Scand J Work Environ Health 1997;23(4):243-256

<https://doi.org/10.5271/sjweh.217>

Issue date: Aug 1997

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The following articles refer to this text: [2001;27\(2\):125-132](#); [2001;27\(4\):258-267](#); [2001;27\(5\):346-352](#); [2001;27\(6\):373-380](#); [2001;27\(6\):388-394](#); [2002;28\(3\):168-175](#); [2002;28\(5\):293-303](#); [2002;28\(5\):304-313](#); [2002;28\(5\):314-323](#); [2003;29\(6\):431-440](#); [2004;30\(1\):56-63](#); [2004;30\(4\):261-278](#); [2008;34\(5\):364-373](#); [2009;35\(1\):80](#); [2009;35\(6\):429-436](#); [2016;42\(2\):125-134](#); [2019;45\(2\):146-157](#); [2020;46\(1\):1-4](#); [2021;47\(4\):277-286](#)

Key terms: [epidemiology](#); [lifting](#); [postural load](#); [review](#); [vibration](#)

This article in PubMed: www.ncbi.nlm.nih.gov/pubmed/9322815

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Positive and negative evidence of risk factors for back disorders

by Alex Burdorf, PhD,^{1,2} Gary Sorock, PhD¹

Burdorf A, Sorock G. Positive and negative evidence of risk factors for back disorders. *Scand J Work Environ Health* 1997;23(4):243—56.

The scientific literature on work-related back disorders was reviewed to identify consistent risk factors and to determine the strength of the association between the two. Thirty-five publications were selected with quantitative information. Lifting or carrying loads, whole-body vibration, and frequent bending and twisting proved to be the physical load risk factors consistently associated with work-related back disorders. Job dissatisfaction and low job decision latitude proved to be important, but the evidence was not consistent across different studies and study designs. The epidemiologic studies illustrated the importance of several confounders, especially age, smoking habits, and education. In this review, gender, height, weight, exercise, and marital status were consistently not associated with back disorders in occupational populations.

Key terms epidemiology, lifting, postural load, review, vibration.

For several decades back disorders have been recognized as a major cause of sickness absence and disability among many occupational populations. With advancing mechanization and automation it was thought that its occurrence would decline. In general, this has not been the case, and in most occupations back disorders are still a primary cause of disability (1, 2). In spite of the large number of epidemiologic studies in the past 2 decades, the etiology and risk factors of work-related back disorders are not well understood (3). Quantitative guidelines for physical load at work have been derived from experimental studies with outcome variables such as performance, oxygen consumption, fatigue, and several physiological parameters (4—6). However, these guidelines are based on short-term physiological, biomechanical, and psychophysical responses to physical load experienced during a limited period. There is little, if any, epidemiologic evidence to support or refute the appropriateness of these guidelines to prevent the development of back disorders in occupational populations. To date, epidemiologic studies have shown disappointing progress in validating the contribution of the factors well-established in experimental research (7).

In the process of unraveling the multifactorial etiology of back disorders and the specific contribution of work-related risk factors, epidemiologic surveys have

identified various individual, psychosocial, and physical factors (8—14). Contradictory observations have been reported for most risk factors. An important reason for the current confusion is that many studies have estimated risk factors by job title only and, hence, presented crude associations between risk factors and back disorders (15, 16). These studies do not allow quantitative exposure-response relationships to be established and are of little avail to the prevention of back disorders. The overall picture is also blurred because most epidemiologic studies are dominated by the role of a limited number of risk factors, whereas only a few studies take into consideration all the relevant factors that have previously been studied (17).

In this article the epidemiologic data accumulated on work-related risk factors for back disorders over the past 15 years have been reviewed. The aim is to clarify to some extent the controversy as to which risk factors are important. While various review articles on work-related risk factors and back disorders have been published (2, 8—14, 17), few have presented quantitative information on the strength of associations and the consistency of findings in various study designs concerning potential risk factors. This review evaluates publications that have provided quantitative information on relationships between work-related risk factors and back disorders. The

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evaluation takes into account "positive", "inconclusive", and "negative" studies in order to identify the risk factors that are consistently shown to be associated with back disorders and those consistently shown not to be predictors. To further the discussion of the likelihood of causal inferences, the evidence presented in the epidemiologic literature is summarized by the range of risk estimates of work-related risk factors, their corresponding 95% confidence intervals, and the proportion of back disorders that was attributable to these risk factors. In addition, it is determined whether contradictory observations can be explained by study characteristics, potential bias, or possible artifacts. The primary goal of this review is to identify the important risk factors for work-related back disorders, to present information on the strength of the associations, and to estimate their relative contribution to the occurrence of back disorders in occupational populations.

Selection of references

An extensive search of the available literature was made for epidemiologic studies published from January 1980 to June 1996. Several strategies were undertaken to identify as many relevant articles as possible. Searches were carried out on computer-based bibliographic data bases such as MEDLINE (National Library of Medicine, United States), NIOSHTIC (National Institute for Occupational Safety and Health, United States), HSELINE (Health and Safety Executive, United Kingdom), CISDOC (International Labour Organisation, Switzerland) and Ergoweb (homepage of University of Utah on the Internet). In addition, scientific journals which regularly pay attention to the epidemiology of musculoskeletal disorders were manually searched. Review articles were checked for useful references (8—14). All possible articles were collected, except those published in foreign journals that were not available through university libraries. The initial selection criterion was that the articles should describe the occurrence of back disorders in occupational groups or relate the occurrence of back disorders in community-based populations to specific work conditions. Altogether 140 articles were eligible for inclusion and subsequently scrutinized for available information, methodological quality, and the interpretation of exposure and outcome measures.

Three exclusion criteria were used to limit the selection to studies with quantitative information on associations between work-related risk factors and back disorders. The first exclusion criterion pertained to lack of quantitative information on work-related risk factors (ie, a clear description of how the risk factors were measured at least at the ordinal level) was needed for inclusion. According to this criterion, 68 of 140 (49%) articles were excluded. Of these 68 studies, 47 publications only mentioned occupations or job titles, 7 articles applied

expert assessments to determine the presence of risk factors in jobs without presenting clear information on the assessment procedure, 5 studies lacked a clear definition of exposure to the risk factor, and 9 studies did not adequately describe exposure conditions among the compared groups. The second criterion excluded 30 (21%) articles that did not contain a suitable risk estimate for work-related risk factors or sufficient information that allowed the calculation of a risk estimate. Thus 14 studies were excluded in which the exposure information was not directly linked to the population under study, 7 studies used composite scores to combine work-related risk factors or health outcomes, and 9 studies applied statistical techniques not suitable to derive risk estimates such as the odds ratio or relative risk. The third exclusion criterion was used to eliminate 7 (5%) articles with serious methodological concerns in relation to the particular purpose of this review. Four studies of subjects drawn from populations in hospitals or family practices were not included because of potential selection bias (18—21). In these studies, if the subjects selected were more likely to be severely injured than workers in their regular work environment, then true effects of the work-related risk factors for back disorders may have been masked or inflated. One study was not included because it had a participation rate below 50% (22). Two studies were excluded because the incidence of back pain was estimated by the recall of back pain episodes up to 20 years in the past (23, 24).

Thus there remained 35 (25%) publications that met our selection criteria. These articles (25—59) formed the basis for our detailed review of the associations between work-related risk factors and the occurrence of back disorders.

Analysis and presentation of risk estimates

On the basis of 5 authoritative review articles, the following list was drawn up of possible work-related risk factors and important individual characteristics (8, 10—13):

1. Physical factors at work
 - A. Manual materials handling
 - B. Frequent bending and twisting
 - C. Heavy physical load
 - D. Static work posture
 - E. Repetitive movements
 - F. Whole-body vibration
2. Psychological factors at work
 - A. Mental stress
 - B. Job dissatisfaction
 - C. Work pace
 - D. Low job support
 - E. Low job decision latitude or monotonous work

3. Individual characteristics

- A. Age
- B. Gender
- C. Height
- D. Weight
- E. Smoking
- F. Exercise or sport
- G. Marital status
- H. Education

This list was used to identify the associations between work-related risk factors and back disorders and to evaluate whether the associations were adjusted for relevant individual characteristics of the subjects under study.

The analysis focused on associations expressed by risk estimates such as the odds ratio and the relative risk. Whenever possible, the risk estimate was retrieved from the original article, together with the variables that were adjusted for in the statistical analysis. The risk estimates from the original articles are used throughout the tables. In several publications this information was not presented, but for all studies that provided sufficient raw data for 2×2 tables, odds ratios or relative risks were calculated with 95% confidence intervals. In cross-sectional studies the prevalence odds ratio overestimates the true risk when the prevalence of disease is rather high (60). Since this condition is particularly true in studies on back disorders, when possible and appropriate, the raw data were reanalyzed in contingency tables to calculate the prevalence rate ratio. Subsequently, the relative risk of the longitudinal studies and the prevalence rate ratio of the cross-sectional surveys were used to calculate the attributable fraction (AF_e). The attributable fraction is the proportion by which the rate of the outcome among the exposed would be reduced if the exposure were eliminated (61). This fraction is calculated as the ratio of $RR - 1$ over RR , where RR is the relative risk or the prevalence rate ratio. The attributable fraction was not calculated for case-referent studies since the study design did not permit rate ratio calculations. The reader should keep in mind that, in the tables summarizing the findings of the epidemiologic studies, the risk estimate refers to the original estimate presented and the attributable fraction refers to the recalculated rate ratio.

In this review, 3 types of statistical associations have been distinguished (61). The association is described as positive when the occurrence of back disorders is statistically associated with higher values of the risk factor. In a negative association, a higher value of the risk factor is statistically associated with a lower occurrence of back disorders. In null associations, the risk estimate does not differ statistically from unity. The null associations were further evaluated as to whether the results actually suggest the absence of an effect or whether the studies are inconclusive due to lack of information (62).

Findings from epidemiologic studies

Table 1 summarizes the work-related risk factors and individual characteristics investigated for the 35 publications selected in this review (25–49). These publications comprise 36 epidemiologic studies since 1 publication was both cross-sectional and longitudinal (47). Division by study design showed that 20 (55%) were cross-sectional surveys among occupational populations, 8 (22%) were cross-sectional community-based studies, 6 (17%) were longitudinal studies among workers, and 2 (6%) had a case-referent design. Tables 2 to 5 present the basic characteristics of these studies and the risk estimates of the significant associations between work-related risk factors and back disorders. One cross-sectional survey (37) and 1 longitudinal study (50) are not included in these tables since none of the evaluated work-related factors were associated with back disorders. The results of all the selected studies are reviewed in the following sections.

Manual materials handling

The importance of lifting and other forceful movements has been demonstrated by various authors. Independent of study design, 16 of 19 studies reported a positive association between back disorders and the lifting or carrying of loads (table 1). The risk estimates varied from 1.12 to 3.07 with attributable fractions between 11% and 54%. The 2 highest odds ratios were associated with heavy lifting among miners (36) and firefighters (46). The 6 studies among nurses illustrated that the lifting of patients is an important risk factor for back disorders. Handling 1 or 2 patients per shift resulted in a significantly increased odds ratio of 1.40 for low-back pain in the past year (45, 54) and of 2.19 for a back injury claim (58). Arad et al (25) showed a trend in 1-month prevalence rates of low-back pain for nurses with increasing numbers of patient lifts per shift. A corresponding effect was observed among French nurses for low-back pain and a lifting index comprising several lifting, pushing, and pulling movements (45).

Three studies found no relationship with regard to the effect of lifting activities on back disorders. A community-based survey among working women reported an elevated odds ratio of 1.23 that failed to reach statistical significance for low-back pain (57). A cross-sectional study among concrete workers found no association between the duration of lifting loads over 10 kg during work and the prevalence of back pain in the past 12 months, but there was very little contrast in exposure among the occupational groups (33). In a longitudinal study among commercial travelers no influence of frequent load carrying was observed for self-reported back pain, whereas the cross-sectional analysis at the start of the study demonstrated a positive association (47).

Table 1. Epidemiologic studies with positive, null, and negative associations between risk factors and back disorders.^a

Risk factor ^b	Positive association	Null association	Negative association
1. Physical risk factors of work			
A. Manual materials handling (N = 19)	25, 35, 36, 39, 43, 44, 45, 46, 47, 48, 51, 54, 55, 56, 58, 59	33, 47, 57	—
B. Frequent bending and twisting (N = 10)	31, 32, 33, 39, 43, 48, 49, 51, 58	50	—
C. Heavy physical load (N = 7)	35, 38, 40, 42, 46, 56	26	—
D. Static work posture (N = 7)	34, 47, 52	39, 43, 47, 57	—
E. Repetitive movements (N = 3)	51	42, 57	—
F. Whole-body vibration (N = 13)	27, 28, 29, 30, 31, 32, 33, 41, 43, 44, 47, 51	50	—
2. Psychological risk factors of work			
A. Mental stress (N = 5)	38, 39, 54	51, 57	—
B. Job dissatisfaction (N = 7)	26, 39, 53, 56, 57	44, 46	—
C. High work pace (N = 4)	40	37, 50, 51	—
D. Lack of job support (N = 2)	—	39, 50	—
E. Low job decision latitude or monotonous work (N = 7)	39, 40, 51, 56, 57	37, 50	—
3. Individual risk factors			
A. Age (N = 30)	27, 30, 31, 38, 39, 40, 43, 47, 49, 51, 53, 57	26, 28, 32, 33, 34, 35, 39, 42, 45, 47, 48, 50, 58, 59	25, 27, 29
B. Gender (N = 9)	40, 53	26, 38, 42, 43, 47, 51, 58	—
C. Height (N = 12)	38, 54	27, 28, 33, 34, 38, 39, 42, 45, 47, 51	—
D. Weight (N = 18)	43	27, 29, 31, 32, 33, 34, 35, 38, 39, 42, 44, 45, 46, 47, 51, 58, 59	—
E. Smoking (N = 15)	38, 39, 42, 43, 47	25, 31, 32, 38, 39, 44, 46, 47, 50, 51, 54	—
F. Exercise or sport (N = 14)	45, 50	25, 32, 35, 39, 40, 44, 48, 49, 51, 54	31, 46
G. Unmarried (N = 7)	—	25, 26, 31, 44, 46, 47, 58	—
H. Low education (N = 11)	31, 32, 40, 42, 43	26, 32, 46, 47, 50, 51, 57	—

^a The numbers in this table are reference numbers, some publications present associations for several health outcomes.

^b N = number of studies.

Frequent bending and twisting

Ten studies have focused on the association between back pain and postural load due to frequent bending and twisting of the trunk. Nine studies reported positive associations, and the observed risk estimates ranged from 1.29 to 2.80 with an outlier of 8.09. The latter risk estimate was derived from a case-referent study that extrapolated the risk from 0% to 100% trunk flexion or rotation or both, while adjusting for lifting activities. This study showed that the risk of back disorders increased with exposure to multiple awkward back postures and increasing duration of exposure. It was also able to disentangle the separate effects of bending and twisting, illustrating that both mild flexion and twists had an odds ratio of about 2.3 (48). Two other studies among tractor drivers and concrete workers also reported dose-response relationships for duration of worktime in awkward postures with the prevalence of back pain (31, 33). Riihimäki et al (49) confirmed the association between sciatic pain and trunk flexion or rotation among office workers whose work rarely involved lifting. In the 3-year follow-up of office workers, machine operators, and carpenters the average duration of trunk flexion or rotation per shift was significantly associated with the incidence of sciatica, but this association was not statistically significant when adjusted for occupation, smoking, history of back pain, and physical exercise (50).

Heavy physical load

Seven studies dealt with heavy physical work and back disorders. Four cross-sectional community-based studies demonstrated increased risks of 1.54 — 2.58 with associated attributable fractions between 31% and 58% (38, 40, 42, 56). In these studies, heavy physical load was assessed as a dichotomous variable in a self-administered questionnaire. A cross-sectional survey among nurses found an odds ratio of 2.07 for high physical load, expressed by prolonged standing, frequent bending, and other awkward postures. This risk estimate was adjusted for manual materials handling (35). In a case-referent study among fire fighters, physical exertion during work was strongly associated with a back injury claim (46). A large longitudinal study failed to demonstrate an association between physical load and the incidence of back injury claims during the follow-up period (26).

Static work posture

The importance of changes in work posture has been stressed by several authors in recent years (8, 13). Prolonged sedentary postures have been positively associated with low-back pain among dentists and crane operators (34, 52), but this association was not confirmed in other studies (39, 43, 50, 57). Similar contradictory observations have been reported on the duration of standing on the job (47). In a community-based study among

Table 2. Significant associations between work-related risk factors and the occurrence of back disorders in cross-sectional epidemiologic studies among occupational populations. (OR = odds ratio, 95% CI = 95% confidence interval, AF_e = attributable fraction exposed, F = female, M = male)

Authors	Study population	Back disorders	Work-related risk factor	OR	95% CI	AF _e	Adjustments ^a
Arad & Ryan, 1986 (25)	831 nurses (F)	Low-back pain in past month (42%)	Lifts per shift (> 6 versus less)	2.47	1.78—3.42	41%	None
Bongers et al, 1990 (27)	133 helicopter pilots and 228 nonflying officers (M)	Regularly experienced low-back pain (55% and 11%)	Whole-body vibration ($a_z > 0.5 \text{ m/s}^2$)	9.00	4.90—16.40	80%	1B, 3A, 3C, 3D
Boshuizen et al, 1992 (29)	242 drivers and 210 operators (M)	Low-back pain in past 12 months (51% and 42%)	Whole-body vibration ($a_z > 0.5 \text{ m/s}^2$)	1.73	1.06—2.81	18%	3A
Boshuizen et al, 1990 (28)	450 tractor drivers and 110 agriculture workers (M)	Regularly experienced low-back pain (31% and 19%)	Whole-body vibration ($a_z > 0.3 \text{ m/s}^2$)	1.93	1.12—3.35	39%	1B, 3A, 3C, 3D
Bovenzi & Zadini, 1992 (32)	234 bus drivers and 125 maintenance workers (M)	Low-back pain in past 12 months (83% and 66%)	Whole-body vibration ($a_z > 0.6 \text{ m/s}^2$)	3.62	1.60—8.22	..	1B, 3A, 3C, 3D, 3E, 3F, 3H
			Awkward posture (frequent)	2.29	1.22—4.29	..	1F, 3A, 3C, 3D, 3E, 3F, 3H
Bovenzi & Betta, 1994 (31)	1155 tractor drivers and 220 office workers (M)	Low-back pain in past 12 months (67% and 35%)	Whole-body vibration ($a_z > 0.5 \text{ m/s}^2$)	1.56	1.02—2.41	..	1B, 2A, 3A, 3C—3H
			Awkward posture (hard)	2.03	1.16—3.54	..	1F, 2A, 3A, 3C—3H
Burdorf et al, 1991 (33)	114 concrete workers and 52 maintenance workers (M)	Low-back pain in past 12 months (59% and 31%)	Bends and twists (37% versus 27%)	2.80	1.31—6.01	30%	3A
			Whole-body vibration (yes/no)	3.06	1.26—7.45	..	3A
Burdorf et al, 1993 (34)	94 crane operators and 86 office workers (M)	Low-back pain in past 12 months (50% and 34%)	Static sedentary posture (yes/no)	3.29	1.52—7.12	32%	3A
Estryn-Behar et al, 1990 (35)	1505 nurses (F)	Low-back pain in past 12 months (47%)	Postural load (high versus low)	2.07	..	39%	1A, 3A, 3D
			Manual materials handling (high versus low)	2.00	..	38%	1B, 3A, 3D
Gilad & Kirschenbaum, 1986 (36)	250 mine workers (M)	Back pain in past 12 months (59%)	Lifting (frequent versus never)	3.06	1.11—8.67	35%	None
Holmström et al, 1992 (39)	1772 construction workers (M)	Low-back pain in past 12 months (54%)	Manual materials handling (every 5 min versus less)	1.12	1.01—1.25	11%	3A
			Daily stooping (> 4 h versus < 1 h)	1.29	1.10—1.50	22%	3A
			Mental stress (high versus low)	1.30	1.20—1.60	23%	3A
			Job dissatisfaction	1.43	1.11—1.67	30%	3A
			Low job discretion	1.25	1.11—1.43	20%	3A
Johanning, 1991 (41)	492 subway train operators and 92 control tower operators	Sciatica in past 12 months (22% and 8%)	Whole-body vibration ($a_z > 0.4 \text{ m/s}^2$)	3.90	1.70—8.60	65%	3A, 3B
Magnusson et al, 1996 (44)	228 drivers and 137 sedentary workers (M)	Low-back pain in past 12 months (58% and 42%)	Whole-body vibration (yes/no)	1.79	1.16—2.75	27%	None
			Lifting (frequent versus none)	1.55	1.01—2.39	..	None
Mandel & Lohman, 1987 (45)	428 nurses (F)	Low-back pain in past 12 months (42%)	Lifting (> 10 patients per week)	1.39	1.05—1.84	23%	3F
Pietri et al, 1992 (47)	1709 commercial travelers (M & F)	Low-back pain in past 12 months (27%)	Whole-body vibration (> 20 h versus < 10 h)	2.0	1.3—3.1	39%	3A, 3B, 3E
			Frequent load carrying	1.3	1.0—1.7	22%	3A, 3B, 3E
			Prolonged standing (yes/no)	1.3	1.0—1.6	14%	3A, 3B, 3E
Riihimäki et al, 1989 (49)	852 machine operators, 696 carpenters, 674 office clerks	Sciatica in past 12 months (34%, 29% and 19%)	Bending and twisting (rather much versus rather little)	1.5	1.2—1.9	..	3A
Shugars et al, 1984 (52)	487 dentists (M & F)	Low-back pain (54%)	Sitting (> 80% versus < 80%)	1.71	1.04—2.81	22%	None
Smedley et al, 1995 (54)	1616 nurses (F)	Low-back pain in past 12 months (45%)	Mental stress (frequent)	2.08	1.59—2.72	30%	None
Wells et al, 1983 (59)	196 letter carriers, 76 meter readers, 127 clerks (M)	Significant back pain (28%, 21% and 11%)	Lifting (> 1 patient per day)	1.4	1.1—1.6	19%	2A, 3A, 3C
			Carrying weight (yes/no)	2.19	1.30—3.72	46%	None

^a For the identification of the covariates, see table 1.

women the explicit question on regular change in posture was not related to low-back pain in the past month (57).

Repetitive movements

Repetitive work was investigated in 3 community-based studies. Two studies found no association with back pain

Table 3. Significant associations between work-related risk factors and the occurrence of back disorders in cross-sectional community-based epidemiologic studies. (OR = odds ratio, 95% CI = 95% confidence interval, AF_e = attributable fraction exposed)

Authors	Study population	Back disorders	Work-related risk factor	OR	95% CI	AF _e	Adjustments ^a
Heliövaara et al, 1991 (38)	2946 Finnish women and 2727 Finnish men	Medically diagnosed low-back pain (12% and 12%) Medically diagnosed sciatica (5% and 6%)	Physical load (yes/no)	2.58	2.10—3.16	56%	2A, 3A, 3B, 3C, 3D, 3E
			Mental stress (yes/no)	1.57	1.28—1.94	33%	1C, 3A, 3B, 3C, 3D, 3E
			Physical load (yes/no)	2.48	1.82—3.37	58%	2A, 3A, 3B, 3C, 3D, 3E
			Mental stress (yes/no)	1.84	1.36—2.49	44%	1C, 3A, 3B, 3C, 3D, 3E
Houtman et al, 1994 (40)	5865 Dutch workers (M & F)	Back complaints (25%)	Heavy physical load (yes/no)	1.62	1.36—1.91	..	2C, 2E, 3A, 3B, 3H
			Work pace (yes/no)	1.21	1.06—1.39	..	1C, 2E, 3A, 3B, 3H
			Monotonous work (yes/no)	1.35	1.10—1.64	..	1C, 2C, 3A, 3B, 3H
Leigh & Sheetz, 1989 (42)	1414 American workers (M & F)	Back pain in past 12 months (20%)	Heavy physical load (yes/no)	1.68	1.05—2.90	37%	1E, 3B, 3C, 3D, 3E, 3H
Liira et al, 1996 (43)	8020 Canadian blue-collar workers (M & F)	Long-term back problems (8.4%)	Bends & lifts (> 50 times/day)	1.65	1.25—2.18	39%	3A, 3B, 3E
			Frequent lifts (< 50 lb; 19.68 kg)	1.46	1.12—1.89	32%	3A, 3B, 3E
			Whole-body vibration (yes/no)	1.84	1.25—2.72	46%	3A, 3B, 3E
			Awkward back posture	2.33	1.72—3.15	57%	3A, 3B, 3E
Saraste & Hultman, 1987 (51)	2872 Swedish women and men	Low-back pain (36%)	Bends & twist (always/no)	2.59	2.06—3.27	56%	None
			Daily heavy lifting (yes/no)	1.89	1.56—2.30	40%	None
			Whole-body vibration (yes/no)	2.14	1.31—3.52	52%	None
			Repetitive work (always/no)	1.97	1.63—2.38	41%	None
Skovron et al, 1994 (53)	1865 Belgian workers (M & F)	Low-back pain ever (57%)	Job dissatisfaction (yes/no)	2.40	1.13—5.10	..	3A, 3B
Svensson & Andersson, 1983 (56)	940 Swedish men 40—47 years	Low-back pain in past month (31%)	Frequent lifting (yes/no)	1.70	1.12—2.58	36%	None
			Heavy physical load (yes/no)	1.54	1.00—2.40	31%	None
			Job dissatisfaction (yes/no)	1.97	1.22—3.19	38%	None
			Monotonous work (yes/no)	2.34	1.22—4.46	44%	None
Svensson & Andersson, 1989 (57)	1410 Swedish women	Low-back pain in past month (35%)	Regularly bending (yes/no)	1.37	1.06—1.77	21%	None
			Job dissatisfaction (yes/no)	1.39	1.06—1.82	21%	None
			Monotonous work (yes/no)	1.67	1.12—2.50	31%	None

^a For the identification of the covariates, see table 1.**Table 4.** Significant associations between work-related risk factors and the occurrence of back disorders in longitudinal epidemiologic studies among occupational populations. (OR = odds ratio, 95% CI = 95% confidence interval, AF_e = attributable fraction exposed)

Authors	Study population	Back disorders	Work-related risk factor	OR	95% CI	AF _e	Adjustments ^a
Bigos et al, 1991 (26)	3020 aircraft workers (M & F)	Low-back pain claim (2.9% per year)	Job dissatisfaction	1.70	1.31—2.21	41%	None
Boshuizen et al, 1990 (30)	789 tractor drivers (M)	Sickness absence > 28 days due to back disorders due to intervertebral disc	Whole-body vibration (a _z > 0.4 m/s ²)	1.47	1.04—2.10	32%	3A
			Whole-body vibration (a _z > 0.4 m/s ²)	3.10	1.16—8.30	68%	3A
Pietri et al, 1992 (47)	601 commercial travelers	Low-back pain incidence (13% per year)	Whole-body vibration (> 20 h versus < 10 h)	3.28	1.03—10.49	70%	3A, 3B, 3E
Stobbe et al, 1988 (55)	415 nurses (F)	Back pain claim (5.2% per year)	Lifting (> 5 patients versus < 2)	2.16	1.12—4.19	54%	None
Venning et al, 1987 (58)	4306 nurses (M & F)	Back pain claim (2.8% per year)	Lifting (≥ 1 patient versus 0)	2.19	..	54%	None

^a For the identification of the covariates, see table 1.**Table 5.** Significant associations between work-related risk factors and the occurrence of back disorders, expressed by odds ratio, in case-referent epidemiologic studies among occupational populations. (OR = odds ratio, 95% CI = 95% confidence interval, AF_e = attributable fraction of exposed)

Authors	Study population	Back disorders	Work-related risk factor	OR	95% CI	AF _e	Adjustments ^a
Nuwayhid et al, 1993 (46)	115 fire fighters Referents: 109 fire fighters	Low-back pain claim	Physical exertion on job	3.71	1.94—7.10	..	None
			Lifting (> 18 kg versus less)	3.07	1.19—7.88	..	None
Punnett et al, 1991 (48)	95 assembly workers Referents: 124 assembly workers	Low-back pain, medical consultation	Bends & twist (100% versus 0%)	8.09	1.5—44.0	..	1A, 3A
			Lifting (> 44.5 N per minute)	2.16	1.0—4.7	..	1B, 3A

^a For the identification of the covariates, see table 1.

(42, 57), whereas 1 study reported an odds ratio of 1.97 that was close to the risk of daily heavy lifting (51). In none of the cross-sectional studies was the influence of repetition of movements addressed.

Whole-body vibration

The influence of daily exposure to whole-body vibration on the occurrence of back disorders has been investigated in a broad variety of occupational groups, including bus and truck drivers, tractor operators, train personnel, and helicopter pilots. The 13 studies on whole-body vibration consistently showed positive significant associations with back disorders, whether studying particular occupational groups or sampling the general population. Only 1 longitudinal study on sciatica among Finnish workers failed to show a statistically significant effect for whole-body vibration in the multivariate analysis (50). In the other studies, the risk estimates varied from 1.47 to 9.00 with attributable fractions between 18% and 80%. The highest risk estimate was found for helicopter pilots compared with nonflying officers. This estimate was adjusted for age, experienced mental stress, and reported time sitting in a twisted posture (27). Three other studies presented significantly increased odds ratios for whole-body vibration after adjustment for postural load on the back due to frequent bending and twisting (28, 31, 32). In several studies dose-response relationships were presented with dose expressed by duration of exposure (27, 28, 32, 47), cumulative vibration dose (27, 28, 30–32), or average intensity of vibration (32).

Psychological risk factors

The number of epidemiologic studies that have addressed work-related psychological risk factors is considerably smaller than the numbers on relationships between physical load and back disorders. However, in the community-based studies there appeared to be equal attention to physical and psychological risk factors at work. The psychological factors that have received the most attention are perceived mental stress, job dissatisfaction, and monotony at work. Increased mental stress was related to back complaints among construction workers (39) and nurses (54) and to medically diagnosed low-back pain in the Finnish work force (38). In the latter study, the risk estimate was adjusted for self-reported postural load, age, gender, anthropometry, and smoking.

Low job satisfaction was suggested to be associated with back complaints (39, 53, 56, 57) in the cross-sectional studies although null associations were found in surveys among professional drivers and firefighters (44, 46). In a prospective study among aircraft workers, the employee's job dissatisfaction was found to be the strongest predictor of subsequent back injury, with a relative risk of 1.70 and an attributable fraction of 41%.

In this study, physical demands at work were not associated, but the assessment of physical load at work was performed without great detail (26).

Monotony at work and low control on the job was associated with back pain in construction workers (39). In 4 community-based studies this factor showed positive associations with back disorders, the risk estimates varying from 1.35 to 2.34 (40, 51, 56, 57). The lowest estimate was found for a large sample of the Dutch work force after adjustment for physical load, work pace, age, gender, and education (40). In contrast, no evidence was found in a cross-sectional study that was specifically designed to evaluate the effect of monotonous, forced-pace work on lumbar complaints in slaughterhouses (37). The multivariate analysis in a longitudinal study on the incidence of sciatica also showed no association with high work pace (50). This study also reported that the initial effect of the dichotomous variable "problems with workmates or superiors" became insignificant in the final multivariate logistic model.

Individual characteristics

The individual characteristic most often studied was age. Twelve studies reported positive associations between age and back disorders, 15 studies demonstrated no association, and 3 surveys found higher prevalences of back disorders among younger workers. The common pattern of age is best illustrated by the community-based studies that showed an increase in the prevalence of back disorders with age up to about 45–50 years, leveling off in older age groups or even decreasing slightly (38, 40, 43, 51, 53, 57). In multivariate analyses, if present, the age-dependent pattern of back pain prevalence largely remained unchanged after adjustment for several work-related risk factors (38, 40, 43, 53). In 9 of 14 cross-sectional studies on occupational populations with information on age this pattern could not be distinguished. The small sample size (32–34) and a narrow age distribution (59) were the 2 most prominent reasons. In longitudinal studies on the incidence of low-back pain or back injury claims, the low frequency of incident cases may also have obscured an age effect (26, 47, 58). Interestingly, a few studies demonstrated that the age-dependent pattern was present for the more severe, chronic back pain cases, whereas isolated back pain episodes were not related to age or sometimes showed a negative association with the highest prevalence among the youngest workers (27, 29, 49).

In most studies the influence of gender cannot be evaluated since these studies had selected entirely male or female populations. Two community-based studies presented some evidence that women are at higher risk, with odds ratios between 1.42 and 1.57 (40, 53). It is tempting to raise the point that this risk difference may reflect differences in job demands. In only 1 community-

based study was the gender difference significant after adjustment for self-reported physical load (40). In other studies the univariate associations between gender and back disorders greatly diminished after control for age, smoking, education, and several work-related physical factors (38, 47).

Although some cross-sectional studies have suggested that height and weight are risk factors for low-back pain (38, 43, 54), this association was not substantiated by most studies in our review. In 1 community-based study taller persons were at risk for sciatica, with an odds ratio of 1.20 per 10-cm increase but not for other low-back pain (38). Among nurses the prevalence of back pain during the previous 12 months was elevated among nurses taller than 1.57 m, although the result was not statistically significant, with an odds ratio of 1.23 (95% CI 0.97–1.56) (54). None of the other studies with various designs could reproduce this result. Likewise, only 1 study reported that the prevalence of long-term back problems doubled among obese persons (43), but all the other studies revealed no difference for weight or any standard measure of obesity, such as body mass index.

The studies with null associations between smoking and back pain outnumbered those that presented a positive association. In 1 community-based study, smoking was associated with low-back pain but not with sciatica (38). The opposite effect was also found with a strong association for severe low-back pain but no association for all low-back pain cases (39). In 2 community-based studies the odds ratio for smoking was significantly elevated (about 1.5) after adjustment for various individual and work-related risk factors (42, 43).

Several studies have reported on other individual characteristics. The evidence for the effect of exercise and sport showed contradictory results. Two studies presented an increased risk for back disorders among workers with regular exercise (45, 50), 1 study suggested that involvement in sport may decrease the prevalence of transient low-back symptoms (31), and 1 study demonstrated that physical training among firefighters reduced the likelihood of low-back injury claims (46). However, most studies failed to demonstrate any effect of exercise or sport on the occurrence of back disorders. The effect of education was primarily evaluated in cross-sectional studies, and several studies showed that low educational attainment (primary school or less) resulted in odds ratios ranging from 1.39 to 2.54 (31, 32, 40, 42, 43). Two studies reported that this effect remained significant after control for self-reported physical load (40, 42). Divorced or widowed marital status was mentioned in 1 study as associated with back pain, but no quantitative information on the association was presented (42). In 7 other studies no effect of marital status was observed.

Discussion

Publication bias

A literature review is always subject to "publication bias", namely, studies not showing increased risks are less likely to get published (63). There is no information available to support the existence of this type of bias, although in this review only 2 studies were included that did not report a positive association between a work-related risk factor and back disorders (37, 50). The effect of publication bias was partly avoided through the analysis of both risk factors and potential confounders in every study. Since most epidemiologic studies focus on just 1 or 2 work-related risk factors, the confounder in 1 study may be treated as a risk factor in another. Thus information on the influence of confounders on risk estimates will present some information on risk factors as well. Moreover, since most studies examine the effect of multiple variables on health outcome, publication based on any 1 association is less likely.

The procedure of retrieving potentially relevant studies and the subsequent selection for our review may have influenced the results. The inclusion and exclusion criteria were aimed at identifying the studies that presented quantitative information on work-related risk factors and their associations with the occurrence of back disorders. Although this selection is arbitrary to some extent, for example, biased towards articles in the English language, we have no reason to assume that the selected publications bias the results in a particular direction. Several studies that did not meet the inclusion criteria reported associations between work-related risk factors and back disorders. However, these associations were difficult to interpret since, in some studies, the risk factors were described in qualitative terms that hampered comparability. In other studies, the associations were not presented in the form of odds ratios or relative risks and, therefore, were difficult to evaluate in this epidemiologic review. It has to be kept in mind also that this review is restricted to working populations. In other populations different results may be found, and available evidence for work-related risk factors may be less prominent.

Interpretation of null associations

This review not only discussed studies indicating that work-related risk factors were associated with the occurrence of back disorders but also evaluated negative and null associations. Table 1 shows that some publications described null associations; particular work-related factors did not have a significant effect on the occurrence of back disorders. As is shown in table 6, in 7 null associations with physical factors (39, 42, 43, 47, 50, 57) and 5 associations with psychological factors (37, 39, 51,

Table 6. Summary of epidemiologic studies with risk estimates of null and positive associations between work-related risk factors and the occurrence of back disorders.

Work-related risk factor	Null associations ^{a, b}		Positive associations			
	Risk estimate		Risk estimate		Attributable fraction	
	N ^c	Range	N ^c	Range	N ^c	Range
Physical risk factors at work						
Manual materials handling	2	0.90—1.23	17	1.12—3.07	14	11—54
Frequent bending and twisting	—	—	9	1.29—8.09	5	21—57
Heavy physical load	—	—	7	1.54—3.71	5	31—58
Static work posture	4	0.80—0.97	3	1.30—3.29	3	14—32
Repetitive movements	1	1.20	1	1.97	1	41
Whole-body vibration	—	—	14	1.47—9.00	11	18—80
Psychological risk factors at work						
Mental stress	1	1.26	4	1.30—2.08	4	23—44
Job dissatisfaction	—	—	5	1.39—2.40	4	21—41
Work pace	2	0.98—1.15	1	1.21	—	—
Lack of job support	1	1.00	—	—	—	—
Job decision latitude or monotonous work	1	0.98	5	1.25—2.34	4	20—44

^a Confidence intervals of the risk estimates included the null estimate (1.0).

^b Only in 12 of 23 null associations was the magnitude of the risk estimate presented.

^c Number of associations presented in the epidemiologic studies.

57), the actual risk estimate was presented in the original article. This information can be used to evaluate whether the results actually suggest the absence of an effect or whether the studies were inconclusive due to lack of information (62).

An inconclusive association may be the result of (i) a small sample size, (ii) lack of exposure variability, (iii) presence of another risk factor or confounder, and (iv) nondifferential measurement error. The first reason for an inconclusive result, a small sample size, cannot explain the nonsignificant associations with odds ratios above 1 in the community-based studies. These studies had at least 1400 subjects and their power was high enough to be able to demonstrate an association if one was present (42, 51, 57). However, lack of power due to small groups seems to be an important explanation for inconclusive associations between age and back disorders in the cross-sectional and longitudinal studies (26, 32—34, 47, 58). In these studies, the confidence intervals around the risk estimate were rather large and thus the actual risk estimate was rather uninformative. A second cause for inconclusiveness may result from the lack of the necessary contrast in exposure to risk factors. Occupational populations are much more homogeneous with regard to age and education, and hence associations with back disorders may not be encountered, whereas these associations are strongly present in community-based surveys. A narrow exposure distribution is not a likely explanation for the null associations in table 6. A third possible reason for inconclusive studies is confounding. A risk studied factor may fail to superpose an effect in addition to the effects of other risk factors. This possibility may explain why the univariate association of repetitive work and back disorders in a sample of Ameri-

can workers (42) became insignificant (OR 1.2, 95% CI 0.8—1.8) after adjustment for the stronger predictor heavy physical load (OR 1.7, 95% CI 1.1—2.9). A similar effect was observed in a longitudinal study for carrying loads among commercial travelers (OR 0.9, 95% CI 0.5—1.5) when whole-body vibration (OR 3.3, 95% CI 1.0—10.5) was entered into the multivariate model (47). The 4th reason for not finding significant associations is the presence of substantial nondifferential misclassification in the work-related risk factors. Inaccuracies in exposure categorization would tend to reduce the apparent association between the risk factor and back disorder (10, 64). All the studies with no apparent associations relied on exposure estimates derived from self-administered questionnaires, and none of these studies presented information on the reliability of the exposure questions. In a community-based survey the associations of back pain with regular lifting (OR 1.23, 95% CI 0.95—1.57) and perceived mental stress (OR 1.26, 95% CI 0.98—1.63) may have been attenuated because of inaccurate measurement (57).

For several null associations it is difficult to answer the question of whether associations are absent or whether the findings are inconclusive, for example, in the case of the reported null associations for lack of support (39), monotonous work (37), and high work pace (37, 51). With respect to the conflicting evidence on static work posture, one might argue that the 4 studies with no elevated risk suggest the absence of any effect (39, 43, 50, 57). It could also be argued that the measure of exposure in these studies does not reflect the true nature of the risk factor. Prolonged sitting or standing per se is probably not a risk factor when workers can change their posture and move around freely whenever

they want (34, 50). In sedentary occupations workers are at risk when they are forced to sit for long periods in constrained postures (34, 52). This risk factor is difficult to ascertain in epidemiologic studies.

Study design and associations

A strong preference in study design was observed for conducting cross-sectional studies on occupational populations or samples of the working population. This type of study is very sensitive to selection processes that are influenced by health status, for example, changes in job as a consequence of back pain. This type of selection bias will attenuate a true effect towards the null. It is very difficult to account for this selection bias when exposed and unexposed subjects drawn from different populations are compared. To reduce the influence of selection bias, several studies selected all workers from the same base population. This design option was typical for the community-based studies on work-related risk factors (38, 40, 42, 43, 51, 53, 56, 57). This approach has also been favored in studies among nurses (25, 35, 45, 54). The risk estimate is derived from comparing subjects who are the most exposed with those least exposed. Although this study design may be desirable when a strong selection during employment is expected, considerable differences in health selection may still occur during employment or at entry into the profession.

Alternatively, true associations may be overestimated in cross-sectional or case-referent studies due to information bias. Subjects with back pain may overstate their physical load in the workplace relative to those without back pain (10). Although there is no evidence available for this type of information bias, its presence cannot be ruled out since most studies relied on self-reported exposure.

Longitudinal studies are less prone to selection bias and hence are to be preferred. Five cohort studies were identified that presented useful evidence on the contribution of lifting, whole-body vibration, and dissatisfaction with the job to the incidence of back disorders (26, 30, 47, 55, 58). In our review, no systematic differences in risk estimates among the studies were observed that could be attributed to the study design. Two studies (27, 48) presented very high risk estimates that were well outside the range of estimates found in other studies. Since both studies had a small reference group, these estimates may have been influenced by a low accuracy of the estimates of exposure and back prevalence in the reference groups.

A common feature of most study designs is that the survey is conducted to address a limited set of risk factors. Very few studies have investigated the relative contribution of mechanical, psychological, and individual factors to the occurrence of back disorders (31, 38, 54, 40, 42). Hence most risk estimates are not adjusted for

other relevant risk factors and thus may underestimate or overestimate the true risk of the factor under consideration.

Measurement of health outcome and exposure

The reviewed studies varied widely in the methods and terminology used to ascertain the occurrence of back disorders. The description of the health outcome included low-back pain, back trouble, chronic back pain, and sciatica. The methods used to determine the incidence or prevalence of back disorders included self-administered questionnaires, interviews, disease registers, and worker's compensation records. Five studies used worker's compensation claims as the end point of interest. This number is too low to evaluate whether work-related risk factors for the onset of back pain differ from those for filing a back claim. Most studies have applied a questionnaire (partly) based on the Nordic questionnaire on musculoskeletal symptoms (65). The validity of the Nordic questions concerning the occurrence of low-back pain is sufficiently high to warrant its application in epidemiologic studies (66). However, self-reported back pain may be influenced by determinants of reporting health status in general, such as age and education. Another problem is that this questionnaire does not allow proper differentiation of symptoms according to type, severity, duration, and frequency. Hence, it is difficult to distinguish persons with chronic, persistent back pain from those whose back pain is an isolated or insignificant event. It is obvious that the interpretation of the results is hindered by the substantial differences in parameters of health outcome and the diagnostic criteria applied.

In most studies the information on work-related risk factors was collected by means of self-reports, either in an interview or on a questionnaire. This assessment technique may lead to some spurious results since 1 survey found that patients with back pain perceived their work to be heavier than asymptomatic patients in the same occupation (19). Few studies have applied measurement techniques that permit accurate characterization of particular determinants of physical load (29—31, 33, 34, 41, 48). The studies with questionnaires seldom addressed the validity of derived exposure variables. There is ample evidence that self-reported physical load has a low accuracy and precision and, at best, can be used to rank occupational groups on an ordinal scale with crude exposure categories (67, 68). Such an approach was adopted in several studies that demonstrated an increased prevalence of back disorders with higher exposure to lifting activities (25, 35), frequent bending and twisting (31, 33), and physical load (40, 43). Although there are large differences in the exposure definition and the validity of the assessment techniques applied, the studies showed a remarkable consistency in risk estimates for manual ma-

terials handling, frequent bending and twisting of the trunk, and exposure to whole-body vibration.

Causality of associations

In this review evidence from a variety of epidemiologic studies is used to determine inferences between risk factors and work-related back disorders. In principle, causality of association requires evidence on the strength of association, consistency in findings, biological plausibility, temporal sequence of risk and effect, dose-response gradient, specificity of risk factor for health outcome, and reversibility (69). It is obvious that all these criteria cannot be fulfilled satisfactorily for any of the risk factors addressed in this review. The criterion on temporality calls for cohort studies, and this design is not commonly encountered in the epidemiology of musculoskeletal disorders. Most studies do not meet the specificity guidelines since back pain is often used as the health outcome. Although proof of reversibility makes a very strong case for a particular risk factor, intervention studies on work-related risk factors for back disorders that show a decrease in the occurrence of back disorders after ergonomic improvements are very scarce. Thus the state of the art does not allow unequivocal conclusions about the contribution of specific work-related risk factors to the incidence of back disorders.

Despite these methodological concerns, the available literature has presented persuasive evidence for several risk factors for work-related back disorders. Various studies with clear differences in design, methodology, and populations have consistently produced comparable findings for manual materials handling, frequent bending and twisting, heavy physical load, and whole-body vibration. With regard to manual materials handling, sufficient biomechanical and physiological evidence is available to support the biological plausibility of lifting as a risk factor for back disorders (4–6). The results on lifting do not distinguish between the effect of infrequent lifting of heavy loads and frequent lifting of light loads. The studies among nurses indicate that a single lift of a patient is associated with an increased risk of back pain or back disability (45, 54, 58). This finding is consistent with biomechanical evaluations that predict high compression forces on the lower back during patient lifting (70). Frequent bending and twisting of the trunk was consistently related to back disorders in various studies. In 1 case-referent study with detailed exposure assessment, a clear dose-response relationship was shown (48). The findings for heavy physical load demonstrate that this is an important work-related risk factor. Several community-based studies have presented dose-response gradients (38, 40, 43). The strength of the gradients is difficult to assess since self-reports have been applied to rank exposure to physical load on ordinal scales. A second problem is that this particular risk factor probably

includes manual materials handling and frequent bending and twisting. Hence, in epidemiologic surveys, heavy physical load might be a surrogate measure for other risk factors rather than a separate risk factor.

The positive associations between whole-body vibration and back disorders were supported by dose-response trends in some studies. However, the observed effect may be due to exposure to whole-body vibration or to prolonged constrained posture. The vibration measurements showed moderate to high intensities close to the 4–5 Hz natural frequency of the spine. Mechanical vibration in this frequency range causes the largest displacements of spinal structures and requires considerable muscle tension to hold the upper body steady (71). Driving vehicles is also characterized by constrained sedentary postures for long periods, and these postures increase the intradiscal pressure (8, 13). Since whole-body vibration and prolonged sitting are concomitant exposures for all professional drivers, the contributions of these risk factors are difficult to disentangle in epidemiologic research.

With respect to work-related psychological factors, it remains to be explained whether psychological aspects are causal factors or whether they interact with and aggravate back pain and disability. The latter mechanism implies that these factors influence the reporting of back disorders and hence have to be regarded as an effect modifier (72). In this review, most of the positive associations stemmed from cross-sectional studies in which it was difficult to account for the temporal sequence of psychological factors at work and back disorders. In 1 community-based study a clear trend was observed for the effect of intellectual discretion which remained significant after adjustment for individual factors and physical load. A possible explanation is the experimental finding that low job demands seem to be associated with low pain thresholds (40, 73).

With regard to individual characteristics, age was identified in 12 of 30 studies as an important predictor for back disorders. These studies consistently found that the prevalence of back disorders increased with age and in the oldest age groups fell slightly. It was suggested that the severity of back disorders increases progressively with age. It is biologically plausible that age is an important factor in the development of back disorders since the load-bearing capacity of the spine decreases with age (5). Various studies did not find an age-dependent pattern of back disorder, largely due to populations too small to evaluate trends over 3 to 5 age groups. Smoking was found to be associated with back disorders in several studies although various studies were inconclusive or negative for this risk factor. Several theories have been proposed to explain the effect of smoking (74, 75). However, in this review, the contribution of smoking was difficult to disentangle from the effects of

social class, education, occupation, and life-style. There is some conflicting evidence for an association between back disorders and education or social class. Several studies have demonstrated an inverse relationship between level of education and the 1-year prevalence of back pain. However, it is unclear whether this is a secondary effect since few studies have been able to adjust for confounding by physical load (40, 42).

There is little evidence of a biological difference in back pain between men and women although 1 community-based survey reported that women are at greater risk, independently from physical load at work (40). It has also been suggested that women with multiple pregnancies might have an increased prevalence of back pain (76, 77), but this finding was not confirmed in the studies that evaluated this factor (35, 38, 45, 54, 78). The same was found for height, weight, and marital status. Few studies have suggested that these risk factors are important (23, 79, 80), but most studies among workers consistently demonstrated no effect on back disorders. In occupational populations their effects, if present, are likely to be very small in relation to other individual characteristics and work-related risk factors.

Concluding remarks

This review concludes that there is a clear relationship between back disorders and physical load, that is, between back disorders and materials handling, frequent bending and twisting, physically heavy work, and whole-body vibration. Although much remains to be learned about dose-response relationships, the evidence presented indicates that preventive measures reducing the exposure to these risk factors will decrease the occurrence of back disorders. However, this evidence is not specific enough to provide detailed, quantitative guidelines for workplace and task design. There is some evidence for an association between psychological factors and back disorders, but this evidence is not consistent across different studies and study designs. When the influence of work-related risk factors on the occurrence of back disorders is studied, these associations may be masked by several nonoccupational risk factors, the high prevalence of back disorders in the community, and the wide diversity of back disorders. This review has shown that age, smoking habits, and education may be important confounders in epidemiologic studies on risk factors for work-related back disorders.

Acknowledgments

This study was supported by a scholarship from the Liberty Mutual Research Center for Safety and Health in Hopkinton, Massachusetts, in the United States. The con-

tributions from many colleagues at the research center are gratefully acknowledged.

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Received for publication: 1 September 1996