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# Exposure measurement technique and its effect on the association of physical load and back disorders

by

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## Abstract

*In epidemiologic studies on low back disorders measurement techniques for physical load can be classified into self-reports, observations, and direct measurements. The choice for a particular measurement technique depends on appreciation of the applicability in various situations. The aim of the present paper is to review the scientific literature on work-related back disorders in order to evaluate the strength of the associations between physical load and back problems among different studies, and, second, to analyse whether the strength of the associations can partly be explained by the measurement strategy chosen. Forty-three publications were selected with quantitative information on physical load and back disorders. The analysis showed that the strength of association is, next to the work-related risk factor studied, partly explained by independent effects caused by the measurement technique and study design. Observations and direct measurements are less prone to information bias and, hence, will result in a better assessment of the true effect.*

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## Samenvatting

In epidemiologische studies naar rugklachten kunnen de technieken om fysieke belasting te meten onderscheiden worden in vragenlijsten, observaties op de werkplek en continue registraties met elektronische instrumenten. De keuze voor een meettechniek wordt bepaald door de toepasbaarheid in een bepaalde situatie. Het doel van deze review is ten eerste om de sterkte van de verbanden tussen fysieke belasting en rugklachten zoals gerapporteerd in de wetenschappelijke literatuur samen te vatten en ten tweede om te onderzoeken in welke mate de sterkte van deze verbanden verklaard wordt door de gebruikte meettechnieken. Drieenveertig publicaties met kwantitatieve informatie over fysieke belasting en rugklachten werden geselecteerd. De analyse liet zien dat de sterkte van de associatie wordt bepaald door het type fysieke belasting op de werkplek en de gekozen meettechniek. Observaties op de werkplek en continue registratie bleken minder gevoelig voor meetfouten en resulteren zodoende in een betere schatter van het ware effect van fysieke belasting op rugklachten.

## Keywords

Epidemiology, lifting, meta-regression, postural load, review.

## Introduction

For several decades back disorders have been recognized as a major cause of disability and sickness absence among many occupational groups. Among others, physical load has been identified as a significantly contributing factor in the occurrence of back problems. In epidemiologic studies physical load cannot be determined independently from the worker. Posture, movement, and external load are the result of both physical requirements forced on the worker and of the worker's capacity to adopt particular techniques to perform the assigned tasks. When moving from exposure to dose, the worker's interaction with the workplace will play a crucial role; thus, the assessment technique should encompass exposure as well as dose measures (1)

Despite the evidence associating low-back pain with this variety of work factors dose respons-relations are far from clear (2, 3). Most epidemiologic studies have presented crude associations between risk factors and back problems, with risk factors determined at qualitative levels and health end points defined as non-specific disorders. This qualitative assessment of risk factors is often based on an expert's opinion on presence or absence of generic risk factors such as awkward postures, static load, and heavy labor (4, 5). In order to study dose-respons relationships between physical load and low back-pain, attention needs to be directed at quantitative characterization of physical load.

Measurement techniques in epidemiologic research can be classified in self-reports, observations, and direct instrumentation. Self-reports, most often used, refer to information gathered by the worker's respons to questions in questionnairres, diaries, or interviews. In the past two decades observation techniques and direct measurement techniques have become available to assess physical load in the workplace (6). These methods consist of recording information by systematic observation of the worker on the job either by a trained observer or a video-based system. Direct measurement techniques monitor a certain factor over time, using a device specifically designed for that purpose. Although direct measurement techniques offer the highest level of precision and accuracy, the major limitations are the costs and feasability, especially in large epidemiologic studies. Anyhow, an increasing number of epidemiologic studies have used these measurement techniques to assess physical load.

The aim of the present paper is to review the scientific literature on work-related back problems of the past 20 years in order to evaluate the strength of the associations between physical load and back disorders in different studies. A second aim is to evaluate whether the strength is explained by the measurement technique used. In order to illustrate the potential effect of measurement techniques on the occurrence of low back problems, a practical example is presented in a study among nursing home personnel in the Netherlands.

## Material and methods

### *Selection procedure of references and method of analysis*

An extensive search of available literature was made for epidemiologic studies published from January 1980 to December 1999. Computerized searches were carried out on several databases including MEDLINE

(National library of Medicine, United States of America), NIOSHTIC (National Institute for Occupational Safety and Health, United States of America), HSELINE (Health and Safety Executive, United Kingdom), CIS-DOC (International Labour Organization, Switserland) and Ergoweb (University of Utah homepage). Furthermore, various review articles were browsed for useful references. The search was restricted to articles in the english language. All possible articles were collected and scrutinised for the description of the occurrence of back problems in relation to specific groups or specific work loads. In total, 255 articles were eligible for initial conclusion and subsequently scrutinized for available information.

Six 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 criterion excluded all review papers (15%). The second exclusion criterion targeted papers (4%) which presented an additional analysis of previously published material whereby this secondary analysis largely confirmed earlier findings. The third exclusion criterion addressed the lack of clear information on incidence or prevalence of back disorders in the study population (4%). Description of disease frequency was regarded as essential in order to summarise associations between physical load and occurrence of back problems in epidemiologic risk measures. Hence, some studies with an ecological approach using disease rates without describing the distribution pattern of these rates over different exposure levels were not taken into account. The fourth exclusion criterium pertained to quantitative information on work-related risk factors, i.e. a clear definition and description of the determinants of physical load and their distributions among the subjects of study. On this criterion 101 (40%) articles were excluded. The fifth exclusion criterion comprised 39 (16%) articles that did not contain a suitable risk estimate for work-related risk factors or sufficient information that allowed calculation of the risk estimate. The sixth exclusion criterion was used to eliminate 16 (6%) articles with serious methodological concerns in relation to the particular purposes of the review undertaken, i.e. studies with low participation rates (below 70%) and studies very likely affected by serious recall bias.

Thus, there remained 43 (17%) publications (7-49) that met the above selection criteria. The 43 publications comprise 44 studes since 1 publication covered both a cross-sectional and a longitudinal study (35). The main characteristics of these publications are summarized in Annex tables A1 to A4. In these tables 3 publications are not included since no significant association was presented (7, 28, 38). These articles formed the basis for the evaluation of the effect of measurement techniques on the associations between physical load and the occurrence of back problems.

*Data extraction and analysis*

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. 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 the interpretation of the results of the publications, information on the work related risk factor, measurement technique, study design, study size, and level of multivariate analysis were extracted. In the present review, studies were classified in one of the following work related risk factors: manual materials handling, frequent bending and twisting, heavy physical load, static work posture, repetetive movements, and whole body vibrations. Measurement technique was classified in self-reports, observations at the workplace, and direct measurent techniques. Study design was classified in cross-sectional studies, case-control studies, longitudinal studies, and community studies. Study size was classified in studies with less than 250 subjects, 250-1000 subjects, and over 1000 subjects. Level of multivariate analysis was defined by the number of confounders adjusted for in the analysis.

To evaluate the impact of the measurement technique on the associations between physical load and back problems, a random effect meta-regression model was defined where the risk estimates are modeled conditional on the measurement technique according to model (1).

$$E\,(r \mid M\ P\ C) = \alpha + M\,\underline{\beta} + P\,\underline{\gamma} + C\,\underline{\varphi}$$

Where r is the risk estimate of the association between risk factors and the occurrence of back problems in the studies. Matrix **M** contains information on the measurement technique in the studies. The matrix **P** contains the random effects across studies. Matrix **C** contains information on the covariates (study design, study size, and level of adjustments). $\alpha$ is the intercept term; $\underline{\beta} = (\beta_1, \ldots, \beta_l)'$ is the column vector of risk-regression coefficients corresponding to the three measurement techniques (self-reports, observations, measurements). In this analysis self-reports were defined as the reference category, hence $\beta$ expresses the increment in the risk estimate for a study with exposure based on observations or direct measurements compared with studies based on self-reports. $\underline{\gamma}$ is the vector with independent normal random variables with zero means. $\underline{\varphi}$ are the vectors of risk-regression coefficients corresponding to covariates (the type of work related risk factor, study design, study size, and number of confounders adjusted for in the multivariate analysis). The parameters of model 1 were estimated using the MIXED procedure available with SAS statistical software (SAS, inc., Cary, NC).

## *Study among nursing home personnel*

### *Population*

The subjects in the present study (n = 769) participated in a large epidemiologic study among nursing home personnel. The study population consisted of 12 different professions: 26 head nurses and head care givers, 103 nurses, 10 student nurses, 254 care givers, 17 cooks, 41 kitchen workers, 49 housekeepers, 14 transportation and technical workers, 9 laundry workers, 38 (physical) therapists, 146 office workers and workers in management, and 62 miscellaneous workers. All subjects worked for more than 10 hours a week.

### *Assessment of physical load*

*Self-reports.* Among all workers in the study population information on trunk flexion, rotation, lifting loads, and sitting during work was gathered by the following question: “Do you have to…. at work?”. Possible answers were: “Never, sometimes, often, or always”.

*Observations.* Among a random sample of 299 workers, observations at the workplace were performed to collect information on physical load during work among the 12 *a priori* defined occupational groups by means of a multimoment method. It is based on instant interval sampling during either a limited number of work cycles over the course of the workday, or a representative period of work activities and distinguishes different postures and movements. In this study an observational multimoment method was used to describe trunk flexion over 45 degrees, combined flexion and rotation, lifting loads of more than 10kg, and sitting at work among the workers. On each of the workers every 20 seconds observations were made during 4 period of 30 minutes, thus collecting 360 observations per worker. Exposure for each worker within the whole study population was determined by a group-based technique. On basis of the 299 observed workers for each occupational group the average percentage of work time with a strenuous posture or extertion of forces was calculated. Subsequently, for each worker in the study (n = 769) the personal exposure to physical load was modeled by multiplying the group’s average exposure with the number of work hours per week. Subsequently, exposure was categorised in four quartiles.

Information on back problems was gathered with self-administered questionnaires. The questions were derived from the Nordic questionnaire for the analysis of musculoskeletal symptoms (50). “Back problems” were defined as any complaints in the lumbar region in the past 12 months. In total, 448 (58%) of the subjects reported an episode of back problems in the past 12 months. In addition to the physical factors, the occurrence of the psychosocial work demands “working under pressure”, “social support”, and “work pace” was ascertained. Exposure to these covariates was based on dichotomous self-reports and combined in one dichotomous measure. The risk of back problems conditional on physical load and covariates was described using a logistic regression model.

## Results

### *Findings*

Figure 1 summarizes the results of the 43 articles selected in this review stratified by work-related risk factor (7-49). In Annex A1 to A4 an extensive

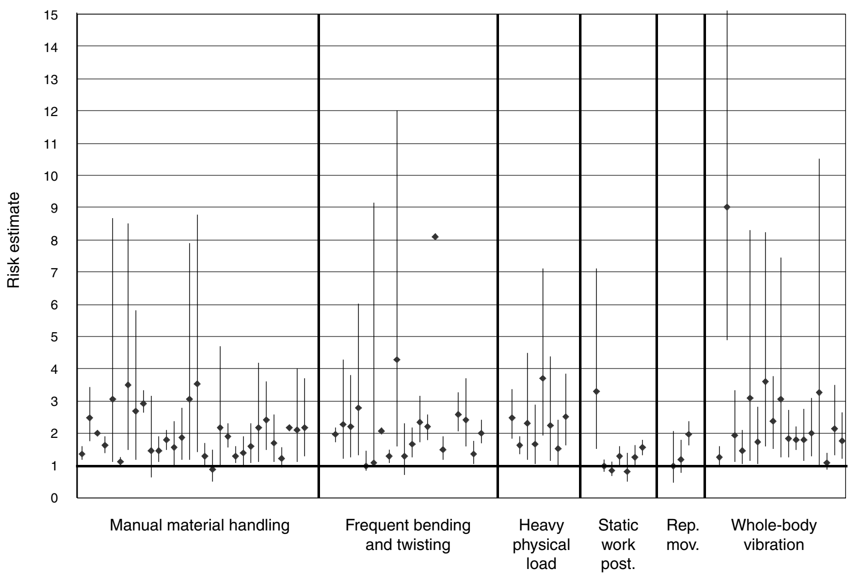


*Fig. 1:* Risk estimates and 95% confidence intervals for different work related risk factors of 44 epidemiologic studies on back pain in occupational populations.

description of the basic characteristics of the studies is given. In 27 studies (61%) (6, 8, 18-20, 23, 26-28, 30-36, 39-48) that investigated the effects of manual material handling on back problems, risk estimates were found ranging from 0.90 up to 3.54. In the 18 studies (41%) (7, 13-15, 17, 18, 23, 25, 26, 30, 31, 36-39, 43, 45, 49) concerning frequent bending and twisting the risk estimates ranged from 1.08 up to 8.09. Seven studies (16%) (22, 24, 25, 29, 33, 44, 49) showed that the risk estimates of heavy physical load ranged from 1.54 up to 3.71, and in 6 studies (14%) (16, 23, 30, 35, 45, 49) static work posture showed risk estimates from 0.80 up to 3.29. Furthermore, 3 studies (7%) (21, 29, 29) concerning repetetive movements showed that the estimates ranged from 0.98 up to 1.97, and in 15 studies (34%) (7, 9-15, 30-32, 35, 37, 39, 49) where whole body vibration was the aim of investigation, risk estimates from 1.10 up to 9.00 were found.

### *Study characteristics*

In table 1 the study characteristics of the included studies are presented. Division by measurement techniques showed that in 31 studies (70%) self-reports were used for data collection, 8 (18%) used observations at the workplace, and 5 studies (11%) used direct measurement techniques. A cross-sectional design was most often performed and longitudinal designs were least often conducted. Most studies had a reasonable size, but case-control studies tended to have the smallest study population. Adjustment for confounding in the multivariate analysis ranged from 0 to 8 confounders, but most studies only controlled for a few confounders.

The results of the meta-regression analysis are presented in table 2. It is shown that, adjusted for type of work-related risk factors and study characteristics, studies using observations at the workplace reported on average an increment of 1.13 in the risk estimate of the association between risk factor and occurrence of back problems ($\beta$ = 1.13, 95% CI −0.06; 2.33) than studies using self-reports, but this difference was only borderline significant. Studies relying on direct measurement techniques showed a similar increment of 1.18 ($\beta$ = 1.18, 95% CI 0.30; 2.07), which was statistically significant. Between observations and direct measurement techniques no significant difference was found. Furthermore, longitudinal studies showed significantly higher risker estimates than cross-sectional studies and case-control studies. Study size and number of confounders did not have an impact on the strength of the associations between risk factors and back problems.

TABLE 1
*Study characteristics of 44 epidemiologic studies on back pain in occupational populations*

| | Number of studies |
|---|---|
| **Work related risk factor** | |
| Manual material handling | 27 (61%) |
| Frequent bending and twisting | 18 (41%) |
| Heavy physical load | 7 (16%) |
| Static work posture | 6 (14%) |
| Repetitive movements | 3 (7%) |
| Whole body vibration | 15 (34%) |
| **Measurement technique** | |
| Self-reports | 31 (70%) |
| Observations | 8 (18%) |
| Direct measurements | 5 (11%) |
| **Study design** | |
| Cross-sectional | 24 (55%) |
| Case control | 8 (18%) |
| Longitudinal | 4 (9%) |
| Community based | 8 (18%) |
| **Study size** | |
| <250 | 7 (16%) |
| 250-1000 | 19 (43%) |
| >1000 | 18 (41%) |
| **Number of confounders adjusted for** | *Mean ± SD* |
| | 1.9 ± 2.1 |
| | *range* 0 – 8 |

TABLE 2
*The effect of study characteristics on associations between risk factors and back problems in a meta regression analysis on 44 epidemiologic studies on back pain in occupational populations, expressed by increment (β) in risk estimate*

| | n | β | (95% CI) |
|---|---|---|---|
| **Measurement technique** | | | |
| Self-reports | 31 | 0 | reference |
| Observations | 8 | 1.13 | (−0.06; 2.33) |
| Direct measurements | 5 | 1.18 | (0.30; 2.07) |
| **Study design** | | | |
| Cross-sectional | 24 | 0 | reference |
| Case control | 8 | −0.17 | (−1.03; 0.69) |
| Longitudinal | 4 | 1.37 | (0.31; 2.44) |
| Community based | 8 | 0.18 | (−0.65; 1.02) |
| **Study size** | | | |
| <250 | 7 | 0 | reference |
| 250 – 1000 | 19 | 0.14 | (−0.82; 1.10) |
| >1000 | 18 | −0.21 | (−1.27; 0.85) |

*Nursing home personnel study*

In table 3 the effects of two different measurement techniques on the associations between work-related risk factors and back problems in the past 12 months are presented. Self-reports showed higher risk estimates compared with observations at the work place. Trunk flexion measured with self-reports showed a significant effect for the category “a lot” (Odds Ratio (OR) = 1.67, 95% CI 1.05; 2.66), for combined trunk flexion and rotation both the categories “quite a lot” and “a lot” showed odds ratios of 2.35 (95% CI 1.51; 3.64) and 2.58 (95% CI 1.38; 4.87). Using observations, the category “quite a lot” showed an odds ratio of 1.50 (95% CI 1.02; 2.20). For heavy physical loads the highest category of self-reports on lifting showed an odds ratio of 2.58 (1.36; 4.87). In contrast, when using the exposure information from the observations only the third quartile (50-75 percentile) of percentage work time with trunk flexion over 45 degrees was significantly associated with low back problems in the past 12 months (OR = 1.50).For static work posture, no significant associations were found.

TABLE 3

*Measurement techniques and strength of associations between work-related risk factors and back problems in the past 12 months (adjusted for psychosocial work demands) i n a cross-sectional study among nursing home personnel (n = 769)*

| Work-related risk factor | Observation | Self-reports | Odds Ratios (95%CI) Self-reports | Odds Ratios (95%CI) Observations |
|---|---|---|---|---|
| **Frequent bending and twisting** | Trunk flexion (over 45 degrees) | Never | 1.00 reference | 1.00 reference |
| | | Sometimes | 1.35 (0.86; 2.13) | 1.21 (0.79; 1.86) |
| | | Quite a lot | 1.16 (0.76; 1.78) | 1.50 (1.02; 2.20) |
| | | A lot | 1.67 (1.05; 2.66) | 1.14 (0.72; 1.80) |
| | Combined trunk flexion and rotation | Never | 1.00 reference | 1.00 reference |
| | | Sometimes | 1.34 (0.93; 1.94) | 1.25 (0.45; 3.48) |
| | | Quite a lot | 2.35 (1.51; 3.64) | 1.46 (0.96; 2.25) |
| | | A lot | 2.58 (1.36; 4.87) | 1.01 (0.68; 1.61) |
| **Heavy physical load** | Lifting loads over 100 N | Never | 1.00 reference | 1.00 reference |
| | | Sometimes | 1.24 (0.80; 1.94) | 1.12 (0.73; 1.71) |
| | | Quite a lot | 1.38 (0.88; 2.16) | 1.26 (0.86; 1.85) |
| | | A lot | 1.68 (1.01; 2.73) | 1.29 (0.77; 2.14) |
| **Static work posture** | Sitting at work | Never | 1.00 reference | 1.00 reference |
| | | Sometimes | 0.99 (0.71; 1.40) | 1.22 (0.72; 2.07) |
| | | Quite a lot | 1.17 (0.74; 1.85) | 1.25 (0.84; 1.86) |
| | | A lot | 0.83 (0.43; 1.59) | 0.92 (0.60; 1.39) |

## Discussion

The aim of this paper was to review the scientific literature on work-related back problems of the past 20 years in order to evaluate the strength of the associations between physical load and back problems in different studies. Concerning manual material handling, the importance of lifting and/or carrying of loads on back problems has been demonstrated by most studies in this review. Also, most of the studies that focused on the association between back pain and postural load due to frequent bending and twisting of the trunk reported positive associations. Furthermore, all studies on heavy physical work and back problems showed significant associations. Contradictory observations have been reported on prolonged sedentary postures and on duration of standing on the job. Overall, the evidence on static work posture is not consistent. Most studies on whole-body vibration consistently showed positive significant associations with back problems.

A second aim was to evaluate whether the strength may be explained by the measurement technique used. In most studies the information on work-related risk factors was collected by means of self-reports, either in an interview or in a questionnaire. These studies 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 (51, 52). In the present review the studies with observations and direct measurement techniques showed significantly higher risk estimates than the studies based on questionnaires. This finding may be explained by larger (nondifferential) misclassification of exposure in questionnaire studies or by larger contrast in exposure in studies with actual workplace surveys to determine exposure levels. The magnitude of the risk estimate could not be evaluated in relation to the contrast in exposure since exposure parameters were not very comparable. It is obvious that some studies used reference groups (low exposed) that may have experienced a similar level of physical load as exposed groups in other studies.

In the cross-sectional study of nursing home personnel it was found that the effects of both frequent bending and twisting and heavy physical load were more pronounced using self-reports than observations. One has to bear in mind that self-reports and observations were essentially measured differently. The four categories of self-reports represent generic descriptions of exposure which may be encompass both frequency and duration aspects of exposure. In the observations the four categories represent quartiles in the distribution of worktime in trunk angles over 45 degrees. Hence, variables may differ too much to be compared. Another explanation for the difference might be information bias, i.e. differential misclassification. With the self-reports, subjects with back pain may overstate their physical load in the workplace relative to those without back problems (53). This explanation seems to be supported by the trend of increasing effects over the different categories in the self-reports ("dose-respons"), which is not seen with the observations. It is difficult to ascertain this explananation in this particular study, especially since in the meta-analysis studies with observational methods to characterize exposure showed, in general, higher risk estimates than those based upon self-reports.

Longitudinal studies reported higher risk estimates than cross-sectional studies, case-control studies, and community studies. A reasonable explanation is that in cross-sectional, case-control, and community studies the occurrence of back problems is expressed as the prevalence of occurrence, whereas in longitudinal studies the occurrence of back problems is mostly expressed as the (cumulative) incidence. By nature, prevalence rates are larger than incidence rates and specifically for back problems background prevalences may be very high. Hence, dividing prevalence rates of exposed workers by prevalence rates of unexposed workers (as is the case in cross-sectional or case-control studies) will result in smaller ratios (risk estimates) than when incidence rates of exposed workers are divided by incidence rates of unexposed workers (as in the longitudinal studies). This effect may have exceeded the potential overestimation in cross-sectional studies which have used an Odds Ratio rather than a Prevalence Ratio and, thus, with a high prevalence of back problems will overestimate the risk (54).

In conclusion, the review demonstrated a clear relationship between back disorders and physical load, that is manual material handling, frequent bending and twisting, physically heavy work, and whole-body vibration. The strength of the associations between physical load at work and the ocurrence of back problems is partly explained by independent effects caused by the measurement technique and study design. Observations and direct measurements are less prone to information bias by which underestimation of the true effect is less likely. Longitudinal studies showed higher risk estimates than cross-sectional and case control studies, probably due to less recall bias and a different definition of the measures of association.

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# Annex 1

TABLE A1

*Significant associations between work-related risk factors and the occurrence of back disorders, expressed as odds ratio, in cross-sectional epidemiologic studies among occupational populations*

| Author | Study population | Back disorders | Work-related risk factor | Risk | 95% CI[1] | M[3] |
|---|---|---|---|---|---|---|
| Alcouffe 1999 | 7010 workers (M & F) | LBP in past 12 months (56%) | Lifting (every day >10kg | 1.37 | 1.18-1.59 | q |
| | | | Whole-body vibration (>4 h/day versus never) | 1.26 | 1.01-1.59 | q |
| | | | Awkward postures (yes/no) | 1.96 | 1.72-2.17 | q |
| Arad 1986 | 831 nurses (F) | LBP in past month (42%) | Lifts per shift (>6 vs less) | 2.47 | 1.78-3.42 | q |
| Bongers 1990 | 133 helicopter pilots and 228 non-flying officers (M) | Regularly experienced LBP (55% and 11%) | WBV ($a_z$ > 0.5 m/s$^2$) | 9.00 | 4.90-16.40 | m |
| Boshuizen 1990 | 450 tractor drivers and 110 agriculture workers (M) | Regularly experienced LBP (31% and 19%) | WBV ($a_z$ > 0.3 m/s$^2$) | 1.93 | 1.12-3.35 | m |
| Boshuizen 1992 | 242 drivers and 210 operators (M) | LBP in past 12 months (51% and 42%) | WBV ($a_z$ > 0.5 m/s$^2$) | 1.73 | 1.06-2.81 | m |
| Bovenzi 1992 | 234 bus drivers and 125 maintenance workers (M) | LBP in past 12 months (83% and 66%) | WBV ($a_z$ > 0.6 m/s$^2$) | 3.62 | 1.60-8.22 | m |
| | | | Awkward posture (frequent) | 2.29 | 1.22-4.29 | q |
| Bovenzi 1994 | 1155 tractor drivers and 220 office workers (M) | LBP in past 12 months (67% and 35%) | WBV ($a_z$ > 0.5 m/s$^2$) | 2.39 | 1.52-3.76 | m |
| | | | Awkward posture (hard) | 2.21 | 1.27-3.82 | q |
| Burdorf 1991 | 114 concrete workers and 52 maintenance workers (M) | LBP in past 12 months (59% and 31%) | Bends & twists (37% vs 27%) | 2.80 | 1.31-6.01 | o |
| | | | WBV (yes/no) | 3.06 | 1.26-7.45 | o |
| Burdorf 1993 | 94 crane operators and 86 office workers (M) | LBP in past 12 months (50% and 34%) | Static sedentary posture (yes/no) | 3.29 | 1.52-7.12 | o |

TABLE A1 (continued)

*Significant associations between work-related risk factors and the occurrence of back disorders, expressed as odds ratio, in cross-sectional epidemiologic studies among occupational populations*

| Author | Study population | Back disorders | Work-related risk factor | Risk | 95% CI[1] | M[2] |
|---|---|---|---|---|---|---|
| Burdorf 1997 | 161 tank terminal workers | LBP in past 12 months (35%) | Lack of social support (yes/no) | 3.80 | 1.58-9.14 | o |
| Estryn-Behar 1990 | 1,505 nurses (F) | LBP in past 12 months (47%) | Postural load (high vs low) | 2.07 | na | q |
| | | | MMH (high vs low) | 2.00 | na | q |
| Gilad 1986 | 250 production workers (M) | BP in past 12 months (59%) | Lifting (frequent vs never) | 3.06 | 1.11-8.67 | |
| Holmström 1992 | 1,772 construction workers (M) | LBP in past 12 months (54%) | MMH (every 5 min vs less) | 1.12 | 1.01-1.25 | q |
| | | | Daily stooping (>4 h vs<1h) | 1.29 | 1.10-1.50 | q |
| Magnusson 1996 | 228 drivers and 137 sedentary workers (M) | LBP in past 12 months (58% and 42%) | WBV (yes/no) | 1.79 | 1.16-2.75 | m |
| | | | Lifting (frequent vs none) | 1.55 | 1.01-2.39 | q |
| | | | Lifting >10 kg (frequent vs none) | 1.86 | 1.20-2.80 | q |
| Ory 1997 | 418 tannery workers (M) | LBP in past 12 months (61%) | Lifting (regular over 20 kg vs seldom) | 3.54 | 1.42-8.78 | o |
| Pietri 1992 | 1,709 commercial travellers (M & F) | LBP in past 12 months (27%) | WBV (>20 h vs<10 h) | 2.0 | 1.3-3.1 | q |
| | | | Frequent load carrying | 1.3 | 1.0-1.7 | q |
| | | | Prolonged standing (yes/no) | 1.3 | 1.0-1.6 | q |
| Riihimäki 1989 | 852 machine operators, 696 carpenters, 674 office clerks | Sciatica in past 12 months (34%, 29% and 19%) | Bending and twisting (rather much vs rather/little) | 1.5 | 1.2-1.9 | q |
| Smedley 1995 | 1,616 nurses (F) | LBP in past 12 months (45%) | Lifting (>1 patient/day) | 1.3 | 1.1-1.6 | q |
| Suadicani 1994 | 469 steel workers (M & F) | LBP in past 12 months (50%) | Lifting (>1 year heavy objects vs 0) | 2.4 | 1.5-3.6 | o |
| | | | Awkward posture (>1 year vs 0) | 2.4 | 1.6-3.7 | o |
| Waters 1999 | 284 industrial workers (M) | LBP in past 12 months (30%) | Lifting (Lifting Index >1) | 2.12 | 1.13-4.02 | m |
| Wells 1983 | 196 letter carriers, 76 meter readers, 127 clercks (M) | Significant BP (28%, 21% and 11%) | Carrying weight (yes/no) | 2.19 | 1.30-3.72 | o |

[1] Confidence interval, [2] Measurement instruments for exposure (q = questionnaire, i = interview, o = observation, m = measurement); LBP = low-back pain, WBV = whole-body vibration, MMH = manual material handling, na = not available.

TABLE A2

*Significant associations between work-related risk factors and the occurrence of back disorders, expressed by odds ratio, in case-control epidemiologic studies among occupational populations*

| Author | Study population | Back disorders | Work-related risk factor | Risk | 95% CI | M |
|---|---|---|---|---|---|---|
| Josephson 1998 | 81 female nurses Referents: 188 female nurses | LBP medical care | Severe trunk flexion (at least 1 hour/day) | 4.3 | 1.6-12 | q |
| | | | High perceived exertion (PPE-Borg > = 14) | 2.3 | 1.2-4.5 | q |
| Kelsey 1984 | 325 medical patients Referents: 241 care seekers in same clinics | Acute prolapsed lumbar intervertebral disc | Lifting loads >11.3 kg (25lb) (>25 times/day) | 3.5 | 1.5-8.5 | q |
| | | | Carrying loads >11.3 kg (25lb) (>25 times/day) | 2.7 | 1.2-5.8 | q |
| Nuwayhid 1993 | 115 fire fighters Referents: 109 fire fighters | LBP claim | Physical exertion on job | 3.71 | 1.94-7.10 | i |
| | | | Lifting (>18 kg vs less) | 3.07 | 1.19-7.88 | i |
| | | | Climbing (>100 steps/day vs less) | 2.26 | 1.17-4.38 | i |
| Punnett 1991 | 95 assembly workers Referents: 124 assembly workers | LBP claim | Bends & twist (100% vs 0%) | 8.09 | 1.5-44.0 | o |
| | | | Lifting (>44.5 N/minute) | 2.16 | 1.0-4.7 | o |

TABLE A3

*Significant associations between work-related risk factors and the occurrence of back disorders, expressed by relative risk, in longitudinal epidemiologic studies among occupational populations*

| Author | Study population | Back disorders | Work-related risk factor | Risk | 95% CI | M |
|---|---|---|---|---|---|---|
| Boshuizen 1990 | 789 tractor drivers (M) | Sickness absence >28 days | | | | |
| | | due to back disorders | WBV ($a_z$ > 0.4 m/$s^2$) | 1.47 | 1.04-2.10 | m |
| | | due to intervertebral disc | WBV ($a_z$ > 0.4 m/$s^2$) | 3.10 | 1.16-8.30 | m |
| Gardner 1999 | 31,076 material handlers in retail merchandise stores | BP claim due to material handling (2.8%/year) | Material handling (lifting jobs versus light-lifting jobs) | 1.62 | 1.38-1.91 | o |
| Kraus 1997 | 31,000 employees (M & F) in retail stores | BP claim (± 3.4%/year) | Lifting (frequently lifting or carrying loads >11.35 kg) | 2.94 | 2.64-3.32 | o |
| Pietri 1992 | 601 commercial travellers | LBP incidence (13%/year) | WBV (>20 h vs <10 h) | 3.28 | 1.03-10.49 | q |
| Smedley 1997 | 838 female nurses | LBP incidence (47% | Lifting (> = 1 patient vs 0) | 1.4 | 1.00-1.90 | q |
| | (no LBP in past month) | cum incidence/2 year) | Transfer (> = 5 patients vs less) | 1.6 | 1.10-2.30 | q |
| Stobbe 1988 | 415 nurses (F) | BP claim (5.2%/year) | Lifting (>5 patients vs<2) | 2.16 | 1.12-4.19 | q |
| Venning 1987 | 4,306 nurses (M & F) | BP claim (2.8%/year) | Lifting (∃ 1 patient vs 0) | 2.19 | na | q |

TABLE A4

*Significant associations between work-related risk factors and the occurrence of back disorders, expressed by odds ratio, in cross-sectional community-based epidemiologic studies*

| Author | Study population | Back disorders | Work-related risk factor | Risk | 95% CI | M |
|---|---|---|---|---|---|---|
| Heliovaara 1991 | 2,946 Finnish women and 2,727 Finnish men | Medically diagnosed LBP (12% and 12%) | Physical load (yes/no) | 2.58 | 2.10-3.16 | q |
| | | Medically diagnosed sciatica (5% and 6%) | Physical load (yes/no) | 2.48 | 1.82-3.37 | q |
| Houtman 1994 | 5,865 Dutch workers (M &F) | Back complaints (25%) | Heavy physical load (yes/no) | 1.62 | 1.36-1.91 | q |
| Leigh 1989 | 1,414 USA workers (M & F) | BP in past 12 month (20%) | Heavy physical load (yes/no) | 1.68 | 1.05-2.90 | q |
| Liira 1996 | 8,020 Canadian blue-collar workers (M & F) | Long-term back problems (8.4%) | Bends & lifts (>50x/day) | 1.65 | 1.25-2.18 | q |
| | | | Frequent lifts <50 lb | 1.46 | 1.12-1.89 | q |
| | | | WBV (yes/no) | 1.84 | 1.25-2.72 | q |
| | | | Awkward back posture | 2.33 | 1.72-3.15 | q |
| Linton 1990 | 22,180 Swedish workers (M & F) | LBP in past 12 months with medical consult (16%) | Lifting (heavy loads yes/no) | 1.8 | 1.5-2.1 | q |
| | | | Awkward postures (yes/no) | 2.2 | 1.8-2.6 | q |
| | | | Vibration (yes/no) | 1.8 | 1.5-2.2 | q |
| Saraste 1987 | 2,872 Swedish women and men | LBP (36%) | Bends & twist (always/no) | 2.59 | 2.06-3.27 | q |
| | | | Daily heavy lifting (yes/no) | 1.89 | 1.56-2.30 | q |
| | | | WBV (yes/no) | 2.14 | 1.31-3.52 | q |
| | | | Repetitive work (always/no) | 1.97 | 1.63-2.38 | q |
| Svensson 1983 | 940 Swedish men 40-47 year | LBP in past month (31%) | Frequent lifting (yes/no) | 1.70 | 1.12-2.58 | q |
| | | | Heavy physical load (yes/no) | 1.54 | 1.00-2.40 | q |
| Svensson 1989 | 1,410 Swedish women | LBP in past month (35%) | Regularly bending (yes/no) | 1.37 | 1.06-1.77 | q |
| Xu 1997 | 5940 workers (M & F) | LBP in past 12 months (43%) | Bending and twisting (all the time versus seldom) | 2.02 | 1.71-2.42 | q |
| | | | Heavy physical load (all the time versus seldom) | 2.51 | 1.64-3.85 | q |
| | | | Whole-body vibration (all the time versus seldom) | 1.78 | 1.21-2.66 | q |
| | | | Standing (all the time versus seldom) | 1.55 | 1.31-1.81 | q |