

Physical load during work and leisure time as risk factors for back pain

by Wilhelmina E Hoogendoorn, MSc,^{1,2} Mireille NM van Poppel, MSc,¹ Paulien M Bongers, PhD,² Bart W Koes, PhD,¹ Lex M Bouter, PhD¹

Hoogendoorn WE, van Poppel MNM, Bongers PM, Koes BW, Bouter LM. Physical load during work and leisure time as risk factors for back pain. *Scand J Work Environ Health* 1999;25(5):387—403.

This systematic review assessed aspects of physical load during work and leisure time as risk factors for back pain. Several reviews on this topic are available, but this one is based on a strict systematic approach to identify and summarize the evidence, comparable with that applied in the clinical literature on the efficacy of intervention for back pain. A computerized bibliographical search was made of several data bases for studies with a cohort or case-referent design. Cross-sectional studies were excluded. A rating system was used to assess the strength of the evidence, based on the methodological quality of 28 cohort and 3 case-referent studies and the consistency of the findings. Strong evidence exists for manual materials handling, bending and twisting, and whole-body vibration as risk factors for back pain. The evidence was moderate for patient handling and heavy physical work, and no evidence was found for standing or walking, sitting, sports, and total leisure-time physical activity.

Key terms bending, lifting, low-back pain, methodological quality, observational studies, overview, rating system, sports, twisting, whole-body vibration.

Back pain is a major health problem in the Western world. The lifetime prevalence has been estimated at 60% to 90%, and the point prevalence varies between 15% and 42%, depending on the study population and the definition of back pain. The annual incidence of back pain has been reported to be approximately 5% (1—4).

In a recent study of a general population in The Netherlands, the annual prevalence of low-back pain was found to be 46% for men and 52% for women. This study also showed that the high prevalence of back pain has important consequences in terms of disability, the utilization of health services, and sick leave. Twenty-eight percent of the people with low-back pain were restricted in their daily activities, 42% underwent medical treatment, 23% took time off work, 8% received a (partial) disability pension, and 6% changed jobs or had adaptations in the workplace (5). In 1991, the total cost of back pain to society in The Netherlands was estimated to be 1.7% of the gross national product (6).

The prevalence rate of low-back pain also varies between workers in different professions. High prevalence rates are found, in particular, for nonsedentary occupations (7, 8). This phenomenon indicates that work-related factors may play a role in the etiology of back pain. In order to define potentially effective intervention in the

workplace, the relationship between various exposures and back pain must be examined more specifically.

Several reviews on risk factors for back pain have already been published (9—15). However, none of them include clearly defined inclusion and exclusion criteria, a methodological quality assessment of the studies, and explicit criteria on which overall conclusions on the strength of the evidence were based. The current interest in evidence-based medicine has led to an extensive increase in the publication of systematic reviews, because a systematic approach is less susceptible to bias. This increase has, in turn, led to the development of methodological guidelines for systematic reviews (16).

This paper examines the evidence for certain aspects of physical load as risk factors for back pain. Physical load is assumed to have both an acute and a cumulative effect on the occurrence of back pain. A load that exceeds the failure tolerance of the tissue, applied once, can cause back pain. However, cumulative load resulting from subfailure magnitude loads may be even more important. In such cases, back pain is assumed to be the result of a repeated application of loads or the long-term application of a sustained load. Moreover, a combination of cumulative and acute loads can also cause back pain (17, 18).

¹ Institute for Research in Extramural Medicine, Vrije Universiteit, Amsterdam, The Netherlands.

² TNO Work and Employment, Hoofddorp, The Netherlands.

Reprint requests to: TNO Work and Employment, Lisette Hoogendoorn, PO Box 718, 2130 AS Hoofddorp, The Netherlands. [E-mail: L.Hoogendoorn@arbeid.tno.nl]

In this paper, a systematic approach, comparable with that applied in the clinical literature on the efficacy of intervention for back pain (16, 19), was used to answer the following research questions, based on the available literature: (i) which aspects of physical load at work are risk factors for the occurrence of back pain and (ii) which aspects of physical load during leisure time are risk factors for the occurrence of back pain?

Material and methods

Search strategy and screening

The available literature was identified by means of a computerized search of several bibliographical data bases, including Medline (1966-November 1997), Embase (1988-October 1997), Psyclit (1974-September 1997), NIOSHTIC, CISDOC and HSELINE (1977-July 1997), and Sportdiscus (1949-October 1997). The following key words were used: back pain, low-back pain, lumbago, backache, intervertebral disk displacement, hernia, herniated disc, sciatica, sciatic pain, risk factors, causality, causative, precipitating factors, determinants, predictor, etiology, aetiology, epidemiology, and case-control studies, retrospective studies, case-referent, prospective studies, longitudinal studies, follow-up studies, and cohort studies. For practical reasons, the search was restricted to publications in English, Dutch, German and French. The abstracts of all the citations were retrieved and examined.

Selection

A selection was made from the identified papers. The first reviewer (WH) was responsible for the entire selection, but in order to check the reproducibility of the selection process, a second reviewer (MP) selected a random sample (N=100) from the papers identified in Medline.

The studies had to meet the following inclusion criteria:

- . The design of the study had to be case-referent or cohort (prospective or historical) with at least 1 year of follow-up. Studies with a cross-sectional design, defined as studies in which the exposure(s) and the disease were assessed at the same time, were excluded.
- . The study had to concern a working population or a community-based population. Studies involving patient populations were excluded.
- . The operationalization of back pain had to be based on symptoms or signs of nonspecific back pain, self-reported or measured otherwise, including such consequences of back pain as sick leave, medical consultation, or treatment and disability. Studies on back pain due to a definite herniated lumbar intervertebral disc

diagnosed according to well-defined diagnostic criteria and studies on back pain due to osteoporosis, cancer, or other specific causes were excluded. Studies which focused on back pain during pregnancy were also excluded.

- . The exposures accepted for study included physical load during work or physical load during leisure time. Studies which only involved a comparison between different occupational groups were excluded.
- . The publication had to be a full report. Letters and abstracts were excluded.

The references of all the selected articles and recently published review articles (9, 11) were screened for additional, potentially eligible publications.

Methodological quality assessment

The selected studies were scored by two reviewers (WH, MP), independently, on the basis of a standardized set of criteria. The criteria concerned the study population, the exposure measurements, the assessment of back pain, and the analysis and presentation of the data. Two slightly different, separate criteria lists were used for the cohort studies and the case-referent studies. A description of these 2 lists is given in the appendix. These lists were adapted from criteria lists used in systematic reviews of randomized controlled trials on treatment (16) and criteria lists used in other reviews of observational studies (20, 21).

The reviewers rated each criterion according to the following rules: + = informative description of the criterion at issue, and study meets the criterion, - = informative description, but study does not meet the criterion, and ? = lacking or insufficient information, assigning "+" or "-" was not possible.

All disagreements between the reviewers were subsequently discussed during a consensus meeting. If disagreements were not resolved during this meeting, a third reviewer (PB) was consulted for a final judgment. Each study was assigned a total methods score, which was the sum of all positive ratings for the criteria on validity and precision. This evaluation finally resulted in a hierarchical order for both the cohort and the case-referent studies, ranking the studies according to their methodological quality.

Data extraction and analysis

Data on the effect of the exposures of interest were abstracted from the text and tables of the original publications. Whenever possible, the data extraction not only included information on the statistical significance of the effect, but also on the magnitude of the estimated effect. For some studies that did not provide an effect estimate, this figure was computed from the data provided in the article. If a study (only) reported that a factor did not

enter the model in stepwise modeling, this result was disregarded in the data extraction because a stepwise analysis is not appropriate for modeling focused on the assessment of a causal relationship (22).

Due to the expected heterogeneity with regard to the study population, exposure measurements, and assessment of back pain, it had been previously decided to refrain from statistically pooling the findings of the individual studies. In order to synthesize the available information, use was made of a method based on levels of evidence adapted from the *US Clinical Practice Guideline for Acute Low Back Pain in Adults* (23). The rating system was applied to each individual exposure, and it consisted of 3 levels of scientific evidence based on the number, the quality, and the outcome of the studies as follows: (i) strong evidence: provided by generally consistent findings in multiple high-quality studies, (ii) moderate evidence: provided by generally consistent findings in 1 high-quality study and ³1 low-quality studies, or in multiple low-quality studies, (iii) no evidence: only 1 study available or inconsistent findings in multiple studies. Strong or moderate evidence could concern both the presence and the absence of an effect. A study was considered to be of high quality if the methodological quality score was more than 50% of the maximum score, and low-quality studies were those with a methodological score of less than 50% of the maximum score. The findings of the studies were considered to be inconsistent if less than 75% of the available studies reported the same conclusion. In the case of multiple high-quality studies, the available low-quality studies were disregarded in the drawing of an overall conclusion.

In the assessment of the level of evidence for an exposure, an increased risk was regarded as a positive effect, regardless of the statistical significance. A risk estimate [relative risk (RR) or odds ratio (OR)] in the region of 1 was considered to indicate no effect, and a decreased risk was considered to indicate a negative effect, notwithstanding the statistical significance of this effect. Studies that only reported nonsignificance, without presenting an effect estimate, were excluded from the evaluation. This exclusion, and ignoring the statistical significance of the findings, was based on the fact that, in general, the information provided in the articles was too meager to evaluate if no significant effect was found, either because there was no effect or because of a lack of statistical power, due to a small study size, a small percentage of exposed subjects, or a small percentage of subjects who developed the disease in question (24). As ignoring the statistical significance could be controversial, the exposures for which it was concluded that there was strong or moderate evidence of an effect were subjected to a sensitivity analysis. In this analysis all the studies with a nonsignificant effect were considered to indicate no effect.

If studies reported results of analyses with different outcome measures, the assessment of the effect was based on the results obtained for symptoms and findings, as opposed to measures of the consequences of back pain such as sick leave, medical consultation or treatment and disability. If studies reported results of analyses in different subgroups, the studies were considered to indicate a positive or a negative effect if such an effect was found in at least 1 of the subgroups.

Results

Selection

The literature search in the various data bases resulted in the identification of 1363 publications, mostly in English. Twenty-seven studies met the inclusion criteria (25–93). On the basis of a screening of the references of the articles on these studies and recent reviews (9, 11), an additional 9 studies were included (94–104). The selection of studies for inclusion, from a random sample (N=100) of the papers identified in Medline by the second reviewer, led to an initial 2% disagreement. Five of the 36 selected studies were excluded post hoc for the following reasons: (i) there was low variability in physical load because the study population was restricted to workers with lifting tasks (50, 51, 95, 98, 99), (ii) the physical exposures at work were measured by means of a questionnaire on which only 1 of a list of items could be ticked (85), and (iii) the early retirements that were studied did not necessarily have a back disorder as the main diagnosis (25, 26). Thus a total of 31 studies was finally included in this review, comprised of 28 cohort studies (27–49, 52–76, 78, 82–84, 86–94, 96, 97, 100, 102–104) and 3 case-referent studies (77, 79–81, 101). For most of the studies there was more than 1 publication, and the assessment of the methodological quality of these studies was based on the information provided in all the publications.

Methodological quality assessment

The scoring of the 28 cohort studies and the 3 case-referent studies led to an overall initial disagreement of 20% (95 of 476 items) and 25% (14 of 57 items), respectively. The 2 reviewers subsequently reached consensus on all the initial disagreements.

Tables 1 and 2 show the cohort and case-referent studies on physical load as a risk factor for back pain in order of their methodological quality score. Eleven of the 28 (39%) cohort studies (28–45, 49, 52, 61–71, 73, 78, 82–84, 86, 100) and 2 of the 3 (67%) case-referent studies (77, 79–81) had a positive score for over 50% of the criteria on validity and precision, and they were therefore considered to be of high quality.

Table 1. Cohort studies on physical load during work and leisure time as risk factors for back pain, ranked according to their methodological quality score^a.

Authors	1	2	3	4	7	8	9	10	11	12	13	17	18	19	21	22	23	Percentage + V/P (=3—23)
Biering-Sørensen et al (28—36)	+	+	+	+	+	?	+	?	+	-	+	+	+	-	+	+	+	73
Leino et al (61—66)	+	-	+	+	+	?	+	?	+	-	+	+	+	-	+	+	+	73
Bigos et al (37—45)	+	+	-	?	+	?	+	?	+	+	?	?	+	+	+	+	+	67
Burdorf et al (49)	+	+	+	+	+	?	-	-	+	-	+	?	+	-	+	+	+	60
Riihimäki et al (82—84)	+	+	-	+	+	?	+	?	+	-	+	?	+	-	+	+	+	60
Klaber-Moffet et al (52)	+	+	+	+	-	-	-	-	+	-	+	?	+	+	-	+	+	53
Macfarlane et al (67—71)	+	+	-	-	+	?	+	?	-	+	-	+	+	+	+	+	+	53
Mannion et al (73)	+	+	?	+	+	?	-	-	+	-	+	?	+	-	+	+	+	53
Pietri et al (78)	+	+	?	+	+	?	-	-	+	-	+	?	+	-	+	+	+	53
Ready et al (100)	+	+	-	+	-	-	+	?	+	-	+	?	+	+	+	+	-	53
Rosignol et al (86)	+	+	-	+	-	-	+	?	+	-	+	?	+	+	+	+	-	53
Smedley et al (91, 92)	+	+	-	-	+	?	-	-	-	-	+	?	+	+	+	+	+	47
Videman et al (103)	+	+	?	+	+	?	-	-	+	-	-	?	+	-	+	+	+	47
Biering-Sørensen et al (27)	+	+	+	+	+	?	-	-	-	-	-	?	+	-	-	+	+	40
Gyntelberg et al (96, 97)	+	+	+	+	+	?	-	-	+	-	-	?	+	-	+	-	-	40
Kuh et al (53, 54)	+	+	+	+	-	-	-	-	-	-	-	?	+	-	+	+	+	40
Kujala et al (55—59)	+	+	+	+	-	-	-	-	+	-	-	?	+	-	+	+	-	40
Kujala et al (60)	+	+	-	-	+	?	-	-	+	-	+	?	+	-	-	+	+	40
Manninen et al (72)	+	+	+	-	+	?	-	-	-	-	-	?	+	-	+	+	-	40
Venning et al (93)	+	-	-	+	+	?	-	-	-	-	-	?	+	+	-	+	+	40
Muramatsu et al (75)	+	+	-	+	-	-	-	-	+	-	+	?	-	-	-	+	+	33
Niedhammer et al (76)	+	+	?	+	-	-	-	-	+	-	+	?	+	-	-	+	?	33
Viihari-Juntura et al (104)	+	+	?	-	?	?	+	?	+	?	-	?	+	-	+	+	-	33
Stobbe et al (102)	+	-	?	?	-	-	-	-	-	-	-	?	+	+	+	+	+	33
Bergenudd & Nilsson (94)	+	+	?	-	-	-	+	?	?	-	?	?	-	-	+	+	+	27
Salminen et al (87—90)	+	+	+	+	-	-	-	-	+	-	-	?	+	-	-	-	-	27
Mooney et al (74)	+	-	+	?	-	-	-	-	-	-	-	?	+	+	+	-	-	27
Brattberg et al (46—48)	+	+	+	+	-	-	-	-	+	-	-	?	-	-	-	-	-	20

^a The numbers refer to the numbers of the criteria in the list for the methodological quality assessment in the appendix; +=yes, -=no, ?=don't know.

Table 2. Case-referent studies on physical load during work and leisure time as risk factors for back pain, ranked according to their methodological quality score^a.

Authors	1	2	5	6	7	8	9	10	11	12	13	14	15	16	17	20	21	22	23	Percentage + V/P (=5—23)
Punnett et al (79—81)	+	+	+	+	+	+	-	-	+	-	+	-	+	-	?	+	+	+	+	65
Nuwayhid et al (77)	+	-	-	-	+	?	+	?	+	+	+	+	-	-	+	+	+	+	+	65
Ryden et al (101)	+	+	-	?	-	-	+	?	+	-	+	+	?	+	?	-	+	+	-	41

^a The numbers refer to the numbers of the criteria in the list for the methodological quality assessment in the appendix; +=yes, -=no, ?=don't know.

Tables 3 and 4 give a detailed description of important aspects of the cohort and case-referent studies included in the review.

Physical load at work

Lifting: manual materials handling and patient handling

Four high-quality studies and 1 low-quality study reporting on the effect of manual materials handling were

identified (53, 67, 77—79). Manual materials handling includes lifting, moving, carrying, and holding loads. Three high-quality studies found a statistically significant positive effect for manual materials handling (67, 77, 79) and 1 high-quality study found no effect (78). According to these findings there is strong evidence for manual materials handling as a risk factor for back pain. The magnitude of the risk estimates [relative risk (RR) or odds ratio (OR)] ranged from 1.5 to 3.1.

Three low-quality studies examined the effect of patient handling (91, 93, 102). Patient handling includes the

Table 3. Summary of the cohort studies on physical load and back pain. (MQS = methodological quality score based on items on validity and precision, NS = not significant, RR = relative risk, OR = odds ratio, the corresponding 95% confidence intervals for the RR and OR are shown in parentheses)

Authors	MQS	Study population	Operationalization of back pain	Follow-up	Results
Bergenudd & Nilsson (94) ^a	4	1542 10-year-old residents of Malmö, 830 included in 1983, follow-up response 69%	Present back pain at follow-up in 1983 (questionnaire)	45 years, 3 or 4 measurements	Work (job-exposure matrix, adjusted for gender): occupational work load 1942–1983 [RR _{≥10 years moderate physical work} 1.6 (1.2–2.1), RR _{≥10 years heavy physical work} 1.3 (0.8–2.2)]
Biering-Sørensen et al (27)	6	728 50-year-old inhabitants of Copenhagen, follow-up response 85%	1. Low-back pain during last 10 years 2. Absences from work due to low-back pain during last 10 years (interview)	10 years, 2 measurements	Work (questionnaire, adjusted for gender, outcome 1+ 2): physical activity during work, including housework (NS)
Biering-Sørensen et al (28–36) ^b	11	928 30-, 40-, 50- and 60-year old inhabitants of Copenhagen, follow-up response 99% Analysis restricted to 351 persons with no low-back trouble before base line	Low-back pain within the last 12 months (questionnaire)	12 months, 2 measurements	Work (questionnaire): physical activity at work (NS) Nonwork (questionnaire): physical activity during leisure time (NS)
Bigos et al (37–45) ^b	10	3020 blue-collar workers at one of the plants of Boeing-Everett	Incident reports or claims for acute back injury complaints	1 day-4 years (mean 3 years)	Work (questionnaire): perceived physical exertion (NS at P=0.00132)
Brattberg et al (46–48) ^c	3	1245 children (8-, 11-, 13- and 17-year-olds), 597 included in the longitudinal study, follow-up response 79%	Often having back pain at follow-up (questionnaire)	2 years, 2 measurements	Nonwork (questionnaire): frequency of participation in physical activities (NS)
Burdorf et al ^d (49)	9	221 male novice golfers 20-to-60-year-olds, follow-up response 89%	Back pain during past 12 months (questionnaire)	12 months, 2 measurements	Work (questionnaire, subjects without history of back pain): standing or walking >4 hours/day (NS), sitting >4 hours/day (NS) Nonwork (questionnaire, subjects without history of back pain): various aspects of playing golf (NS), involvement in other sports [RR=0.36 (0.07–1.83)]
Gyntelberg et al (96, 97)	6	5249 men aged 40–59 years and employed in large private or public enterprises, follow-up response 91%	Low-back pain during the past year (questionnaire or interview)	1 year, 2 measurements	Work (questionnaire): work on the job makes persons sweat [RR _{now and then-rarely or never} 1.24 (1.12–1.38), RR _{often-rarely or never} 1.45 (1.23–1.72)], physical activity on the job (heavy and sedentary compared with light) (P≤0.05) Nonwork (questionnaire): bicycling/day [RR _{11–20 min–≤10 min} 0.95 (0.82–1.09), RR _{21–30 min–≤10 min} 1.05 (0.89–1.25), RR _{>30 min–≤10 min} 0.91 (0.78–1.06)], often sweating from leisure-time physical activity [RR 1.03 (0.92–1.14)], taking regular part in sports [RR=0.84 (0.74–0.96)]
Klaber Moffett et al (52) ^a	8	376 female student nurses recruited on entry to 2 schools of nursing, follow-up response 80%	1. ≥3 days of low-back pain during follow-up 2. ≥21 days low-back pain or 1 day of sick leave with back pain during follow-up (diaries collected at approximately 3 monthly intervals)	20 months, 7 measurements	Nonwork (questionnaire, outcome 1): exercise habits at base line (number of times a sporting activity was given up) (P≤0.05)
Kuh et al (53, 54) ^a	6	5362 single, legitimate births that occurred in England, Wales, or Scotland in 1 week in March 1946, response at relevant follow-up 61% Analysis restricted to 1566 men with job histories and no back pain before 16 years of age	Recalled first ever experienced sciatica, lumbago or severe backache at age 43 years (interview)	43 years, 20 measurements	Work (job-exposure matrix): regular lifting of weights in excess of 25 kg [RR _{high-low probability} 1.3 (1.0–1.7)]
Kujala et al (55–59)	6	116 athletes and nonathletes; boy athletes (ice hockey and soccer players) and girl athletes (gymnasts and figure skaters) Nonathletes of the same age attending 2 elementary schools and participating in recreational sports less than twice a week, follow-up response 85%	1. Low-back pain interfering with school or leisure activities for at least a 1-week period 2. Acute injuries causing low-back pain (questionnaire at every follow-up)	3 years, 4 measurements	Nonwork (questionnaire, outcome 1): weekly frequency or duration of training before base line (NS), training years before base line (NS), frequency or duration of training during the years preceding low-back-pain report (NS) Nonwork (adjusted for gender, outcome 1): participation in sports [RR _{athletes-nonathletes} 2.45 (1.13–5.31)] Nonwork (outcome 2): participation in sports [RR _{athletes-nonathletes} 1.90 (0.70–5.28)]

(continued)

Table 3. Continued.

Authors	MQS	Study population	Operationalization of back pain	Follow-up	Results
Kujala et al (60)	6	456 25-, 35-, 45- and 55-year-olds from Turku, Finland, without acute or chronic disease, severe or recent back symptoms or other musculoskeletal symptoms, follow-up response 57%	1. Back pain during the past 5 years 2. Back pain radiating to the leg during the past 5 years (questionnaire)	5 years, 2 measurements	Work (questionnaire, outcome 1): general occupational physical demands ($P \leq 0.05$), occupational musculoskeletal loading (job-exposure matrix) ($P \leq 0.05$) Nonwork (questionnaire, outcome 1): leisure physical activity (NS) Work (questionnaire, outcome 2): general occupational physical demands ($P \leq 0.05$), occupational musculoskeletal loading (job-exposure matrix) ($P \leq 0.05$) Nonwork (questionnaire, outcome 2): leisure physical activity (NS)
Leino et al (61–66) ^d	11	902 blue- and white-collar employees of metal industry plants, follow-up response 67%	1. Low-back symptom score during the past 12 months at the last follow-up (questionnaire) 2. Low-back clinical findings score (physiotherapist)	10 years, 3 measurements	Work (questionnaire, outcome 1 and 2): physical load (NS) Nonwork (questionnaire base line, outcome 1 and 2): total activity outside work in kilocalories (NS) Nonwork (mean questionnaire base line and first follow-up, adjusted for low-back symptoms at 1st follow-up, age, occupational class, smoking intensity, body mass index and stress symptoms, outcome 1): exercise activity in kilocalories for men (st.beta -0.078) ($P \leq 0.05$) and women (st.beta -0.001; NS)
Macfarlane et al (67–71) ^d	8	4501 adults aged 18–75 years registered with two general or family practices in Manchester, England; included in the follow-up study were 2715 free of current low-back pain at base line, follow-up response 64%	1. Episodes of low-back pain leading to consultation with a general practitioner (computer records from the general practitioners) 2. Episodes of low-back pain not leading to consultation and >1 day over the past 12 months (questionnaire)	12 months, 2 measurements	Work (questionnaire, adjusted for age of cohort members with no history of low-back pain, outcome 1 and 2 combined): Standing or walking >2 hours [OR 1.6 (0.8–3.3)], sitting >2 hours [OR 0.9 (0.1–1.5)], driving a car >4 hours [OR 1.1 (0.5–2.7)], lifting/moving ≥ 25 lb [OR 1.5 (0.8–2.8)] for men and standing/walking >2 hours [OR 2.9 (1.5–5.5)], sitting >2 hours [OR 0.4 (0.2–0.7)], driving a car >4 hours [OR 4.8 (0.4–54)], lifting/moving ≥ 25 pounds OR 2.0 (1.0–4.0)] for women
Manninen et al (72)	6	537 Finnish farmers aged 45–54 years who reported no low-back or neck-shoulder pain during the past year at base line, follow-up response 68%	1. Sciatic pain during the past year 2. Unspecified low-back pain during the past year (telephone interview)	12 years, 2 measurements	Work (questionnaire, adjusted for gender, outcome 1): use of a tractor [RR 0.78 (0.32–1.89)] Work (questionnaire, adjusted for gender, outcome 2): use of a tractor [RR 1.42 (0.53–3.76)]
Mannion et al (73)	8	403 volunteering health-care workers aged 18–40 years who had no history of serious low-back or leg pain, follow-up response 92%	1. Back-related pain during follow-up 2. Back-related pain with medical consultation or treatment or time absent from work during follow-up (questionnaire every 6 months during follow-up)	18 months, 4 measurements	Work (questionnaire, outcome 1 and 2): heaviness of job (NS) Nonwork (questionnaire, outcome 1 and 2): frequency of leisure exercise (NS)
Mooney et al (74)	4	3643 employees of a large shipbuilding firm including workers in 32 job categories	On-the-job low-back injury claims	3 years	Work (job-exposure matrix): physical demand level, based on lifting requirements and energy required [RR _{light-sedentary} 0.73 (0.25–2.18), RR _{medium-sedentary} 4.52 (2.70–7.56), RR _{heavy-sedentary} 13.28 (8.02–22.00), RR _{very heavy-sedentary} 9.79 (5.73–16.73)]
Muramatsu et al (75)	5	2200 noninstitutionalized older adults in Japan aged ≥ 60 , follow-up response 90% Analysis focused on those currently not suffering from low-back pain at base line	Self-reported "chronic low-back pain" (interview at follow-up)	3 years, 2 measurements	Nonwork (interview, adjusted for age, gender, education, marital status, contact with child, psychological distress, have friend or neighbor, social contact, social participation, instrumental support, emotional support, smoking, drinking, comorbidity, self-rated health and functional limitations): physical activity (frequency of yard work, exercise or sports and walking, NS)
Niedhammer et al (76) ⁱ	5	469 nurses, response at first follow-up 89%, response at second follow-up 78% Analysis restricted to 210 nurses who had not left hospital work or suffered from musculoskeletal disorders between 1980 and 1985	Lumbar pain within the previous 12 months (interview at second follow-up)	10 years, 3 measurements at 5-year intervals	Nonwork (questionnaire 1985, adjusted for age, children ≤ 3 , tobacco, symptoms of psychological disorders, commuting, and psychosocial and physical factors at work): sports activities (OR=1.11, NS)

(continued)

Table 3. Continued.

Authors	MQS	Study population	Operationalization of back pain	Follow-up	Results
Pietri et al (78)	8	1381 commercial travelers, follow-up response 81% Analysis restricted to 627 people who had never had low-back pain before the base line	Symptoms of low-back pain during the past 12 months (interview)	12 months, 2 measurements	Work (interview, adjusted for age, gender, smoking, psychosomatic factors, no comfortable car seat and the other variables shown): time (hours) driving per week [OR _{10 to 14 < 10} 4.0 (1.1—14.3), OR _{15 to 19 < 10} 4.8 (1.4—16.4), OR _{20 to 24 < 10} 3.3 (0.9—12.0), OR _{≥25 < 10} 3.7 (0.9—14.0)], frequent load carrying [OR _{yes-no} 0.9 (0.5—1.5)], frequent prolonged standing [OR _{yes-no} 0.8 (0.5—1.4)] Nonwork (interview, adjusted for age): regular sport (NS)
Ready et al (100)	8	131 full-time female nurses and unit assistants, follow-up response 91%	Back injuries reported by the employees on an employee accident report	18 months	Nonwork (questionnaire): physical activity pattern outside of work (NS)
Riihimäki et al (82—84) ^{a, 9}	9	2222 male longshoremen and earthmover operators, carpenters and municipal office workers aged 25—49 years, follow-up response 82% Analysis restricted to 1149 men who had never had sciatic pain at base line	Three-year cumulative incidence of sciatic pain (questionnaire)	3 years, 2 measurements	Work (questionnaire, adjusted for draft and cold, high pace of work, monotonous work, problems with workmates or superiors and the other variables shown): amount of twisted or bent postures (P≤0.05), vibration (P≤0.05) Nonwork (questionnaire, adjusted for smoking and the other variables shown): annual car driving (NS), weekly physical exercise (P≤0.05) Nonwork (questionnaire, adjusted for occupation, smoking and history of other low-back pain): physical exercise [RR _{>1/week<=1/week} 1.26 (1.00—1.60)]
Rossignol et al (86)	8	269 male aircraft assembly workers, follow-up response 76%	1. Compensation for a back problem during follow-up (computerized records) 2. Absenteeism for a back problem during follow-up (computerized records) 3. Limitation in work performance in preceding week (questionnaire) 4. Back symptoms in preceding week (questionnaire)	12 months, 2 measurements	Nonwork (questionnaire, outcome 1, 2, 3, 4): number of hours spent in sport or physical activities in past week (NS)
Salminen et al (87—90)	4	76 eighth grade students, follow-up response 82%	Low-back pain during the past 12 months at last follow-up (questionnaire and interview)	3 years, 3 measurements	Nonwork (questionnaire): low physical activity (≤2 days/week) at base line and follow-up (NS)
Smedley et al (91, 92) ^d	7	961 hospital-based nurses without low-back pain in the month before they completed the base-line questionnaire, response after 12 months 66%	1. Low-back pain >1 day during follow-up 2. Low-back pain leading to loss of time from work during follow-up (three monthly questionnaires during the whole follow-up)	2 years, 8 measurements	Work (questionnaire, adjusted for age, height, earlier history of low-back pain, and symptoms other than back pain at base line, outcome 1): frequency in average work shift: transfer patient on canvas and poles [OR _{1 to 4 < 0} 0.8 (0.6—1.1), OR _{≥5 < 0} 1.4 (0.8—2.3)], manually transfer patient between bed and chair [OR _{1 to 4 < 0} 1.3 (0.9—1.7), OR _{5 to 9 < 0} 1.6 (1.1—2.3), OR _{≥10 < 0} 1.6 (1.1—2.3)], transfer patient between bed and chair with hoist [OR _{1 to 4 < 0} 1.5 (1.0—2.0), OR _{≥5 < 0} 1.6 (0.8—2.3)], manually move patient around on bed [OR _{1 to 4 < 0} 1.3 (0.8—1.9), OR _{5 to 9 < 0} 1.5 (1.0—2.3), OR _{≥10 < 0} 1.7 (1.1—2.5)], manually lift patient up off floor [OR _{≥1 < 0} 1.1 (0.9—1.5)], lift patient from floor with hoist [OR _{≥1 < 0} 1.3 (0.8—2.0)], manually lift patient in or out of bath [OR _{≥1 < 0} 0.9 (0.6—1.4)], lift patient in or out of bath with hoist [OR _{1 to 4 < 0} 1.4 (1.0—1.9), OR _{≥5 < 0} 2.1 (1.2—3.6)]
Stobbe et al (102) Retrospective cohort	5	415 licensed practical nurses, nurses aides and attendants	Reports of nonlost-time and lost-time back injuries (form of the Occupational Safety and Health Administration)	40 months, retrospective data collection	Work (job-exposure matrix, adjusted for employment time and occupation): patient lifting (OR _{>5 patients lifts per shift<=2 lifts per shift} =2.71) (P≤0.05)
Venning et al (93)	6	4306 nursing aides and orderlies, and all registered nurses, excluding senior administrative officers, follow-up response 93%	Any work-related injury or complaint of discomfort concerning the back (registration health office)	12 months	Work (questionnaire, adjusted for job category, service area and previous history of reported back complaint): lifting (OR _{lifting patients >10kg and ≥1/day<=less} =2.19) (P≤0.05)

(continued)

Table 3. Continued.

Authors	MQS	Study population	Operationalization of back pain	Follow-up	Results
Videman et al (103) ^d Retrospective cohort	7	2504 surviving former athletes in 1985 who had been members of at least one Finnish national team between the years 1920 and 1965, and referents identified from the register of men eligible for military service, follow-up response 82%	1. Having had back pain which interfered with work in the past 2. Ever having had a physician that diagnosed sciatica (questionnaire)	20–65 years, depending on the year in which someone was member of a national team, follow-up measurement in 1985	Nonwork (adjusted for age and occupational physical loading in 1985, outcome 2): type of sports training [OR _{endurance-referents} 1.54 (0.96–2.48), OR _{sprint-referents} 1.01 (0.59–1.73), OR _{jumping-referents} 0.84 (0.44–1.60), OR _{throwing-referents} 1.20 (0.67–2.15), OR _{games-referents} 1.08 (0.76–1.53), OR _{contact-referents} 0.68 (0.44–1.06), OR _{weight lifting-referents} 1.46 (0.76–2.80), OR _{shooting-referents} 1.16 (0.52–2.58)]
Viikari-Juntura et al (104) ^a	5	2900 Finnish-speaking children under the age of 14 years, follow-up response 28% Included in this study were 180 respondents who lived in the Helsinki metropolitan region, 162 of these participated	1. Pain, ache, stiffness or numbness in the low-back region during the last 12 months and a mean disability index of ≥ 15 at the last follow-up in 1986–1987 2. Pain, ache, stiffness, or numbness in the low back >7 days or a mean disability index of ≥ 15 at the last follow-up in 1986–1987 (questionnaire)	32 years, 4 measurements	Work among women (questionnaire 1985, adjusted for alexithymia, social confidence, fundamental education, sense of coherence and twisted or bent torso, outcome 1): Physical heaviness of work [OR 0.02 (0.00–1.90)]

^a The article on this study does not make exactly clear when what was measured.

^b Some of the results of the multivariable analyses in the article(s) on this study were disregarded in the data abstraction because it was only reported that a factor did not enter the model in stepwise modeling.

^c It is unclear if the analysis of risk factors in this study was really based on longitudinal data.

^d More results of this study, for example, with different operationalizations of back pain, are presented in a more-detailed version of this table, which is available from the author. The results that are presented were used in the assessment of the levels of evidence.

^e The article on this study does not make exactly clear how the exposure of persons without complaints was assessed, and therefore it is not possible to judge if the conducted statistical analysis is correct.

^f Variables concerning physical load at work were also examined in this study, but disregarded in the data abstraction because the information was derived from an open question in which it was asked to report the work-related stressful factors that were experienced, three at most.

^g The results for work-related risk factors for a multivariable analysis including occupation in the article on this study were disregarded in the data abstraction because of the possibility of overadjustment due to the high correlation between occupation and work-related risk factors.

lifting and moving of patients. All the studies found a statistically significant positive effect for patient handling. According to these results there is moderate evidence that patient handling is a risk factor for back pain. The magnitude of the risk estimates (RR/OR) ranged from 1.7 to 2.7.

Bending and twisting

Two high-quality studies reported on the effect of bending and twisting (79, 82). Both studies found a statistically significant positive effect for bending and twisting. According to these results there is strong evidence for a positive effect for bending and twisting. In the only study that presented an effect estimate, an odds ratio of 8.1 was found (79).

Standing or walking

Three high-quality studies determined the effect of prolonged standing or walking (49, 67, 78). One found a statistically significant positive effect for prolonged standing or walking (67), and 1 found no effect (78). The third study only reported that no statistically significant effect

was found (49). According to these inconsistent results, there is no evidence for an effect of prolonged standing or walking.

Sitting

Two high-quality studies (49, 67) studied the effect of prolonged sitting. One found a statistically significant negative effect for women only (67), and the other only reported that no statistically significant effect was found (49). Therefore, no evidence was found for an effect of prolonged sitting.

Whole-body vibration

Three high-quality studies and 1 low-quality study examined the effect of driving a car (67, 72, 77, 78) and a 4th high-quality study evaluated the effect of whole-body vibration (82). This latter study included a group of machine operators. The exposure of the back during machine operating is somewhat similar to that when driving a car, namely, low-frequency whole-body vibration in a seated position. Three high-quality studies found a statistically significant positive effect for this exposure (77, 78, 82).

Table 4. Summary of the case-referent studies on physical load and back pain. (MQS=methodological quality score based on items on validity and precision, OR = odds ratio, the corresponding 95% confidence interval is given in parentheses)

Authors	MQS	Study population	Definition of cases and referents	Results
Nuwayhid et al (77) ^a	11	Over 900 fire fighters and 1900 fire officers assigned to 142 ladder and 210 engineer companies; N=115 cases (response 62%) and 109 referents (response 75%)	Cases: full-duty fire fighter, who reported low-back pain to the New York City Fire Department clinic, was evaluated by the physician in charge and received ≥ 1 day medical leave during the 6-month study period; persons with previous low-back pain, professional care or lost workdays were excluded Referents: full-duty fire fighters with no previous low-back pain experience or with earlier episodes that did not entail professional care or loss of workdays	Work (interview): physical exertion in index on-duty period [OR 3.71 (1.94—7.10)], driving more miles weekly ($P \leq 0.05$) Work in index on-duty period (interview, adjusted for rank, previous occupation, steps climbed, driving, second job, off-duty activity): lift loads > 18 kg [OR 3.07 (1.19—7.88)] Nonwork in index off-duty period (interview): exercise [OR 0.73 (0.43—1.25)], driving ≥ 25 miles [OR 1.27 (0.75—2.16)], at least one activity on composite index of off-duty activities [OR 0.41 (0.23—0.73)]
Punnett et al (79—81) ^b	11	Employees of an automobile assembly plant; N=95 cases (response 82%) and 124 referents (response 84%)	Cases: new reports of back disorders during the 10-month study period and who had symptoms in an interview Referents: workers with no report of a back disorder during the study period and who had no symptoms or signs of back disorders in an interview and an examination and who had no medical report for any back, neck, or shoulder disorder within the 90 days preceding the study	Work (video-based observations, adjusted for age, history of back injury or ruptured spinal disc prior to onset of pain and for the other variables shown, no adjustment necessary for years in the plant, years in current job, history of systemic disease, type of weekly recreational activity, hours per week in hobbies or sports, estimated peak low-back compressive force): proportion of the work cycle maintained in mild flexion, severe flexion, and twisting [OR _{0—0%} 1.2, OR _{30%—0%} 1.8, OR _{50%—0%} 2.7, OR _{100%—0%} 8.09 (1.5—44.0)], lifting or holding of a part ≥ 44.5 N [OR 2.16 (1.0—4.7)] Nonwork: engagement in outside activity (hobbies, sports or second jobs [OR 1.16 (0.66—2.05)]
Ryden et al (101)	7	Employees at a children's hospital and health center; N=84 cases and 168 matched referents	Cases: employees with reported low-back injuries while employed at a children's hospital and health center in 1983—1985 Referents: selected from the same population and matched by age, gender and department or physical requirements of the job	Nonwork (employee health records, adjusted for age, gender and department): exercise [OR 1.33 (0.44—2.84)]

^a The article on this study presents two effect estimates for lifting of loads, both adjusted for confounders. One of the presented estimates was lower and nonsignificant due to the inclusion of severity of alarms, a variable that was highly correlated with lifting of loads and therefore disregarded in the data abstraction.

^b More results of this study are presented in a more-detailed version of this table, which is available from the author. The results that are presented were used in the assessment of the levels of evidence.

One high-quality study found a nonsignificant positive effect of driving a car for women only (67). According to these results there is strong evidence that whole-body vibration is a risk factor for back pain. The 2 studies that presented an effect estimate found an odds ratio of approximately 4.8 (67, 78).

Heavy physical work

Finally, there were several studies which did not study specific aspects of physical load, but evaluated physical activity in the workplace in general. Five high and 6 low-quality studies reported on the effect of this exposure (27, 29, 38, 60, 61, 73, 74, 77, 94, 96, 104). Since 4 of the high-quality studies only reported that no statistically significant effect was found (29, 38, 61, 73), assessment of the consistency of the evidence for this exposure was based on the combined results of the 1 high- and the 5 low-quality studies that reported an estimate or the direction of the effect found. One study found a nonsignificant negative effect for heavy physical work (104). Five studies showed that a high level of physical activity had a statistically significant positive effect (60, 74, 77, 94,

96). According to these results there is moderate evidence that a high level of physical activity is a risk factor for back pain. The magnitude of the risk estimates (RR or OR) ranged from 1.5 to 9.8.

The studies differed somewhat in the timing of the exposure. The effect of a cumulative work load (94), the effect of short-term physical exertion (77) and current physical work-load at baseline (60, 74, 96) were examined. It was, however, not possible to draw separate conclusions for the cumulative and short-term effects of heavy physical work.

Sensitivity analysis

For manual materials handling, patient handling, bending and twisting, whole-body vibration, and heavy physical work it was concluded that there was (strong or moderate) evidence of an effect. Considering all the studies that found a nonsignificant effect for these exposures to indicate no effect did not change the conclusions for manual materials handling, patient handling, bending and twisting, or whole-body vibration. For heavy physical work this assumption would mean that 6 studies

indicated no effect, and 5 studies indicated a positive effect, and therefore the conclusion would be drawn that there is no evidence for an effect of heavy physical work, due to inconsistent findings.

Physical load during leisure time

Sports

Six high- and 5 low-quality studies examined the effect of sports activities (52, 60, 62, 73, 76—78, 82, 87, 96, 101). Two high-quality studies that only reported that no statistically significant effect was found and 1 high-quality study that reported a significant effect, but did not show the direction of the effect, were excluded from the evaluation of the evidence (52, 73, 78). Of the remaining high-quality studies, one found a statistically significant positive effect for physical activity (82), one found a statistically significant negative effect among men and no effect among women (62), and one found a nonsignificant negative effect (77). According to these inconsistent results there is no evidence for an effect of sports activities.

Total physical activity during leisure time

Four high-quality studies and 1 low-quality study examined the effect of total physical activity during leisure time (62, 75, 77, 86, 100). Total physical activity during leisure time includes sports activities and other physical activities such as gardening, walking, traveling to and from work, and housework. One high-quality study found a statistically significant negative effect for off-duty activities (77). The other high-quality studies only reported that no statistically significant effect was found (62, 86, 100).

One high-quality study and 2 low-quality studies examined the effect of physical activity, but did not make it explicitly clear whether this only involved sports or exercise or also included other leisure-time physical activities. The high-quality study only reported that no statistically significant effect was found (29, 46). According to these results there is no evidence for an effect of total physical activity during leisure time.

Specific sports and physical activities during leisure time

Four studies determined the effect of participation in specific sports, namely, golf (49), cycling (96) and athletic training (55, 103). No evidence was found that any of these were risk factors because either there was only 1 study available (49, 96) or the findings were inconsistent (55, 103).

Two high-quality studies focused on the effect of driving a car during leisure time. One study (82) found no statistically significant effect for annual car driving (total kilometers) and the other found no effect of driving more than 25 miles (40 km) in the off-duty period before the report of low-back pain (77). According to these results there is no evidence for an effect of driving a car during leisure time.

Discussion

Selection of studies

Although a systematic approach with a large variation of key words was used and references of selected articles were screened to identify all the available literature, the possibility of selection and publication bias cannot be excluded.

An important difference between this review and previously published reviews on the same topic is the exclusion of studies with a cross-sectional design. The main argument for the exclusion of this type of study is that temporality, the only unarguable and therefore necessary criterion for causality (105), is not met in cross-sectional studies, in which exposure and outcome are assessed simultaneously. Cohort studies were only included if the follow-up period was at least 1 year. The major reason for this restriction was that the follow-up needs to be long enough to record sufficient cases of back pain.

In addition, the choice was made to include studies with a fairly broad spectrum of outcome measures. This can lead to contradictory findings if the effect of an exposure is specific to certain categories of the outcome but, on the other hand, maximum power can be achieved (106). Since symptoms, reports of back pain, sick leave, medical consultation, or treatment and disability due to back pain are all part of a continuum, it was assumed that any factor that causes the back pain itself will have an effect on all these outcome measures. However, some factors may not only affect the development, but also the prognosis of back pain. Eventually, in most studies the assessment of the outcome was based on symptom reporting, mainly due to the lack of generally accepted criteria for an objective clinical diagnosis of back pain. Unfortunately, the operationalization of back pain based on the symptom reporting used in the included studies did not make it possible to examine the risk factors for different groups of back pain, classified based on characteristics such as the duration, frequency, intensity, and localization of the pain. (107) Studies with a diagnosed herniated lumbar disc as the outcome measure were excluded, because a separate review of risk factors for this more homogeneous disease entity was regarded to be more appropriate.

Assessment of evidence

The main difference between this review and previously published reviews on the same topic is the application of a systematic approach which includes explicitly defined criteria, on which the conclusions on the strength of the evidence were based. The review could only be qualitative, because, in many of the studies reviewed in this paper, quantitative measures of effect were missing for at least some of the exposures of interest. Moreover, the methods used to measure exposure are often so different that it is not possible to compare the evaluated contrasts of exposure.

Scoring the quality of a study plays an important role in the assessment of the strength of the evidence. However, it is only meant to distinguish between high- and low-quality studies. Criteria lists adapted from lists used in the clinical literature and in other reviews of observational studies were used to assess the methodological quality of the studies. As in the clinical literature, it is still unclear which items are especially important because of the influence of bias (16). One of the specific problems encountered in this review of observational epidemiologic studies, compared with reviews of clinical trials which usually evaluate only 1 contrast, is the fact that the relatively broad objective of this review and most of the evaluated studies resulted in a relatively nonspecific list of criteria. As the evidence for more than 1 exposure per study was evaluated, it was not possible to include a criterion on the power of each individual study. The most appropriate solution to the problem raised would be a series of reviews, each focusing on 1 specific risk factor. Only for such reviews could really specific criteria lists be developed. However, an advantage of a review like ours, with its broader focus over reviews with a more specific focus, is that it offers the possibility to compare the evidence found for different risk factors.

Criterion 5, which only pertains to the list for case-referent studies, may sound contradictory, because the exclusion of subjects with recent back pain from the reference group may be considered incompatible with the requirement that cases and referents have to be drawn from the same population. The criterion reflects that, on one hand, it is important that cases and referents be drawn from the same population and selected independently of their exposure status to make sure that the referents are representative of the source population with respect to exposure. While, on the other hand, there has to be a clear contrast between cases and referents with respect to the disease in question. For recurrent outcomes like back pain this is more difficult than for diseases like cancer. With the exclusion of subjects with low-back pain during the previous 90 days from the reference group, one can make sure that there is a real contrast in disease status between cases and referents.

Another problem which arises from the rating system applied in this review is that the synthetic approach can give a false impression of consistency across study results, because all the studies were prone to a common systematic error (106), such as (residual) confounding. With regard to the definition of the levels of evidence applied in this review, it could be argued that the conclusion could be limited evidence instead of no evidence if only 1 study evaluated the exposure. This procedure was decided against because the consistency of results, an important aspect of the definition of the other levels of evidence in this review, cannot be evaluated on the basis of 1 single study.

In spite of the limitations of defining levels of evidence, it was thought that this approach was appropriate in the present qualitative review. One important advantage is that the reader is given a lot of insight into the process used to assess the evidence. And there is also the possibility to repeat the analysis and to examine how the conclusions are influenced if slight changes are made in the assessment of the findings or the methodological quality of the studies. The sensitivity analysis already included the effect of a different way of dealing with nonsignificant findings. Another means of assessing the methodological quality of a study is to use another cut-off point for the assessment of high-quality studies. The use of a cut-off point of 40% for the assessment of high-quality studies leads to an increase in the number of high-quality studies, which, in turn, leads to strong instead of moderate evidence for the effect of patient handling and heavy physical work. This change would not influence the conclusions with regard to the other exposures, and the use of a cut-off point of 60% does not affect the conclusion for any exposure. Moreover, the results of the review are rather insensitive to the exclusion of the items on the assessment of different exposures (items 8—13) from the criteria list for the methodological quality assessment. Thus the conclusions drawn in this review are also rather insensitive to a slightly different assessment of high- and low-quality studies.

Quality of the studies

An examination of the scoring of studies on the various items shows that all the studies had a clearly defined objective. However, this objective did not always include an examination of the exposures of interest in this review (53, 55, 73, 86, 104). Twenty percent of the studies failed to describe the main features of the study populations, and very few studies used standardized methods of acceptable quality for the assessment of physical load at work and back pain. Furthermore, the rate of participation at base line was less than 80% in approximately two-thirds of the studies. Some 60% of the cohort studies collected data on the outcome at least every 3 months, most

of which used registered data, and many of these studies did not report on the loss to follow-up in their registration system. Three cohort studies did not collect data on the occurrence of back pain for at least 1 year, although the follow-up period was at least 1 year. These studies used the point prevalence of back pain at the end of follow-up as an outcome measure (46, 75, 94). Due to the low number of case-referent studies, it was not possible to present data on the scoring of the specific criteria for this study design.

There are also a few aspects of the quality of the studies that were not included in the criteria list, but were observed during the scoring of the studies. Hardly any studies included repeated measurements of the exposure, although there were many studies with an extremely long follow-up period during which the exposure easily could have changed considerably (27, 60, 61, 72, 100, 103). Moreover, some of these studies did not assess the occurrence of back pain for the entire follow-up period (61, 62, 100, 103). The studies included in the review do not provide much insight into the effect of adjustment for certain covariates, because only a few studies showed the effect estimate for a certain exposure with and without adjustment for covariates (79, 102, 103).

Evidence for aspects of physical load during work as risk factors for back pain

For manual materials handling, bending and twisting, and whole-body vibration it was concluded that there was strong evidence for an effect. For patient handling and heavy physical work it was concluded that there was moderate evidence for an effect. To exclude the possibility of a false impression of consistency of the findings, the potential lack of controlling for likely important confounders was examined for these exposures. In general, only a few studies on lifting, bending and twisting, driving or whole-body vibration, and heavy physical work had adjusted for other physical and psychosocial factors at work. None of the studies had adjusted for physical load during leisure time. The effect of driving a car has been attributed to whole-body vibration on one hand and to prolonged sitting on the other. However, none of the studies on driving a car or whole-body vibration had adjusted for prolonged sitting.

In the sensitivity analysis, instead of moderate evidence, no evidence was found for the effect of heavy physical work. For this exposure 6 studies only reported that no statistically significant effects were found. However, it is debatable whether these studies can lead to the conclusion that there is no effect. In the original papers of 4 studies (29, 38, 73, 104) it was emphasized that physical work load factors could not be effectively studied, due to the method of selection of the subjects in combination with the nonspecific method used for the assessment of the exposure. In the 2 other studies, the absence

of an effect could be explained by the relatively long follow-up period, which probably coincided with changes in exposure (27, 61). In addition, the effect of physical load was analyzed separately for white- and blue-collar workers, and the occurrence of back pain was only assessed for the last 12 months of the 10-year follow-up period (61).

For standing or walking, it was concluded that there was no evidence because of the contradictory findings. The only study that found an effect had only adjusted for prior back pain (67), and the study in which no effect was found had also adjusted for other aspects of physical load at work (78). However, it is debatable whether this difference in study results indicates the presence of confounding. The absence of an effect in the second study could also have been caused by the combination of a population of persons with similar work conditions and a badly defined measure of exposure, namely, a yes-no question about frequent prolonged standing. No evidence was found for an effect of sitting because the available information was too limited.

Prolonged sitting and standing are both assumed to be a risk factor for back pain because, among other things, they are both aspects of static load. Prolonged working in awkward postures is also an aspect of static load. However, with regard to sitting, standing, and working in awkward postures, none of the studies adequately evaluated the static effect of these exposures. Appropriate measurements for static load of the trunk, which should preferably be included in future studies, are the total duration of working continuously in a certain posture for longer than a certain period of time and the number of changes in posture during a workday for all parts of the body separately and combined.

Evidence for aspects of physical load during leisure time as risk factors for back pain

There appeared to be no evidence for an effect of sports, due to inconsistent findings. The available studies differed in their individual definition of back pain, the composition of the study population, the control for confounding, and also the time-period between the measurement of exposure and back pain. Moreover, no evidence was found for an effect of total physical activity during leisure time, various specific sports, or other physical activities during leisure time.

One important aspect of all the studies on physical activity during leisure time was that the operationalization of physical activity in the studies differed and was, in general, not very specific. It has been concluded that in epidemiologic studies on the role of physical activity in the etiology of diseases, the type, intensity, frequency, and duration of physical activity should be addressed and the measurement method should be in agreement with the disease in question (108). The methods used in

most of the studies included in this review do not meet these criteria. Therefore, it may be worthwhile to develop new methods to measure physical load during leisure time and to evaluate more adequately the effect of this exposure. If this process results in a method involving operationalizations that correspond to the measurements of physical load at work, it may also enhance the possibility to study these exposures simultaneously.

Comparison with the results of previous reviews

It is interesting to see how the conclusions of this review compare with the conclusions of 2 other recently published reviews on the same topic (9, 11). With regard to the work-related physical factors, it appears that there is no significant difference in the conclusions. Both reviews (9, 11) conclude that there is evidence for an effect of lifting, bending and twisting, whole-body vibration, and heavy physical work. Burdorf & Sorock (11) also concluded that the evidence for exercise and sports is contradictory.

Concluding remarks and recommendations

According to the literature reviewed in this paper, there is moderate evidence that patient handling and heavy physical work are risk factors for back pain, and strong evidence that manual materials handling, bending and twisting, and whole-body vibration at work are risk factors for back pain. However, to determine the priorities for intervention in the workplace, it is also important to be aware of the magnitude of the effect of the various risk factors. For the purpose of evaluation, future studies should include quantitative measurements of exposure and report effect measures that reflect the risk of equivalent levels of contrast in exposure, measured in a comparable way. This procedure would make it possible to quantify the role of different risk factors in a meta-analysis.

For standing or walking, sitting, and various aspects of physical load during leisure time it was concluded that there was no evidence of an effect. For these risk factors, further well-designed research is needed if a conclusion is to be drawn on the presence or absence of an effect of these factors. With regard to physical load at work, adequate measures of static load must be related to the occurrence of back pain. Appropriate methods must also be developed to measure the relevant aspects of physical load during leisure time, and the combination of exposure to physical load during work and leisure time should also be addressed.

The results of this review are rather insensitive to slight changes in the assessment of the findings and methodological quality of the studies. The application of a systematic approach, adapted from the evaluation of randomized controlled trials on intervention for back pain, in the review of observational epidemiologic studies is

shown to be worthwhile, notwithstanding the problems encountered.

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Received for publication: 8 January 1999

Appendix

Methodological quality assessment: criteria lists for assessment of the methodological quality of prospective and historical cohort studies and case-referent studies

Criterion	Design ^a	I, V/P ^b
Objective of the study		
1. Positive if the study had a clearly defined objective	CH/CR	I
Study population		
2. Positive if the main features (description of the sampling frame, distribution of the population according to age and gender) of the study population were described	CH/CR	I
3. Positive if the participation rate at base line was at least 80%	CH	V/P
4. Positive if the response after 1 year of follow-up was at least 80% of the number of participants at base line or if the nonresponse was not selective (data shown)	CH	V/P
5. Positive if the cases and referents were drawn from the same population and a clear definition of cases and referents was given. Subjects with low-back pain during the previous 90 days must have been excluded from the reference group	CR	V/P
6. Positive if the participation rate of the cases and referents selected and invited to participate at base line was at least 80%	CR	V/P
Exposure measurements, physical load at work		
7. Positive if data on physical load at work were collected and included in the statistical analysis, data on physical load at work based on information about job title (job-exposure matrix) were not considered to be appropriate	CH/CR	V/P
8. Positive if data were collected by means of standardized methods of acceptable quality ^c	CH/CR	V/P
Exposure measurements, psychosocial factors at work		
9. Positive if data on psychosocial factors at work were collected and included in the statistical analysis.	CH/CR	V/P
10. Positive if data were collected by means of standardized methods of acceptable quality ^c	CH/CR	V/P
Exposure measurements, other		
11. Positive if data on physical or psychosocial exposure during leisure time were collected and included in the statistical analysis	CH/CR	V/P
12. Positive if data on historical exposure at work were collected and included in the statistical analysis	CH/CR	V/P
13. Positive if data on history of back pain, age and gender were collected and included in the statistical analysis. Data on history of back pain should have been based on information about the presence of back pain during at least 1 year before base line	CH/CR	V/P
14. Positive if the exposure was measured in an identical manner among the cases and referents	CR	V/P
15. Positive if the exposure assessments were blinded with respect to disease status	CR	V/P
16. Positive if the exposure was assessed prior to the occurrence of the outcome	CR	V/P
Assessment of back pain		
17. Positive if based on standardized methods of acceptable quality, namely, positive if one of the following criteria were met: (i) self-reported: data presented or in reference showed that the intraclass correlation coefficient was >0.60 or the kappa was >0.40 for the test-retest reliability; (ii) registered data: data presented or in reference demonstrate that the registration system is valid and reliable; (iii) physical examination blinded with respect to exposure status: data presented or in reference showed that the intraclass correlation coefficient was >0.60 or the kappa was >0.40 for the intraobserver reliability if only 1 observer is involved or the interobserver reliability if >1 observer is involved. If no intraclass correlation coefficient or kappa had been computed, but the data presented showed clearly that the reliability of the method was good, this criterion was also rated positively	CH/CR	V/P
18. Positive if the time-period on which the assessment of back pain was based was at least one year	CH	V/P
19. Positive if data were collected at least once every three months or obtained from a continuous registration system	CH	V/P
20. Positive if incident cases were included (prospective enrollment)	CR	V/P
Analysis and data presentation		
21. Positive if the method used for the statistical analysis was appropriate for the outcome studied and the measures of association estimated according to this model (including confidence intervals) were presented	CH/CR	V/P
22. Positive if the analysis included a stratified or multivariable analysis	CH/CR	V/P
23. Positive if the number of cases in the final multivariable model was at least 10 times the number of the independent variables in the analysis	CH/CR	V/P

^a This column shows whether a criterion pertains to the criteria list for cohort (CH) and/or case-referent (CR) studies.

^b I=criterion on informativeness, V/P=criterion on validity/precision.

^c This criterion was rated positively if one of the following criteria was met: direct measurement method: data presented or in reference showed that the intraclass correlation coefficient was >0.60 or the kappa was >0.40; observational method: data presented or in reference showed that the intraclass correlation coefficient was >0.60 or the kappa was >0.40 for the intraobserver reliability if only 1 observer was involved or the interobserver reliability if more than 1 observer was involved; self-reported: data presented or in reference showed that the intraclass correlation coefficient was >0.60 or the kappa was >0.40 for the test-retest reliability. If no intraclass correlation coefficient or kappa had been computed, but the data presented showed clearly that the reliability of the method was good, this criterion was also rated positively.