAS	Questionnaire, measurements of WBV, Postures assessed with OWAS
Covariates considered	Mental stress, years lifting >10 kg and twisting spine, height, smoking, looking backwards, hours sitting	Age, awkward posture, duration of exposure, BMI, mental load, education, smoking, sport activities and previous jobs at risk for back pain	Age, BMI, education, sport activity, car driving, marital status, mental stress, climatic conditions, back trauma, and postural load (or total vibration dose)	Age, height, and weight	Age, height, and weight	Age, history of heavy work, exposure to WBV, work requiring prolonged sitting, cold, drafts, working under severe pressure, job satisfaction, height, weight, duration of total employment
Investigators blinded	NR	NR	NR	NR	N	NR
Heavy physical work	ô	ô	ô	Heavy work: 4.02 (0.76-21.2)	Heavy physical work sig in univariate but not multivariate model	ô
Lifting and forceful movements	ô	ô	ô	Frequent lifting: 5.21 (1.10-25.5)	No association	ô
Awkward postures	ô	ô	ô	ô	Postural Index and LBP: 1.23 *p*=0.04	ô
Whole body vibration	Total vibration dose and back pain: 0.99 (0.85-1.2); In younger workers: vibration in past 5 years and lumbago, 3.1 (1.2-7.9)	Low back: Previous 12 months prevalence of LBP, bus drivers vs. controls: 2.57 (1.5-4.4) Multivariate: LBP symptoms in previous. 12 months: and total vibration dose: OR's= 1.67, 3.46, 2.63	LBP in the past year: OR=2.39 (1.6-3.7) Postural load category: OR=4.56 (2.6-8.0) (for the highest exposure category)	WBV: 0.66 (0.14-3.1)	WBV and LBP, 3.1 *p*=0.001	Combined

See footnotes at end of table. (Continued)

Appendix C Table C-6. Summary table for evaluating back musculoskeletal disorders

Components of study	Boshuizen 1992	Bovenzi 1992	Bovenzi 1994	Burdorf 1990	Burdorf 1991	Burdorf 1993
Static work postures	ð	ð	ð	For univariate analysis: sedentary postures in crance operators: 0.49 (0.11-2.2)	Posture index based on time spent in a working posture with the back in a bent and/or twisted position: 1.23 *p*=0.04	ð
Risk factors (combined)	ð	ð	ð	Job title: 3.6 (1.2-10.6)	ð	Crane operators vs. office workers: 3.29 (1.52-7.12) Straddle-carrier drivers vs. office workers: 2.5 (1.2-5.4)
Psychosocial factors	ð	ð	ð	ð	ð	ð
Individual/other factors considered	ð	ð	ð	ð	Postural load, bending, and twisting are causal factors. Standing and sitting are not found to be risk factors.	ð
Duration of employment	ð	ð	ð	ð	ð	ð
Dose/response	ð	Univariate analysis, total vibration dose: lifetime LBP symptoms: 4.05 (1.8-9.3); 12 months LBP symptoms: 3.25 (1.5-7.0).	Dose/response of combined effects to total vibration dose and postural load, highest combination of categories: 4.58.	ð	ð	ð

See footnotes at end of table.

(Continued)

Appendix C Table C-6. Summary table for evaluating back musculoskeletal disorders

Components of study	Chaffin 1973	Clemmer 1991	Deyo 1989	Heliövaara 1991	Hildebrandt 1995	Hildebrandt 1996
Study type	Cohort	CS	CS	CS	CS	CS
Participation rate $70%	NR	Y	NHANES-II data	Y	Y	Y, but varied from 60% to 80% by department
Outcome	S	Injury report	Data base (LBP)	S and PE	S	S
Exposure	Observation and measurement	Job title	Data base (smoking, obesity, personal characteristics)	Questionnaire	Questionnaire	Questionnaire
Covariates considered	Age, weight, stature, number of prior back episodes, isometric lifting strengths	Age, job, length of employment	Age, gender, smoking, obesity, exercise level, employment status	Age and gender	Age and gender	Age
Investigators blinded	NR	NR	N	N	N	N
Heavy physical work	ð	Roustabouts vs. control room operator: 4.3 (no confidence limits)	ð	Combined ORs=1.9, 2.5	Heavy physical work vs. sedentary work: 1.2, $p<0.05$	Nonsedentary steel workers vs. referents: No association
Lifting and forceful movements	Approx. 5	ð	ð	ð	ð	ð
Awkward postures	ð	ð	ð	ð	ð	ð
Whole body vibration	ð	ð	ð	ð	ð	ð
Static work postures	ð	ð	ð	ð	ð	ð

See footnotes at end of table.

(Continued)

Appendix C Table C-6. Summary table for evaluating back musculoskeletal disorders

Components of study	Chaffin 1973	Clemmer 1991	Deyo 1989	Heliövaara 1991	Hildebrandt 1995	Hildebrandt 1996
Risk factors (combined)	Lifting of loads in positions which create a Lifting Strength Rating $ was considered potentially hazardous to some people	Job was best predictor of lost time.	ò	LBP and physical stress: 2.5 (1.4-4.7)	ò	NS, Reference group had high exposure to adverse working conditions
Psychosocial factors	ò	ò	Ever smoked vs. LBP: 1.13, Sig. 50 pack years vs. LBP: 1.47, Sig. Body mass index vs. LBP: 1.70, Sig.	Stress load index: 2.4 (1.7-3.5)	ò	ò
Individual/ other factors considered	Age, weight, and stature did not correlate with increased incidence of LBP	75% of back strains precipitated by pushing, pulling, or lifting.	ò	Body mass index, alcohol , work-related driving, parity, height not associated with LBP. Smoking sig in both older and younger males, but only older females. Prior traumatic injury increased risk of LBP: 2.5 (1.9-3.3); and sciatica: 2.6 (2.1-3.1)	Rates of LBP: construction: 35%; truckers: 31%; plumbers: 31%	ò
Duration of employment	ò	ò	Smoking risk increases steadily with cumulative exposure and with degree of maximal daily exposure. There is a steady increase in LBP with increasing obesity.	ò	ò	ò
Dose-response	ò	ò	ò	ò	ò	ò

See footnotes at end of table. (Continued)

Appendix C Table C-6. Summary table for evaluating back musculoskeletal disorders

Components of study	Holmström 1992	Huang 1988	Johanning 1991	Johansson 1994	Kelsey 1975b	Kelsey 1984	Knibbe 1996
Study type	CS	CS	CS mail survey	CS	Case control	Case control	CS
Participation rate $70%	Y	Y	N	Y	Y	Y	Y
Outcome	S; (A sample had PE for purposes of validation)	S	S	S	Medical records: S and PE required	S and PE	S
Exposure	Postal questionnaire	Ergonomic assessment including NLE	Job title, measured WBV in exposed group but results not presented	Questionnaire	Questionnaire	Interview and questionnaire	Questionnaire
Covariates considered	Daily traveling time, leisure activity, height and weight	Age, height, length of employment, olecranon height, weight	Age, gender, job title, employment duration	Age and gender. Non work-related S could have an effect masking result, if not identified.	Age, gender	Age, gender, medical service	Age
Investigators blinded	Y	NR	NR	NR	NR	NR	N
Heavy physical work	ò	ò	ò	Blue collar workers vs. white collar workers: no association	ò	ò	ò
Lifting and forceful movements	One year prevalence of BP and manual materials handling: 1.3 (1.2-1.4); Lifting frequency: >1 per 5 min vs.<1 per 5 min: 1.12, *p*<0.001	The workers in the center with higher rates had greater lifting compared to the referent center: no risk estimate	ò	No association	Lifting vs. herniation: 0.94, *p*=0.10	Lifting >25 lb or more, without twisting the body: 3.8 (0.7-20.1)	Registered nurses vs nursing aides: Unadjusted OR=1.2, *p*=0.04; after adjusting for hr worked, aides had higher rate: 1.3
Awkward postures	Stooping and kneeling with severe LBP compared to no stooping: 2.6; in comparison to no kneeling: 3.5	More awkward postures found in center A than B, *p*=0.05.	ò	Extreme work postures sig associated with outcome in blue collar workers	Combined	Twisting without lifting: 3.0 (0.9-10.2)	ò
Whole body vibration	ò	ò	WBV and sciatica pain: 3.9 (1.7-8.6)	ò	Combined	ò	ò

See footnotes at end of table. (Continued)

Appendix C Table C-6. Summary table for evaluating back musculoskeletal disorders

Components of study	Holmström 1992	Huang 1988	Johanning 1991	Johansson 1994	Kelsey 1975b	Kelsey 1984	Knibbe 1996
Static work postures	No association	ð	ð	ð	Sedentary work and disc herniation for workers 35 years and older: 2.4, *p*=0.01; for those < 35 years, 0.81	ð	ð
Risk factors (combined)	ð	ð	ð	ð	Time sitting, >35 years old: 2.4 *p*=0.01; More than half time driving vs. herniation: 2.75, *p*=0.02; Truck driver vs. herniation: 4.67, Chi-sq.=5.88, *p*=0.02	Lifting >25 lb >5 times per day, and twisting the body half the time: 3.1 (1.3-7.5); Simultaneous lifting and twisting with straight knees: 6.1 (1.3-27.9)	Physically demanding work vs. lifetime LBP, prevalence: 87%; 1-year LBP, prevalence: 67%; 1-week LBP, prevalence: 21%; Prevalence of sick leave due to back pain in previous 3 months: 9.7%
Psychosocial factors	High stress and LBP: 1.6 (1.4-1.8); high anxiety: 1.3 (1.1-1.4).	ð	Blue collar workers were less satisfied with “influence on and control of work, supervisor climate, stimulus from work itself, and relations with fellow workers	In blue-collar workers, 10 of 15 psychosocial job factors sig; in white-collar workers, none of the five psychosocial factors sig	ð	ð	ð
Individual/other factors considered	Severe LBP related to smoking; construction tasks such as brick laying, carpentry, etc. did not affect LBP.	ð	Gastrointestinal problems: subway train operators vs. referents: 1.6 (1.1-2.5)	ð	ð	Carrying >11.3 kg, 5-25 per day: 2.1 (1.0-4.3) Carrying >11.3 kg , >25/day: 2.7 (1.2-5.8)	ð
Duration of employment	ð	ð	ð	ð	ð	ð	ð
Dose/response	ð	ð	ð	ð	ð	ð	ð

See footnotes at end of table.

(Continued)

Appendix C Table C-6. Summary table for evaluating back musculoskeletal disorders

Components of study	Leigh 1989	Liles 1984	Magnusson 1996	Magora 1972, 1973	Marras 1993, 1995	Masset 1994	Partridge 1968
Study type	CS	Cohort	CS	CS	CS	CS	CS
Participation rate $70%	Y	NR	NR	NR	NR	Y	Y
Outcome	S	Records	S	S	Records review	S	S and PE
Exposure	Questionnaire (job title)	Observation, use of records	Questionnaire, vibration measurements	Observation, interview, questionnaire	Observation, measurements	Interview, self-reports	Questionnaire, job title
Covariates considered	Gender, race, obesity, height, and repetitious work	ð	ð	ð	ð	Gender (males only), age (all participants younger than 40). General health status, social, demographic, psychologic factors	Age
Investigators blinded	NR	N	NR	NR	NR	NR	N
Heavy physical work	Self reporting: "Job requires a lot of physical effort": 1.5 (1.0-2.2)	ð	ð	ð	ð	No association	Combined
Lifting and forceful movements	ð	Injury rate for highest job severity index category vs lowest : 4.5	Heavy lifting: 1.86 (1.2-2.8) Frequent lifting: 1.55 (1.01-2.39)	1973: Sudden maximal efforts and LBP: 1.65 (1.3-2.1)	Combined	Heavy efforts of the shoulder, 1.62, *p*<0.01	ð
Awkward postures	ð	ð	ð	No association: highest rate of back pain found in the "rarely/never bend" category	ð	Univariate analysis showed trunk torsions associated with LBP in steel workers; no association seen in multivariate	ð
Whole body vibration	ð	ð	Bus and truck drivers compared to referents: 1.8 (1.2-2.8)	Bus drivers compared to bankers: 1.2 (0.8-1.7)	ð	Vehicle driving: 1.2 (*p*<0.001)	ð

See footnotes at end of table. (Continued)

Appendix C Table C-6. Summary table for evaluating back musculoskeletal disorders

Components of study	Leigh 1989	Liles 1984	Magnusson 1996	Magora 1972, 1973	Marras 1993, 1995	Masset 1994	Partridge 1968
Static work postures	ō	ō	ō	No association	ō	Seated posture: 1.5, *p*<0.09	ō
Risk factors (combined)	High vs. low physical demands: 1.68 (1.05-2.90)	ō	Driving: 1.79 (1.16-2.75) Vibration plus frequent lifting: 2.1 (0.8-5.7) Vibration plus heavy lifting: 2.06 (1.3-3.3)	Sudden maximal physical efforts; prolonged sitting or standing, inability to sit during the working day, and poor lifting technique related to LBP	Max. load moment, max. lateral velocity, ave. twisting velocity, lifting frequency, and max. sagital trunk angle related to high-risk LBP groups: 10.7(4.9-23.6)	ō	Rheumatic S: dockers vs. civil servants: 1.2 (0.98-1.64); LBP: dockers vs. civil servants: NS
Psychosocial factors	ō	ō	ō	ō	ō	Negative perception of the work environment: NS.	ō
Individual/other factors considered	Smoker vs. nonsmoker and LBP: 1.48 (1.0-2.19)	ō	ō	ō	Maximum load moment: 73.65 Nm vs. 23.64 Nm: 5.17, (3.19-8.38); Sagittal mean velocity: 11.74 degrees/sec. vs. 6.55 degrees/ sec: 3.33 (2.17-5.11); Max. weight: 104 N vs. 37 N: 3.17 (2.19-4.58)	Physical work load (no objective measurement) and repetition were NS. Final logistic model included "whole set of variables from general health status, social, demographic, and psychologic characteristics."	ō
Duration of employment	ō	ō	ō	ō	ō	ō	ō
Dose/response	ō	ō	ō	ō	ō	ō	ō

See footnotes at end of table.

(Continued)

Appendix C Table C-6. Summary table for evaluating back musculoskeletal disorders

Components of study	Punnett 1991	Riihimäki 1989a	Riihimäki 1989b	Riihimäki 1994; Pietri-Taleb 1995	Ryden 1989	Schibye 1995	Skov 1996
Study type	Case referent (retrospective)	CS mail survey	CS	Prospective	Case control	Cohort	CS
Participation rate $70%	Y	Y	Y	Y	Y	Y	N
Outcome	S and PE	S	X-ray confirmed	S	Records	S	S
Exposure	Observation and measurements, Videotape analysis	Job title and questionnaire	Questionnaire and job title	Postal questionnaire	Work injury reports and self-reports	Questionnaire	Questionnaire, self-reports
Covariates considered	Gender, age, length of employment, recreational activity, medical history, and maximum weight lifted in study job	Age, previous back accidents, awkward postures at work, and annual car driving	Age, self-reported back accidents, body mass index, height, and smoking	Age, gender (only males were studied, previous history of back accidents, mental distress, general state of health, smoking, lifestyle factors, education	Age	Subjects served as their own controls	Age, gender, height, weight, smoking, work-related psychosocial variables, lifting, leisure time sports activities
Investigators blinded	Y	NR	Y	NR	NR	NR	NR
Heavy physical work	ð	Combined	ð	ð	Combined	ð	ð
Lifting and forceful movements	Lift 44.5 N: 2.16 (1.0-4.7)	ð	ð	ð	ð	ð	ð
Awkward postures	Time in non-neutral postures, mild or severe bending: 8.09 (1.4-44)	Sciatica and twisted or bent postures: 1.5 (1.2-1.9)	ð	Association found between twisted and bent postures with sciatica in univariate, but not multivariate analysis	ð	ð	ð

See footnotes at end of table.

(Continued)

Appendix C Table C-6. Summary table for evaluating back musculoskeletal disorders

Components of study	Punnett 1991	Riihimäki 1989a	Riihimäki 1989b	Riihimäki 1994; Pietri-Taleb 1995	Ryden 1989	Schibye 1995	Skov 1996
Whole body vibration	ŏ	Longshoremen and earthmovers compared to referents: 1.3 (1.1-1.7)	ŏ	No association	ŏ	ŏ	In Danish salespeople, the annual driving distance for highest category: 2.8 (1.5-5.1)
Static work postures	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	Sedentary work (% of worktime): 2.45 (1.2-4.9)
Risk factors (combined)	Time in non-neutral posture: 8.09 (1.5-44.0)	Sciatic pain and machine operators: 1.3 (1.1-1.7) Sciatic pain and carpenters: 1.0 (0.8-1.3)	Concrete vs. painting work and disc space narrowing: 1.8 (1.2-2.5); Spondylophytes: 1.6 (1.2-2.3)	Machine operators vs. office workers: 1.4 (0.99-1.87); carpenters vs. office workers: 1.5 (1.1-2.1)	Job title or shifts requiring heaviest physical efforts: 2.2 (1.28-3.89)	No sig differences in back pain in garment workers versus other employment group upon follow-up	Annual driving distance: 2.79 (1.5-5.1)
Psychosocial factors	ŏ	ŏ	ŏ	Monotonous work, problems with co-workers or supervisors, and high paced work were NS.	ŏ	ŏ	ŏ
Individual / other factors considered	Age: 0.96 (0.09-1.0) back injury: 2.37 (1.3-4.3)	ŏ	Age and disc space narrowing: 6.5 (1.7-26.0) Spondylophytes: 14.9 (2.3-95.0)	Physical exercise >1 time per week vs. 1 time per week: 1.26 (1.0-1.6) Smokers vs. non-smokers: 1.29 (0.98-1.7) Severe back pain and later sciatica: 4.5 (2.7-7.6)	Previous back injury: 2.13 (1.07-4.24); Working day shift: 2.23 (1.28-3.89); Self-reported LBP: 1.25 (1.25-4.12); Self-reported slipped disc: 6.20 (2.64-14.57)	Of 82 workers with another job in 1991, 20% reported MSDs a s the reason for change.	ŏ
Duration of employment	Analysis controlled for length of employment.	ŏ	ŏ	ŏ	ŏ	Sig	ŏ
Dose/response	A strong trend found for increasing length of exposure and risk of back disorders to both mild and severe trunk flexion.	Dose/response is observed for twisted or bent postures (see above)	ŏ	ŏ	ŏ	ŏ	Dose/response is observed for annual driving and sedentary work (see above)

See footnotes at end of table. (Continued)

Appendix C Table C-6. Summary table for evaluating back musculoskeletal disorders

Components of study	Skovron 1994	Svensson 1989	Toroptsova 1995	Undeutsch 1982	Videman 1984	Videman 1990	Walsh 1989
Study type	CS	CS (retrospective)	CS	CS	CS	CS and lab study	CS
Participation rate $70%	Y	Y	Y	NR	Y	NR	Y
Outcome	S	S	S; then S and PE	S and PE (Clinical orthopaedic exam given to 134 of the 366 subjects)	S	X-ray confirmed	S
Exposure	Interview	Questionnaire	Interview	Interview and questionnaire	Postal questionnaire	Questionnaire, Reports from family members	Postal questionnaire
Covariates considered	Age and gender	Age, gender (only females studied), level of education, psychosocial factors, work breaks, demand on concentration	Analysis did not control for confounders	Age, height, weight, nationality, years of experience in transport work	Age, gender (only females studied), menstruation, pregnancy, exercise	Age, gender (only male cadavers used) physical exercise, heaviness of occupation	Age, year of onset of symptoms, gender
Investigators blinded	NR	NR	NR	NR	NR	NR	NR
Heavy physical work	õ	No association	õ	õ	Sig. difference in heavy occupational workload category among ages 20-29 year olds but not other age groups: 1.1	Heavy vs. mixed work: 2.8 (0.3-23.7) Heaviest work category: 12.1 (1.4-107)	õ
Lifting and forceful movements	õ	Lifetime incidence of LBP and Lifting: 1.2, *p*<0.01 found in univariate analysis but not in multivariate analysis	Frequent lifting and LBP: 1.43, *p*<0.05	Combined	No association - no sig difference between qualified nurses and nursing aides	õ	Lifting in jobs just prior to injury: 2.0 (1.1-3.7)
Awkward postures	õ	LBP and bending forward: 1.3, *p*<0.05 in univariate; not sig in multivariate analysis	Trunk flexion and LBP: 1.7 *p*<0.01	õ	õ	õ	õ

See footnotes at end of table. (Continued)

Appendix C Table C-6. Summary table for evaluating back musculoskeletal disorders

Components of study	Skovron 1994	Svensson 1989	Toroptsova 1995	Undeutsch 1982	Videman 1984	Videman 1990	Walsh 1989
Whole body vibration	ŏ	ŏ	No association	ŏ	Combined	ŏ	Driving on job held prior to symptoms in males: 1.7 (1.0-2.9)
Static work postures	ŏ	"Standing" associated with LBP: 1.3 in univariate analysis, not sig in multivariate	No association	ŏ	ŏ	Sedentary work and disc degeneration: 24.6 (1.5-409)	Sitting and LBP: females: 1.7 (1.1-2.6)
Risk factors (combined)	Occupation: NS	ŏ	ŏ	In workers with present S, they occurred most frequently while lifting loads and while in bended postures: no risk estimate	ŏ	Driving vs. Mixed work: 2.3 (0.8-6.2)	Driving and LBP: males: 1.7 (1.0-2.9)
Psychosocial factors	Work dissatisfaction: 2.4, *p*=0.02	LBP and worry and fatigue at end of work day: *p*<0.0001 Dissatisfaction with work tasks: *p*<0.05	ŏ	ŏ	ŏ	ŏ	ŏ
Individual / other factors considered	Female gender: 2.16, *p*=0.001; increasing age: 2.0, *p*=0.001	LBP and standing: *p*<0.01	NS for sitting, standing, walking, or repetitive work	Current back S positively correlated with height and age.	ŏ	ŏ	
Duration of employment	ŏ	ŏ	ŏ	Current back S positively correlated with length of experience in transport work.	ŏ	ŏ	ŏ
Dose/response	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ

ŏ Not studied.
ADL Activities of daily living.
CS Cross-sectional.
F Force.
Hrs Hours.
LBP Low-back disorders.
LBP Low-back pain.
LBS Low-back symptoms.
MMPI Minnesota Multiphasic Personality Inventory.
MS Musculoskeletal.
N No.
NHANES National Health and Nutrition Examination Survey.
NR Not reported.
NS Not statistically significant.
OWAS OVAKO working posture analysis system.
PE Physical examination.
R Repetition.
S Symptoms.
Sig. Statistically significant.
WBV Whole body vibration.
Y Considered (yes).