Work-related risk factors for low back pain

Lisette Hoogendoorn

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The studies presented in this thesis were performed at the Institute for Research in Extramural Medicine (EMGO Institute) of the Vrije Universiteit, the Netherlands and at TNO Work and Employment, the Netherlands. The EMGO Institute participates in the Netherlands School of Primary Care Research (CaRe), which was acknowledged in 1995 by the Royal Netherlands Academy of Arts and Sciences (KNAW).

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1

Introduction

Background and magnitude of the problem

This thesis investigates work-related risk factors for low back pain. Low back pain can be defined as any pain in the back between the ribs and the top of the leg, originating from any cause.[1] The area between the ribs and the top of the leg is also referred to as the lumbosacral, buttock and upper leg region in various other definitions.[2] The majority of cases of low back pain are labelled as non-specific, because the cause of the pain is unknown.[1,2] The pain may arise from any of the spinal structures, i.e. discs, facets, ligaments, vertebrae or muscles.[3]

Low back pain is one of the most common work-related health problems. A study of the prevalence of musculoskeletal symptoms among the Dutch population of 25 years and older, performed in 1998, reported an annual prevalence of low back pain of 41.6% among men and 46.2% among women.[4] One of the main difficulties encountered when comparing the prevalence of low back pain in different countries is the lack of standard questionnaires and definitions. For this reason, the data collected during the second European survey on working conditions are of particular interest.[5] Approximately 30% of European workers reported that their work caused low back pain. Prevalence rates for individual countries ranged from 13% to 44%, with a relatively low prevalence of 17% for the Netherlands.[5]

Low back pain is not only a common health problem, but it also has important consequences in terms of sickness absence and (work) disability. In the above-mentioned Dutch study, approximately 20% of the people who reported low back pain also reported sickness absence due to low back pain in the previous year.[4] Data on new work disability pensions in the Netherlands for the year 1999 show that approximately 25% of these pensions are paid to people with musculoskeletal problems.[6] Data on the specific diagnoses in the category of musculoskeletal problems show that 25% of the pensions in this category are definitely paid to people with low back problems. The diagnostic codes of a further 25% of the pensions indicate that these may also concern people with low back problems. However, these codes are not specific enough to positively identify a back problem (National Institute for Social Insurance [LISV], personal communication, 2000). Due to the considerable impact it has on sickness absence and work disability, low back pain is a heavy financial burden on society. Reported estimates of the total cost of back pain in various countries indicate that these costs amount to 1 - 2% of the gross national product.[7] Approximately 90% of the cost are indirect costs, due to loss of productivity, sickness absence and prolonged disability.[7] In 1991, the total cost of back pain to society in the Netherlands was estimated to be approximately US $5 billion, i.e. 1.7% of the gross national product.[8]

Low back pain is assumed to be of multifactorial origin. Individual factors, as well as work-related and nonwork-related physical and psychosocial factors, may play a role in its development. Originally, the focus of most occupational research on low back pain was directed towards physical factors. Handling heavy loads is one of the work-related physical factors that is regarded as a risk factor for low back pain. Data from the second European survey on working conditions show that the work of almost one third of the employees in Europe involves carrying or moving heavy loads, ranging from 24% to 40% for individual countries, and 25% for the Netherlands.[5] Recently, the study of psychosocial work characteristics has also become an important aspect of epidemiological studies on low back pain among workers. High quantitative job demands and low autonomy are two examples of work-related psychosocial factors that are regarded as putative risk factors for low back pain. The job of approximately 50% of the employees in Europe involves working at a very high speed. The highest percentage (70%) was reported in the Netherlands. In addition, approximately 30% of the workers in Europe reported that they were unable to choose or change their working methods.[5] For the individual countries this ranged from 14% to 37%, with a relatively low but still substantial 19% for the Netherlands.[5] A comparison of data from the second European survey in 1996 with data from the first survey in 1991 shows that the percentage of workers whose job involves working at a very high speed has increased during this period. Nevertheless, there seems to be an increase in the number of workers who are able to influence their working methods. Handling heavy loads appears to continue at the same level.[5] An annual survey carried out by Statistics Netherlands among the Dutch population shows similar trends for these work-related physical and psychosocial factors.[9]

Conceptual model of the aetiology of low back pain

Figure 1.1 presents a conceptual model illustrating the possible pathways that may lead to the development of low back pain. This model is primarily based on the model developed by Bongers et al. and presented in their review of the literature on psychosocial factors at work and musculoskeletal disease.[10] Physical and psychosocial load, as presented in the model, may occur both at work and during leisure time. However, in the present description of this conceptual model, emphasis is laid on the work-related factors, since these are the focus of this thesis.

Physical load may cause acute effects, such as trauma, in which case the tissue tolerance is suddenly exceeded. On the other hand, it may have a chronic effect, in which case tissue tolerance is gradually decreased over time to a point where previously acceptable mechanical loads result in low back pain.[11,12] Moreover, physical load may cause different strain responses of body tissue, such as tissue deformation, altered metabolism, altered circulatory patterns, inflammation, muscle fatigue and perceived exertion, which means that low back pain may result from an effect on multiple spinal structures.[13,14,15] Firstly, there may be an effect on the degenerative process in the disc, that is partly a natural process.[3] Secondly, herniation of the intervertebral disc may occur, with irritation of adjacent nerve roots. Thirdly, muscle or ligamentous damage may play a role.[14] Although plausible mechanisms for the relationship between physical load and low back pain do exist, there is still no full understanding of the complex process of how exposure to physical factors results in physiological responses that may ultimately lead to musculoskeletal symptoms. In particular, it is still not entirely clear how damaged structures give rise to pain,[12] even though anatomical sources of pain in the low back have been identified.[15]

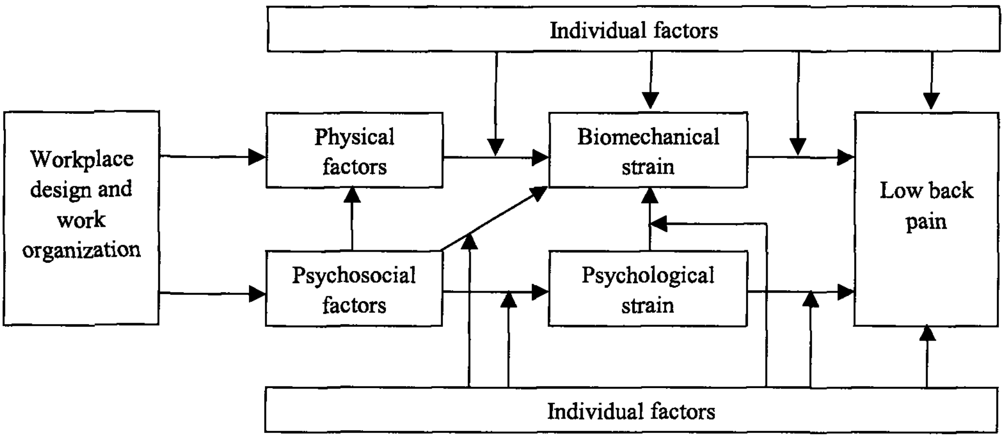

Figure 1.1 Conceptual model of the relationship between putative risk factors and low back pain

Several explanations have also been given for the relationship between psychosocial work characteristics and musculoskeletal symptoms. Firstly, psychosocial work characteristics can directly influence the physical load through changes in posture, movement and exerted forces.[10,16,17] Secondly, the association can be based on confounding by the effect of physical factors at work.[10,16,17] Physical and psychosocial load at work are related, since both are determined by workplace design and work organization. Thirdly, psychosocial work characteristics may directly trigger physiological mechanisms, such as increased muscle tension, or psychosocial work characteristics may increase psychological strain, which, in turn, may increase muscle tension or hormonal excretion. In the long-term this may lead to organic changes and the development or aggravation of musculoskeletal symptoms, or it may lower the level of pain perception, and thus increase symptom-reporting.[10,16,18-20] Fourthly, psychological strain, resulting from psychosocial load at work, may also change the ability of an individual to cope with an illness. This, of course, could also influence the reporting of musculoskeletal symptoms.[10,16,17]

The category of individual factors includes a large range of factors such as age, gender, smoking habits, exercise behaviour, body mass index and coping skills. Individual factors may be independent risk factors of low back pain, but may also influence the relationship between physical and psychosocial factors, on the one hand, and low back pain on the other hand.

Job satisfaction, a variable that is often included in research on low back pain, can be classified into two separate categories that are components of the conceptual model. It can be regarded as a psychosocial work characteristic, on the one hand, and as a psychological strain variable on the other. Conceptually, it makes more sense to include job satisfaction in the latter category. In the literature, however, there is no consensus on this issue. As a consequence, in this thesis, job satisfaction is examined as a psychosocial work characteristic, but also considered as a psychological strain variable when further investigating the hypothesis on the role of psychological strain in the relationship between psychosocial work characteristics and low back pain.

Aims of the study

The main aim of this study was to identify work-related risk factors for the occurrence of low back pain. Within the framework of this main aim, special attention is paid to the following research questions:

- Which work-related physical factors are risk factors for the occurrence of low back pain?
- Is there an exposure-response relationship between the work-related physical factors and low back pain?
- Which psychosocial work characteristics are risk factors for the occurrence of low back pain?
- Do psychological strain variables play an intermediate role in the relationship between psychosocial work characteristics and self-reported low back pain?
- What is the relative importance of work-related physical factors and psychosocial work characteristics as risk factors for low back pain?
- Is there a difference in the relationship of work-related factors with sickness absence due to low back pain, on the one hand, and with self-reported low back pain on the other hand?

Study on Musculoskeletal disorders, Absenteeism, Stress, and Health

The identification of work-related risk factors for low back pain has been the subject of many studies. However, most previous studies on work-related risk factors for low back pain were based on a cross-sectional design, and failed to take into account individual factors as well as work-related physical and psychosocial factors. In addition, hardly any studies have actually measured exposure to physical load at work and only a few previous studies have included company-registered sickness absence due to low back pain as an outcome measure. In an effort to overcome these limitations of previous studies, the Study on Musculoskeletal disorders, Absenteeism, Stress, and Health (SMASH) was initiated in 1994. The objective of this three-year prospective cohort study among a working population was to identify risk factors for musculoskeletal symptoms. In this thesis, the low back pain aspect of SMASH is described.

The study population consisted of approximately 1,750 workers from 34 companies, which were located throughout the Netherlands. The companies were recruited in cooperation with Occupational Health Services. A prerequisite for participating companies was that no major reorganizations were planned for the next three years and that the annual turnover rate of the work-force was lower than 15%. The participating workers had to have a more or less fixed workplace and a limited number of tasks to make it possible to assess their physical load by means of video-recordings. Furthermore, the companies were asked to select workers who had been employed in their current job for at least one year and who were working for a minimum of 20 hours per week. There were 10 to 170 participants from each company. Workers in blue-collar jobs as well as workers in white-collar jobs and caring professions were included in the study.

Figure 1.2 shows the general design of the study. The baseline measurements were conducted between March 1994 and March 1995, and consisted of three aspects: a self-administered questionnaire, assessment of physical load at the workplace by means of video-recordings and force measurements, and assessment of the functional capacity of the workers during a physical examination. The questionnaire included questions on general working conditions, physical load at work and during leisure time, physical load in previous jobs, psychosocial work characteristics, stress symptoms, individual factors, and symptoms of the low back, neck and shoulders. Psychosocial work characteristics were measured by means of a Dutch version of Karasek's Job Content Questionnaire.[21] Table 1.1 shows the underlying items of the dimensions that were included. The psychometric properties and the construction of the scales for quantitative job demands, decision authority, skill discretion and supervisor and co-worker support have been described by De Jonge et al.,[22] based on the data from SMASH.

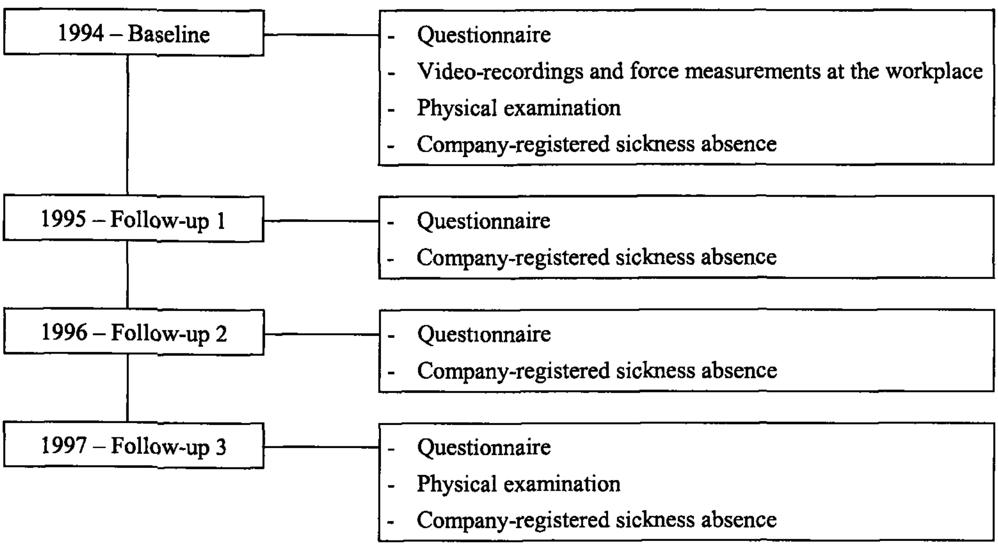

Figure 1.2 Design of the Study on Musculoskeletal disorders, Absenteeism, Stress, and Health

Table 1.1 Description of the underlying items of the psychosocial work characteristics that were assessed by means of the Job Content Questionnaire

Dimension	Items*
Quantitative job demands	My job requires working very fast
	My job requires working very hard
	I am not asked to do an excessive amount of work†
	I have enough time to get the job done†
	My job is very hectic
Conflicting demands	I am free from conflicting demands that others make†
Decision authority	My job allows me to make a lot of decisions on my own
	On my job, I have very little freedom to decide how I do my work†
	I have a lot of say about what happens on my job
Skill discretion	My job requires that I learn new things
	My job requires me to be creative
	My job requires a high level of skill
	I get to do a variety of things on my job
	I have an opportunity to develop my own special abilities
Supervisor support	My supervisor is concerned about the welfare of those under him
	My supervisor pays attention to what I am saying
	My supervisor is helpful in getting the job done
	My supervisor is successful in getting people to work together
Co-worker support	People I work with are competent in doing their jobs
	People I work with take personal interest in me
	People I work with are friendly
	People I work with are helpful in getting the job done

* The response options for the individual items ranged from one (strongly disagree) to four (strongly agree).
† These items were recoded before summing up the individual items.

After the baseline survey there was a follow-up period of three years. After each year of the follow-up period, the workers received a self-administered postal questionnaire, in which the majority of the questions from the baseline questionnaire were repeated. In addition, changes in the workplace were assessed in this questionnaire. At the third follow-up measurement the workers were also invited for a second physical examination. Annually, from 1994 until the end of 1997, the companies provided the first and last dates of all sickness absences of participating workers. The questionnaires and measurement protocols used in SMASH are described in more detail in a report on the study, published in the Dutch language.[23]

Outline of the thesis

In addition to the prospective cohort study (SMASH), systematic reviews of the literature on physical and psychosocial risk factors for back pain were performed. Chapter 2 describes the review concerning physical factors, and the review concerning psychosocial factors is described in Chapter 3. The subsequent chapters all present results from analyses of data from SMASH. Chapter 4 presents results regarding the relationship between work-related physical factors at baseline and self-reported low back pain during the three-year follow-up period. Chapter 5 deals with the relationship between psychosocial work characteristics at baseline and self-reported low back pain during the three-year follow-up period. In addition, to obtain more insight into the pathway of the relationship between psychosocial work characteristics and low back pain, the potential intermediate role of psychological strain variables is also investigated in this chapter. Chapter 6 reports on the influence of work-related physical and psychosocial factors at baseline on company-registered sickness absence due to low back pain during the follow-up period. In Chapter 7, the results of two different analytic methods for the analysis of the data from SMASH are compared. The results of the conventional method used in Chapters 4 and 5 are compared with the results of the generalized estimating equations (GEE) method that includes repeated measurements of the exposure and outcome. Chapters 2 to 7 of this thesis were originally written as separate articles for publication in scientific journals. Therefore, there is some overlap between the chapters, especially in the description of the methodology. Chapter 8 contains the general discussion, and the thesis concludes with a summary in both English and Dutch.

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2

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

a systematic review

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Abstract

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 interventions for back pain. A computerized bibliographical search was made of several data bases for studies with a cohort or case-control design. Cross-sectional studies were excluded. A rating system was used to assess the strength of the evidence, based on the methodological quality of the twenty-eight cohort and three case-control 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, sport and total leisure-time physical activity.

Introduction

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, in nonsedentary occupations.[7,8] This indicates that work-related factors may play a role in the aetiology of back pain. In order to define potentially effective interventions 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 included 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 repeated application of loads or the long-term application of a sustained load. Moreover, a combination of cumulative and acute loads also can cause back pain.[17,18]

In this paper, a systematic approach, comparable with that applied in the clinical literature on the efficacy of interventions for back pain,[16,19] was used to answer the following research questions, based on the available literature:

- Which aspects of physical load at work are risk factors for the occurrence of back pain?
- 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:

1. The design of the study had to be case-control, prospective cohort or historical cohort, and the follow-up period had to be at least one year. 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.
2. The study had to concern a working population or a community-based population. Studies involving patient populations were excluded.
3. The operationalization of back pain had to be based on symptoms or signs of non-specific 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 using 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.

4. The exposures which were studied included physical load at work or physical load during leisure time. Studies which only involved a comparison between different occupational groups were excluded.
5. 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 criteria lists were used for the cohort studies and the case-control studies. A description of these two lists is given in the Appendix at the end of this chapter (Table A1). 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.
? 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-control 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 modelling, this result was disregarded in the data extraction, because a stepwise analysis is not appropriate for modelling 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 statistical pooling of 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 U.S. Clinical Practice Guideline for Acute Low Back Pain in Adults.[23] The rating system was applied to each individual exposure, and it consisted of three levels of scientific evidence based on the number, the quality, and the outcome of the studies as follows:

- Strong evidence: provided by generally consistent findings in multiple high-quality studies.
- Moderate evidence: provided by generally consistent findings in one high-quality study and one or more low-quality studies, or in multiple low-quality studies.
- No evidence: only one 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 meagre 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 one 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: there was low variability in physical load because the study population was restricted to workers with lifting tasks[50,51,95,98,99]; the physical exposures at work were measured by means of a questionnaire on which only one of a list of items could be ticked[85]; 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-control studies.[77,79-81,101] For most of the studies there was more than one 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-control studies led to an overall initial disagreement of 20% (95/476 items) and 25% (14/57 items), respectively. The two reviewers subsequently reached consensus on all initial disagreements.

Tables 2.1 and 2.2 show the cohort and case-control 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-control 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.

Tables 2.3 and 2.4 give a detailed description of important aspects of the cohort and case-control studies included in the review.

Physical load at work

Lifting: manual materials handling and patient handling

Four high-quality studies and one low-quality study reporting on the effect of manual materials handling were identified.[53,67,77-79] Manual material 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 one 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 (RR/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 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 one 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 one low-quality study examined the effect of driving a car[67,72,77,78] and a fourth 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] 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 two 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 six low-quality studies reported on the effect of this exposure.[27,29,38,60,61,73,74,77,94,96,104] Since four 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 one high- and the five 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]

Table 2.1 Cohort studies on physical load during work and leisure time as risk factors for back pain,

First author/Criteria	1	2	3	4	7	8	9	10	11	12
Biering-Sørensen[28-36]	+	+	+	+	+	?	+	?	+	-
Leino[61-66]	+	-	+	+	+	?	+	?	+	-
Bigos[37-45]	+	+	-	?	+	?	+	?	+	+
Burdorf[49]	+	+	+	+	+	?	-	-	+	-
Riihimäki[82-84]	+	+	-	+	+	?	+	?	+	-
Klaber-Moffet[52]	+	+	+	+	-	-	-	-	+	-
Macfarlane[67-71]	+	+	-	-	+	?	+	?	-	+
Mannion[73]	+	+	?	+	+	?	-	-	+	-
Pietri[78]	+	+	?	+	+	?	-	-	+	-
Ready[100]	+	+	-	+	-	-	+	?	+	-
Rossignol[86]	+	+	-	+	-	-	+	?	+	-
Smedley[91,92]	+	+	-	-	+	?	-	-	-	-
Videman[103]	+	+	?	+	+	?	-	-	+	-
Biering-Sørensen[27]	+	+	+	+	+	?	-	-	-	-
Gyntelberg[96,97]	+	+	+	+	+	?	-	-	+	-
Kuh[53,54]	+	+	+	+	-	-	-	-	-	-
Kujala[55-59]	+	+	+	+	-	-	-	-	+	-
Kujala[60]	+	+	-	-	+	?	-	-	+	-
Manninen[72]	+	+	+	-	+	?	-	-	-	-
Venning[93]	+	-	-	+	+	?	-	-	-	-
Muramatsu[75]	+	+	-	+	-	-	-	-	+	-
Niedhammer[76]	+	+	?	+	-	-	-	-	+	-
Viikari-Juntura[104]	+	+	?	-	?	?	+	?	+	?
Stobbe[102]	+	-	?	?	-	-	-	-	-	-
Bergenudd[94]	+	+	?	-	-	-	+	?	?	-
Salminen[87-90]	+	+	+	+	-	-	-	-	+	-
Mooney[74]	+	-	+	?	-	-	-	-	-	-
Brattberg[46-48]	+	+	+	+	-	-	-	-	+	-

Abbreviations: +, yes; -, no; ?, don't know; V/P, criteria on validity/precision.
* The numbers refer to the numbers of the criteria in the list for the methodological quality assessment in Table A1 in the Appendix.

Table 2.2 Case-control studies on physical load during work and leisure time as risk factors for back

First author/Criteria	1	2	5	6	7	8	9	10	11	12
Punnett[79-81]	+	+	+	+	+	+	-	-	+	-
Nuwayhid[77]	+	-	-	-	+	?	+	?	+	+
Ryden[101]	+	+	-	?	-	-	+	?	+	-

Abbreviations: +, yes; -, no; ?, don't know; V/P, criteria on validity/precision.
* The numbers refer to the numbers of the criteria in the list for the methodological quality assessment in Table A1 in the Appendix.

ranked according to methodological quality score*

13	17	18	19	21	22	23	Percentage + V/P (=3-23)
+	+	+	-	+	+	+	73%
+	+	+	-	+	+	+	73%
+	?	+	+	+	+	+	67%
+	?	+	-	+	+	+	60%
+	?	+	-	+	+	+	60%
+	?	+	+	-	+	+	53%
-	+	+	+	+	+	+	53%
+	?	+	-	+	+	+	53%
+	?	+	-	+	+	+	53%
+	?	+	+	+	+	-	53%
+	?	+	+	+	+	-	53%
+	?	+	+	+	+	+	47%
-	?	+	-	+	+	+	47%
-	?	+	-	-	+	+	40%
-	?	+	-	+	-	-	40%
-	?	+	-	+	+	+	40%
-	?	+	-	+	+	-	40%
+	?	+	-	-	+	+	40%
+	?	+	-	+	+	-	40%
-	?	+	+	-	+	+	40%
+	?	-	-	-	+	+	33%
+	?	+	-	-	+	?	33%
-	?	+	-	+	+	-	33%
-	?	+	+	+	+	+	33%
-	?	-	-	+	+	+	27%
-	?	+	-	-	-	-	27%
-	?	+	+	+	-	-	27%
-	?	-	-	-	-	-	20%

pain, ranked according to methodological quality score*

13	14	15	16	17	20	21	22	23	Percentage + V/P (=5-23)
+	-	+	-	?	+	+	+	+	65%
+	+	-	-	+	+	+	+	+	65%
+	+	?	+	?	-	+	+	-	41%

Table 2.3 Summary of the cohort studies on physical load and back pain

First author/MQS	Study population	Operationalization of back pain
Bergenudd[94]/4*	1542 10-year-old residents of Malmö, Sweden, 830 included in 1983, follow-up response 69%	Present BP at follow-up in 1983 (questionnaire)
Biering-Sørensen[27]/6	728 50-year-old inhabitants of Copenhagen, follow-up response 85%	1. LBP during last 10 years 2. Absences from work due to LBP during last 10 years (Interview)
Biering-Sørensen[28-36]/11†	928 30-, 40-, 50- and 60-year-old inhabitants of Copenhagen, follow-up response 99% Analysis restricted to 351 persons with no LB trouble before at baseline	LBP within the last 12 months (questionnaire)
Bigos[37-45]/10†	3020 blue-collar workers at one of the plants of Boeing-Everett	Incident reports or claims for acute back injury complaints
Brattberg[46-48]/3‡	1245 children of (8-, 11-, 13- and 17-years-olds), 597 included in the longitudinal study, follow-up response 79%	Often having BP at follow-up (questionnaire)
Burdorf[49]/9§	221 male novice golfers aged 20 to 60 years, follow-up response 89%	BP during the past 12 months (questionnaire)
Gyntelberg[96,97]/6	5249 males aged 40-59 years and employed in large private or public enterprises, follow-up response 91%	LBP during the last year (questionnaire and/or interview)
Klaber Moffett[52]/8§	376 female student nurses recruited on entry to 2 schools of nursing, follow-up response 80%	1. ≥ 3 days of LBP during follow-up 2. ≥ 21 days LBP and/or 1 day of sick leave with BP during follow-up (Diaries collected at approximately 3-monthly intervals)

Follow-up period	Results
45 years, 3 or 4 measurements	Work (job-exposure matrix, adjusted for gender): occupational work load 1942-1983 [$RR_{\geq 10\text{ years moderate physical work}}$=1.6 (1.2-2.1), $RR_{\geq 10\text{ years heavy physical work}}$=1.3 (0.8-2.2)]
10 years, 2 measurements	Work (questionnaire, adjusted for gender, outcome 1+ 2): physical activity at work, including housework (NS)
12 months, 2 measurements	Work (questionnaire): physical activity at work (NS) Nonwork (questionnaire): physical activity during leisure time (NS)
1 day-4 years (mean 3 years)	Work (questionnaire): perceived physical exertion (NS at p=0.00132)
2 years, 2 measurements	Nonwork (questionnaire):frequency of participation in physical activities (NS)
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)]
1 year, 2 measurements	Work (questionnaire): work on the job makes sweat [$RR_{\text{now and then-rarely or never}}$=1.24 (1.12-1.38), $RR_{\text{often-rarely or never}}$=1.45 (1.23-1.72)], physical activity on the job (heavy and sedentary compared to light, S) Nonwork (questionnaire): bicycling/day [$RR_{11\text{-}20\text{min.-}\leq 10\text{min.}}$=0.95 (0.82-1.09), $RR_{21\text{-}30\text{min -}\leq 10\text{min}}$=1.05 (0.89-1.25), $RR_{>30\text{min.-}\leq 10\text{min.}}$=0.91 (0.78-1.06)], often getting sweat from leisure-time physical activity [RR=1.03 (0.92-1.14)], taking regular part in sports [RR=0.84 (0.74-0.96)]
20 months, 7 measurements	Nonwork (questionnaire, outcome 1): exercise habits at baseline (number of times a sporting activity was given up, S)

Table 2.3 Continued

First author/MQS	Study population	Operationalization of back pain
Kuh[53,54]/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 BP before 16 years of age	Recalled first ever experienced sciatica, lumbago or severe backache at age 43 (interview)
Kujala[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 who participated in recreational sports less than twice a week, follow-up response 85%	1. LBP interfering with school or leisure activities for at least a 1-week period 2. Acute injuries causing LBP (Questionnaire at every follow-up)
Kujala[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. BP during the past 5 years 2. BP radiating to the leg during the past 5 years (Questionnaire)
Leino[61-66]/11§	902 blue- and white-collar employees of metal industry plants, follow-up response 67%	1. LB symptoms score during the past 12 months at the last follow-up (questionnaire) 2. LB clinical findings score (physiotherapist)
Macfarlane[67-71]/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 LBP at baseline, follow-up response 64%	1. Episodes of LBP leading to consultation with the general practitioner (computer records from the general practitioners) 2. Episodes of LBP not leading to consultation and > 1 day over the past 12 months (questionnaire)

Follow-up period	Results
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)]
3 years, 4 measurements	Nonwork (questionnaire, outcome 1): weekly frequency or duration of training before baseline (NS), training years before baseline (NS), frequency or duration of training during the year preceding LBP 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)]
5 years, 2 measurements	Work (questionnaire, outcome 1): general occupational physical demands (S), occupational musculoskeletal loading (job-exposure matrix, S) Nonwork (questionnaire, outcome 1): leisure physical activity (NS) Work (questionnaire, outcome 2): general occupational physical demands (S), occupational musculoskeletal loading (job-exposure matrix, S) Nonwork (questionnaire, outcome 2): leisure physical activity (NS)
10 years, 3 measurements	Work (questionnaire, outcome 1 and 2): physical load (NS) Nonwork (questionnaire baseline, outcome 1 and 2): total activity outside work in kilocalories (NS) Nonwork (mean questionnaire baseline and first follow-up, adjusted for LB symptoms at 1st follow-up, age, occupational class, smoking intensity, body mass index and stress symptoms, outcome 1): Males: exercise activity in kcal (st.beta=-0.078;S) Females: exercise activity in kcal (st.beta=-0.001;NS)
12 months, 2 measurements	Work (questionnaire, adjusted for age in cohort members with no history of low back pain, outcome 1 and 2 combined): Males: standing/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 pounds [OR=1.5 (0.8-2.8)] Females: 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)]

Table 2.3 Continued

First author/MQS	Study population	Operationalization of back pain
Manninen[72]/6	537 Finnish farmers aged 45-54 years who reported no LB or neck-shoulder pain during the past year at baseline, follow-up response 68%	1. Sciatic pain during the past year 2. Unspecified LBP during the past year (Telephone interview)
Mannion[73]/8	403 volunteering health-care workers aged 18-40 years who had no history of serious LB 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)
Mooney[74]/4	3643 employees of a large ship-building firm including workers in 32 job categories	On the job LB injury claims
Muramatsu[75]/5	2200 noninstitutionalized older adults in Japan aged ≥ 60, follow-up response 90% The analysis focused on those currently not suffering from LBP at baseline	Self-reported 'chronic LBP' (interview at follow-up)
Niedhammer[76]/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)
Pietri[78]/8	1381 commercial travellers, follow-up response 81% Analysis restricted to 627 people who had never had LBP before baseline	Symptoms of LBP during the past 12 months (interview)

Follow-up period	Results
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)]
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)
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)]
3 years, 2 measurements	Nonwork (interview, adjusted for age, gender, education, marital status, contact with child, psychological distress, have close friend or neighbour, 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)
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]
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/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), $OR_{\geq 25-<10}$=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)

Table 2.3 Continued

First author/MQS	Study population	Operationalization of back pain
Ready[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
Riihimäki[82-84]/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 never had had sciatic pain at baseline	Three-year cumulative incidence of sciatic pain (questionnaire)
Rossignol[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)
Salminen[87-90]/4	76 eight grade students, follow-up response 82%	LBP during the past 12 months at last follow-up (questionnaire and interview)
Smedley[91,92]/7§	961 hospital-based nurses without LBP in the months before they completed the baseline questionnaire, response after 12 months 66%	1. LBP > 1 day during follow-up 2. LBP leading to loss of time from work during follow-up (Three-monthly questionnaires during the whole follow-up)

Follow-up period	Results
18 months	Nonwork (questionnaire): physical activity pattern outside of work (NS)
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 (S), vibration (S) Nonwork (questionnaire, adjusted for smoking and the other variables shown): annual car driving (NS), weekly physical exercise (S) Nonwork (questionnaire, adjusted for occupation, smoking and history of other LBP): physical exercise [$RR_{>1/week-\leq 1/week}$=1.26 (1.00-1.60)]
12 months, 2 measurements	Nonwork (questionnaire, outcome 1, 2, 3, 4): number of hours spent in sport or physical activities in past week (NS)
3 years, 3 measurements	Nonwork (questionnaire): low physical activity (≤ 2 days/week) at baseline and follow-up (NS)
2 years, 8 measurements	Work (questionnaire, adjusted for age, height, earlier history of LBP, and symptoms other than BP at baseline, outcome 1): frequency in average working shift: transfer patient on canvas and poles [$OR_{1\ to\ 4-0}$=0.8 (0.6-1.1), $OR_{\geq 5-0}$=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), $OR_{\geq 10-0}$=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), $OR_{\geq 5-0}$=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), $OR_{\geq 10-0}$=1.7 (1.1-2.5)], manually lift patient up off floor [$OR_{\geq 1-0}$=1.1 (0.9-1.5)], lift patient from floor with hoist [$OR_{\geq 1-0}$=1.3 (0.8-2.0)], manually lift patient in or out of bath [$OR_{\geq 1-0}$=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), $OR_{\geq 5-0}$=2.1 (1.2-3.6)]

Table 2.3 Continued

First author/MQS	Study population	Operationalization of back pain
Stobbe[102]/5 Retrospective cohort	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)
Venning[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)
Videman[103]/7§ Retrospective cohort	2504 surviving former athletes in 1985 who had been members of at least one Finnish national team between the years 1920 and 1965, and controls identified form the register of men eligible for military service, follow-up response 82%	1. Having had BP which interfered with work in the past years 2. Ever having had a physician that said you had or had had sciatica (Questionnaire)
Viikari-Juntura[104]/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 LB region during the last 12 months and a mean disability index ≥ 15 at the last follow-up in 1986-1987 2. Pain, ache, stiffness, or numbness in the LB > 7 days, or a mean disability index ≥ 15 at the last follow-up in 1986-1987 (Questionnaire)

Abbreviations: MQS, methodological quality score based on items on validity and precision; LBP, low back pain; LB, low back; BP, back pain; RR, relative risk; OR, odds ratio, the corresponding 95% confidence intervals for the RR and OR are shown in parenthesis; S(tatistically significant), p≤0.05; NS, not significant.

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

† Some 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.

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

§ 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.

Follow-up period	Results
40 months, retrospective data collection	Work (job-exposure matrix, adjusted for employment time and occupation): patient lifting [$OR_{>5\text{ patients lifts per shift}-<2\text{ lifts per shift}}$=2.71;S]
12 months	Work (questionnaire, adjusted for job category, service area and previous history of reported back complaint): lifting [$OR_{\text{lifting patients }>10kg\text{ and }\geq 1/\text{day-less}}$=2.19;S]
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 [$OR_{\text{endurance-referents}}$=1.54 (0.96-2.48), $OR_{\text{sprint-referents}}$=1.01 (0.59-1.73), $OR_{\text{jumping-referents}}$=0.84 (0.44-1.60), $OR_{\text{throwing-referents}}$=1.20 (0.67-2.15), $OR_{\text{games-referents}}$=1.08 (0.76-1.53), $OR_{\text{contact-referents}}$=0.68 (0.44-1.06), $OR_{\text{weight lifting-referents}}$=1.46 (0.76-2.80), $OR_{\text{shooting-referents}}$=1.16 (0.52-2.58)]
32 years, 4 measurements	Work in 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)]

¶ 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.

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.

** The results for work-related risk factors from 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.

Table 2.4 Summary of the case-control studies on physical load and back pain

First author/MQS	Study population	Definition of cases and controls
Nuwayhid[77]/11*	Over 900 fire fighters and 1900 fire officers assigned to 142 ladder and 210 engineer companies; N=115 cases (response 62%) and 109 controls (response 75%)	Cases: full-duty fire fighter, who reported LBP 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 LBP, professional care or lost workdays were excluded Controls: full-duty fire fighters with no previous LBP experience or with earlier episodes that did not entail professional care nor loss of workdays
Punnett[79-81]/11†	Employees of an automobile assembly plant; N=95 cases (response 82%) and 124 controls (response 84%)	Cases: new reports of back disorders during the 10-month study period and who had symptoms in an interview Controls: 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
Ryden[101]/7	Employees at a children's hospital and health center; N=84 cases and 168 matched controls	Cases: employees with reported LB injuries while employed at a children's hospital and health center in 1983-1985 Controls: selected from the same population and matched by age, gender and department or physical requirements of the job

Abbreviations: MQS, methodological quality score based on items on validity and precision; LBP, low back pain; LB, low back; OR, odds ratio, the corresponding 95% confidence interval are shown in parenthesis; S(tatistically significant), $p \leq 0.05$.

* 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.

† 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.

Results
Work (interview): physical exertion in index on-duty period [OR=3.71 (1.94-7.10)], driving more miles weekly (S) 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)]
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 [$OR_{10\text{-}0\%}$=1.2, $OR_{30\%\text{-}0\%}$=1.8, $OR_{50\%\text{-}0\%}$=2.7, $OR_{100\%\text{-}0\%}$=8.09 (1.5-44.0)], lifting or holding of a part ≥ 44.5N [OR=2.16 (1.0-4.7)] Nonwork: engagement in outside activity [hobbies, sports or second jobs, OR=1.16 (0.66-2.05)]
Nonwork (employee health records, adjusted for age, gender and department): exercise [OR=1.33 (0.44-2.84)]

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) 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 six studies indicated no effect and five 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 five 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 one 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 of 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 one 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, travelling to and from work, and housework. One high-quality study found a statistically significant negative effect of 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 two 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, playing 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 one 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 kilometres) and the other found no effect of driving more than 25 miles 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 inarguable 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 one year. The major reason to make 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 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 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, this 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 epidemiological studies, compared with reviews of clinical trials which usually evaluate only one contrast, is the fact that the relatively broad objective of this review and most of the evaluated studies resulted in a relatively non-specific list of criteria. As the evidence for more than one 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 one 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 gives the possibility to compare the evidence found for different risk factors.

Criterion 5, which only pertains to the list for case-control studies, may sound contradictory, because the exclusion of subjects with recent back pain from the control group may be considered incompatible with the requirement that cases and controls have to be drawn from the same population. The criterion reflects that, on the one hand, it is important that cases and controls be drawn from the same population and selected independently of their exposure status to make sure that the controls 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 controls 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 control group, one can make sure that there is a real contrast in disease status between cases and controls.

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 one 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 one 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 cutoff point for the assessment of high-quality studies. The use of a cutoff 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 cutoff 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

Examination of the scoring of studies on the various items shows that all 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 baseline 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 three 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 one year, although the follow-up period was at least one 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-control 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 at 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 hand. 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 six 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 four 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 non-specific method used for the assessment of the exposure. In the two 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 analysed 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 individuals with similar working 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 working day 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 sport 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 all the studies differed and was, in general, not very specific. It has been concluded that in epidemiological studies on the role of physical activity in the aetiology 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 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 two 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 and Sorock[11] also concluded that the evidence for exercise and sport 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 interventions 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 interventions for back pain, in the review of observational epidemiological studies is shown to be worthwhile, not withstanding the problems encountered.

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Appendix Methodological quality assessment

Table A1 Criteria lists for assessment of the methodological quality of prospective and historical cohort studies and case-control studies

Criterion	Design*	I, V/P
Objective of the study		
1. Positive if the study had a clearly defined objective.	CH/CC	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/CC	I
3. Positive if the participation rate at baseline was at least 80%.	CH	V/P
4. Positive if the response after one year of follow-up was at least 80% of the number of participants at baseline or if the nonresponse was not selective (data shown).	CH	V/P
5. Positive if the cases and controls were drawn from the same population and a clear definition of cases and controls was given. Subjects with low back pain during the previous 90 days must have been excluded from the control group.	CC	V/P
6. Positive if the participation rate of cases and controls selected and invited to participate at baseline was at least 80%.	CC	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/CC	V/P
8. Positive if data were collected by means of standardized methods of acceptable quality†.	CH/CC	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/CC	V/P
10. Positive if data were collected by means of standardized methods of acceptable quality†.	CH/CC	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/CC	V/P
12. Positive if data on historical exposure at work were collected and included in the statistical analysis.	CH/CC	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 baseline.	CH/CC	V/P
14. Positive if the exposure was measured in an identical manner among the cases and controls.	CC	V/P
15. Positive if the exposure assessments were blinded with respect to		

Table A1 Continued

Criterion	Design*	I, V/P
disease status.	CC	V/P
16. Positive if the exposure was assessed prior to the occurrence of the outcome.	CC	V/P
Assessment of back pain		
17. Positive if based on standardized methods of acceptable quality, namely, positive if one of following criteria were met:	CH/CC	V/P
- 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.		
- Registered data: data presented or in reference demonstrate that the registration system is valid and reliable.		
- 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 one observer is involved or the interobserver reliability if more than one 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.		
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 enrolment).	CC	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/CC	V/P
22. Positive if the analysis included a stratified or multivariable analysis.	CH/CC	V/P
23. Positive if the number of cases in the final multivariable model was at least ten times the number of the independent variables in the analysis.	CH/CC	V/P

Abbreviations: I, criterion on informativeness; V/P, criterion on validity/precision.

* This column shows whether a criterion pertains to the criteria list for cohort (CH) and/or case-control (CC) studies.

† This criterion was rated positively if one of 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 one observer is involved or the interobserver reliability if more than one observer is 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.

3

Psychosocial factors at work and in private life as risk factors for back pain:

a systematic review

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Abstract

This systematic review assessed psychosocial factors at work and in private life as risk factors for back pain. Several reviews on risk factors for back pain have paid attention to psychosocial factors. However, in none of the published reviews was a strict systematic approach used to identify and summarize the available evidence. A computerized bibliographical search of several data bases was performed, restricted to studies with a cohort or case-control design. A rating system was used to assess the strength of the evidence for various factors, based on the methodological quality of the studies and the consistency of the findings. Eleven cohort and two case-control studies were included in this review. Strong evidence was found for low social support in the workplace and low job satisfaction as risk factors for back pain. Insufficient evidence was found for an effect of a high work pace, high qualitative demands, low job content, low job control and psychosocial factors in private life. However, the result for workplace social support was sensitive to slight changes in the rating system, and the effect found for low job satisfaction may be a result of insufficient adjustment for psychosocial work characteristics and physical load at work. In addition, the combined evaluation of job content and job control, both aspects of decision latitude, led to strong evidence of a role for low job decision latitude. Thus, based on this review, there is evidence for an effect of work-related psychosocial factors, but the evidence for the role of specific factors has not been established yet.

Introduction

Back pain and other musculoskeletal symptoms are a major health problem in the Western world. Musculoskeletal disorders have been shown to be the largest group of occupational diseases in studies in different countries.[1] Figures of the British Occupational Physicians Reporting Activity show that of all new cases of diseases reported by occupational physicians in 1996 and 1997 nearly one half were musculoskeletal disorders.[2] According to the World Health Organization definition a work-related disorder is multifactorial, which indicates the role of physical, organizational, psychosocial, and sociological factors in its development.[3] In occupational health research there has been an increasing interest in psychosocial factors at work during the past few years.

Four explanations for the association between psychosocial work characteristics and musculoskeletal symptoms have been suggested. First, psychosocial work characteristics can directly influence the biomechanical load through changes in posture, movement and exerted forces.[4-6] Second, these factors may trigger physiological mechanisms, such as increased muscle tension or increased hormonal excretion, that may in the long term lead to organic changes and the development or intensification of musculoskeletal symptoms or may influence pain perception and thus increase symptoms.[4-7] Third, psychosocial factors may change the ability of an individual to cope with an illness which, in turn, could influence the reporting of musculoskeletal symptoms.[4-7] Fourth, the association may well be confounded by the effect of physical factors at work.[4-7] It seems plausible that psychosocial factors in private life could also affect musculoskeletal symptoms through the second and third mechanism.

In this article, the authors examine the evidence for psychosocial factors at work and in private life as risk factors for back pain. Several reviews on risk factors for back pain have paid attention to psychosocial factors.[4,7-10] However, none of the published reviews included clearly defined inclusion and exclusion criteria, a methodological quality assessment of the studies, as well as explicit criteria on which the assessment of the strength of the evidence was based. In this review a strict systematic approach is used to identify and summarize the available evidence in the literature. The method used is comparable with that applied in the clinical literature on the efficacy of interventions for back pain.[12] In this field, the current interest in evidence-based medicine has led to an extensive increase in the publication of systematic reviews and to the development of methodological guidelines for systematic reviews.[13]

Because individual psychological factors such as personality traits and cognitive and behavioral variables are also referred to as psychosocial factors, it is important to emphasize that this review concentrates only on psychosocial factors at work and in private life. The grouping of psychosocial work characteristics into categories in this review is mainly based on the Demand-Control-Support model, developed by Karasek et al.[14,15] and Johnson and Hall.[16] Although it is questionable whether job satisfaction should be regarded as a separate psychosocial work characteristic or as a response to working conditions such as psychosocial work characteristics and physical load at work, job satisfaction is included because many of the studies on work-related psychosocial factors as risk factors for back pain that have been performed so far focused on job dissatisfaction.

In this article, a systematic approach was applied to answer the following research questions:

- Are psychosocial factors at work risk factors for the occurrence of back pain?
- Are psychosocial factors in private life risk factors for the occurrence of back pain?

A similar evaluation of the evidence for aspects of physical load as risk factors for back pain has been reported elsewhere.[17]

Methods

Identification and selection of the literature

The available literature in the English, Dutch, German, and French language 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. The abstracts of all the citations were retrieved and examined. A selection was made from the identified articles. The first reviewer (WH) was responsible for the entire selection, but to check the reproducibility of the selection process, a second reviewer (MP) selected a random sample (n=100) from the articles identified in Medline.

Studies had to meet the following inclusion criteria:

1. The design of the study had to be case-control, prospective cohort or historical cohort, and the follow-up period had to be at least one year. Studies with a cross-sectional design were excluded.
2. The study had to concern a working population or a community-based population. Studies involving patient populations were excluded.
3. The operationalization of back pain had to be based on symptoms or signs of non-specific 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 and those on back pain due to osteoporosis, cancer, or other specific causes were excluded. Studies that focused on back pain during pregnancy were also excluded.
4. The exposures that were studied included psychosocial factors at work or psychosocial factors in private life (no personality traits). Studies that involved only a comparison between different occupational groups were excluded.
5. The publication had to be a full report. Letters and abstracts were excluded.

The references of all selected articles and recently published review articles[4,7-11] were screened for additional, potentially eligible publications.

Methodological quality assessment and data abstraction and analysis

The selected studies were scored by two reviewers (WH, MP), independently, on the basis of a standardized set of criteria that were adapted from criteria lists used in systematic reviews of randomized controlled clinical trials on treatment[13] and criteria lists used in other reviews of observational studies.[18,19] 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 criteria lists were used for cohort studies and case-control studies (see Table A1 in the Appendix of Chapter 2). These lists were also used in a similar evaluation of the evidence for aspects of physical load as risk factors for back pain.[17] The reviewers rated each criterion positive, negative, or unknown on the basis of the information provided in the article.

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 to achieve 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.

Data on the effect of the exposures of interest were abstracted from the text and tables of the original publications. Whenever possible, this included not only 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 was computed from the information 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.[20]

In order to synthesize the available information, use was made of a method based on levels of evidence.[21] Due to the expected heterogeneity in study population, exposure measurements, and the assessment of back pain, it had been previously decided to refrain from statistical pooling of the findings of the individual studies. The rating system was applied to each psychosocial factor and consisted of three levels of scientific evidence based on the number, the quality, and the outcome of the studies:

- Strong evidence: provided by generally consistent findings in multiple high-quality studies.
- Moderate evidence: provided by generally consistent findings in one high-quality study and one or more low-quality studies, or in multiple low-quality studies.
- Insufficient evidence: only one study available or inconsistent findings in multiple studies.

A study was considered to be of high quality if the methodological quality score was more than 50% of the maximum score and of low quality if the methodological score was 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 assessment of the level of evidence.

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 reported only 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 whether the effect was not statistically significant due to the absence of an effect or a lack of statistical power.[22] Because ignoring the statistical significance could be controversial, those 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 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, rather than on measures of the consequences of back pain such as sick leave, medical consultation or treatment, and disability. If results of analyses in different subgroups were reported, the studies were considered to indicate a positive or a negative effect if such an effect was found in at least one of the subgroups.

Results

Selection and methodological quality assessment

The literature search in the various data bases resulted in the identification of 1363 publications. The publications on ten studies met the inclusion criteria.[23-60] After the references of these articles and recent reviews were screened,[8,10] an additional 4 studies were included.[61-64] The selection of studies for inclusion, from a random sample (n=100) of the articles identified in Medline by the second reviewer, led to initial disagreement for only one study, which was due to differences in the interpretation of the third inclusion criterion.

One of the 14 selected studies was excluded post hoc, because the early retirements that were studied did not necessarily have a back disorder as the main diagnosis.[23,24] For most studies, there was more than one publication, and the assessment of the methodological quality of these studies was based on the information in all the publications.

The scoring of the 11 cohort and 2 case-control studies that were finally included in this review led to an overall initial disagreement of 22% (41/187) and 24% (9/38), respectively. The two reviewers reached consensus on all initial disagreements. Tables 3.1 and 3.2 show the cohort and case-control studies on psychosocial factors as risk factors for back pain, in order of the methodological quality score. Eight (73%) cohort studies[25-54,57-60,62] and one (50%) case-control study[56] had a positive score for more than 50% of the criteria on validity and precision and were therefore considered to be of high quality. Tables 3.3 and 3.4 give a detailed description of important aspects of the cohort and case-control studies included in the review.

Psychosocial factors at work

Work pace

Three high-quality studies examined the effect of a high work pace. In one of these studies it was reported only that no statistically significant effect was found.[41] One study found a statistically significant negative effect of a high work pace on back-related short absenteeism,[48] and the other found a statistically significant positive effect of a high work pace on sciatic pain.[59] Application of the rating system showed that there is insufficient evidence of an effect of a high work pace on the risk of back pain, because of inconsistent findings.

Qualitative demands

One high- and one low-quality study evaluated the effect of high qualitative job demands. Qualitative job demands include conflicting demands, interruption of tasks, and intense concentration for long periods. Hemingway et al.[48] found that high conflicting demands had a statistically significant negative effect on short and long absences from work due to back pain. However, in men, high conflicting demands turned out to have a statistically significant positive effect on short absences. The low-quality study[61] found that high mentally demanding work had a statistically significant positive effect on the point prevalence of back pain. Application of the rating system showed that there is insufficient evidence of an effect of high qualitative demands on the risk of back pain, because of inconsistent findings.

Job content

Four high-quality studies evaluated the effect of poor job content. Job content includes monotonous work and work with few possibilities to learn new things and to develop knowledge and skills. In all studies it was reported only that no statistically significant effect was found.[41,52,59,60] However, in one of these studies, which examined both low back symptoms and findings, the investigators also found that poor work content had a statistically significant positive effect on low back clinical findings in blue collar workers.[52] Application of the rating system showed that there is insufficient evidence of an effect of poor job content, because there was only one usable study available.

Job control

Job control includes aspects such as autonomy and influence. In one high-quality study, researchers examined the effect of work control and reported that no statistically significant effect was found, except in blue-collar women, for whom low work control had a positive effect on both low back symptoms and clinical findings.[52] Application of the rating system showed that there is insufficient evidence of an effect of low job control, because there was only one study available.

In another high-quality study, job control was also examined.[48] However, in this study job control included aspects of both job content and control. This combination is often called decision latitude in the Demand-Control-Support model.[14,15] Low job control was found to have a statistically significant positive effect on short and long absences due to back pain, except in men in lower grade jobs and women in higher grade jobs, in whom the effect was reversed.[48] Application of the rating system also showed that there is insufficient evidence for low decision latitude as a risk factor for back pain, because there was only one study available.

Social support in the workplace

Five high-quality studies and one low-quality study evaluated the effect of low social support in the workplace.[31,47,48,52,59,63] Support in the workplace includes social support of co-workers and supervisors, relationships at work, and problems with workmates and superiors. Results in two high-quality studies showed that low support had a statistically significant positive effect.[31,59] In one high-quality study, investigators found a nonsignificant positive effect.[47]

Table 3.1 Cohort studies on psychosocial factors at work and in private life as risk factors for back

First author/Criteria	*1*	*2*	*3*	*4*	*7*	*8*	*9*	*10*	*11*	*12*
Biering-Sørensen[34-42]	+	+	+	+	+	?	+	?	+	-
Leino[49-54]	+	-	+	+	+	?	+	?	+	-
Bigos[25-33]	+	+	-	?	+	?	+	?	+	+
Riihimäki[57-59]	+	+	-	+	+	?	+	?	+	-
Papageorgiou[43-47]	+	+	-	-	+	?	+	?	-	+
Ready[62]	+	+	-	+	-	-	+	?	+	-
Rossignol[60]	+	+	-	+	-	-	+	?	+	-
Hemingway[48]	+	-	-	+	-	-	+	?	+	-
Muramatsu[55]	+	+	-	+	-	-	-	-	+	-
Viikari-Juntura[64]	+	+	?	-	?	?	+	?	+	?
Bergenudd[61]	+	+	?	-	-	-	+	?	?	-

Abbreviations: +, yes; -, no; ?, don't know; V/P, criteria on validity/precision.
* The numbers refer to the numbers of the criteria in the list for the methodological quality assessment in Table A1 at the end of Chapter 2.

Table 3.2 Case-control studies on psychosocial factors at work and in private life as risk factors for

First author/Criteria	1	2	5	6	7	8	9	10	11	12
Nuwayhid[56]	+	-	-	-	+	?	+	?	+	+
Ryden[63]	+	+	-	?	-	-	+	?	+	-

Abbreviations: +, yes; -, no; ?, don't know; V/P, criteria on validity/precision.
* The numbers refer to the numbers of the criteria in the list for the methodological quality assessment in Table A1 at the end of Chapter 2.

pain, ranked according to methodological quality score*

13	17	18	19	21	22	23	Percentage + V/P(=3-23)
+	+	+	-	+	+	+	73%
+	+	+	-	+	+	+	73%
+	?	+	+	+	+	+	67%
+	?	+	-	+	+	+	60%
-	+	+	+	+	+	+	53%
+	?	+	+	+	+	-	53%
+	?	+	+	+	+	-	53%
+	?	+	+	+	+	-	53%
+	?	-	-	-	+	+	33%
-	?	+	-	+	+	-	33%
-	?	-	-	+	+	+	27%

back pain, ranked according to methodological quality score*

13	14	15	16	17	20	21	22	23	Percentage + V/P(=5-23)
+	+	-	-	+	+	+	+	+	65%
+	+	?	+	?	-	+	+	-	41%

Table 3.3 Summary of the cohort studies on psychosocial factors and back pain

First author/MQS	Study population	Operationalization of back pain
Bergenudd[61]/4*	1542 10-year-old residents of Malmö, Sweden, 830 included in 1983, follow-up response 69%	Present BP at follow-up in 1983 (questionnaire)
Biering-Sørensen[34-42]/11†	928 30-, 40-, 50- and 60-year-old inhabitants of Copenhagen, follow-up response 99% Analysis restricted to 351 persons with no LB trouble before at baseline	LBP within the last 12 months (questionnaire)
Bigos[25-33]/10†	3020 blue-collar workers at one of the plants of Boeing-Everett	Incident reports or claims for acute back injury complaints
Hemingway[48]/8‡	10308 non-industrial civil servants aged 39-55 years, 94% allowed for collection of sick leave data; data on the reasons for absence were available for 5620 participants	1. Number of absences ≤ 7 days due to intervertebral disc, disc pain, sciatica, leg pain, BP, backache, LBP, lumbago, lumbar strain (self-reported reason for absence) 2. Number of absences of > 7 days due to the same complaints (reason for absence from medical certificate) (Sick leave records)
Leino[49-54]/11‡	902 blue- and white-collar employees of metal industry plants, follow-up response 67%	1. LB symptoms score during the past 12 months at the last follow-up (questionnaire) 2. LB clinical findings score (physiotherapist)

Follow-up	Results
45 years, 3 or 4 measurements	Work (questionnaire): low job satisfaction 1964, 1971, 1983 (S), mentally demanding work 1964, 1971, 1983? (S)
12 months, 2 measurements	Work (questionnaire): work speed (NS), monotony (NS), low job satisfaction (S)
1 day-4 years (mean 3 years)	Work (questionnaire): lack of co-worker support (S), lack of supervisor support (S), job dissatisfaction (S) Work (questionnaire, adjusted for hysteria and prior BP): job dissatisfaction [$RR_{increase\ 1\ unit}$=1.7 (1.31-2.21)] Nonwork (questionnaire): family support (NS)
mean 4 years	Work (questionnaire, adjusted for age, education, housing tenure, access to use of car, body mass index, exercise, smoking habits, previous BP and the other variables shown, outcome 1): Males: control [$RR_{medium-high}$=1.31 (1.04-1.64), $RR_{low-high}$=1.44 (1.11-1.85)], conflict [$RR_{medium-high}$=0.88 (0.71-1.09), $RR_{low-high}$=0.73 (0.55-0.95)], pace [$RR_{medium-high}$=1.21 (0.96-1.54), $RR_{low-high}$=1.79 (1.39-2.31)], work social support [$RR_{medium-high}$=1.01 (0.80-1.27), $RR_{low-high}$=1.12 (0.89-1.41)], job satisfaction [$RR_{medium-high}$=1.04 (0.80-1.33), $RR_{low-high}$=1.17 (0.92-1.48)] Females: control [$RR_{medium-high}$=1.04 (0.71-1.53), $RR_{low-high}$=1.01 (0.70-1.47)], conflict [$RR_{medium-high}$=1.17 (0.80-1.73), $RR_{low-high}$=1.30 (0.87-1.73)], pace [$RR_{medium-high}$=1.50 (1.05-2.15), $RR_{low-high}$=1.42 (0.98-2.07)], work social support [$RR_{medium-high}$=0.81 (0.58-1.14), $RR_{low-high}$=0.87 (0.63-1.19)], job satisfaction [$RR_{medium-high}$=1.08 (0.78-1.50), $RR_{low-high}$=1.15 (0.83-1.58)]
	Work (questionnaire, adjusted for age, gender, previous BP and the other variables shown, outcome 1): control [$RR_{low-high}$=1.76 (1.54-2.01)], conflict [$RR_{low-high}$=1.29 (1.13-1.46)]
10 years, 3 measurements	Work (questionnaire, adjusted for age, LB symptoms at baseline and physical load, outcome 1): work content (NS), work control (NS, except in blue-collar women), social relations (NS, except in blue-collar men)

Table 3.3 Continued

First author/MQS	Study population	Operationalization of back pain
Papageorgiou[43-47]/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 LBP at baseline, follow-up response 64%	1. Episodes of LBP leading to consultation with the general practitioner (computer records from the general practitioners) 2. Episodes of LBP not leading to consultation and > 1 day over the past 12 months (questionnaire)
Muramatsu[55]/5	2200 noninstitutionalized older adults in Japan aged ≥ 60, follow-up response 90% The analysis focused on those currently not suffering from LBP at baseline	Self-reported 'chronic LBP' (interview at follow-up)
Ready[62]/8	131 full-time female nurses and unit assistants, follow-up response 91%	Back injuries reported by the employees on an employee accident report
Riihimäki[57-59]/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 never had had sciatic pain at baseline	Three-year cumulative incidence of sciatic pain (questionnaire)
Rossignol[60]/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)

Follow-up	Results
12 months, 2 measurements	Work (questionnaire, adjusted for age, adjustment for psychological distress and social class did not affect the OR found, outcome 2): satisfaction with work [$OR_{slightly\ inadequate}$=1.7 (1.2-2.4), $OR_{marked/severely\ inadequate}$=2.0 (1.2-3.3)], relationships at work [$OR_{slight\ problems}$=1.4 (0.9-2.0), $OR_{marked/severe\ problems}$=0.9 (0.3-3.0)]
3 years, 2 measurements	Nonwork (interview, adjusted for age, gender, education, marital status, physical activity, contact with child, psychological distress, smoking, drinking, comorbidity, self-rated health and functional limitations and the other variables shown): have close friend or neighbour (NS), social contact (NS), social participation (NS), instrumental support (NS), emotional support (S)
18 months	Work (questionnaire): job satisfaction [$RR_{change\ job/change\ conditions\text{-}good}$=2.29 (1.08-4.85)]
3 years, 2 measurements	Work (questionnaire, adjusted for draft and cold, amount of twisted or bent postures, vibration, and the other variables shown): high pace of work (S), monotonous work (NS), problems with workmates or superiors (S)
12 months, 2 measurements	Work (questionnaire, outcome 1, 2, 3, 4): boredom at work (NS) Work (questionnaire, outcome 1): work satisfaction (NS) Work (questionnaire, outcome 2, 3, 4): work satisfaction (OR=≥ 3.0, S)

Table 3.3 Continued

First author/MQS	Study population	Operationalization of back pain
Viikari-Juntura[64]/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 LB region during the last 12 months and a mean disability index ≥ 15 at the last follow-up in 1986-1987 2. Pain, ache, stiffness, or numbness in the LB > 7 days, or a mean disability index ≥ 15 at the last follow-up in 1986-1987 (Questionnaire)

Abbreviations: MQS, methodological quality score based on items on validity and precision; LBP, low back pain; LB, low back; BP, back pain; RR, relative risk; OR, odds ratio, the corresponding 95% confidence intervals for the RR and OR are shown in parenthesis; S(tatistically significant), p≤0.05; NS, not significant.
* The article on this study does not make exactly clear when what was measured.
† Some 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.

Table 3.4 Summary of the case-control studies on psychosocial factors and back pain

First author/MQS	Study population	Definition of cases and controls
Nuwayhid[56]/11	Over 900 fire fighters and 1900 fire officers assigned to 142 ladder and 210 engineer companies; N=115 cases (response 62%) and N=109 controls (response 75%)	Cases: full-duty fire fighter, who reported LBP 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 LBP, professional care or lost workdays were excluded. Controls: full-duty fire fighter with no previous LBP experience or with earlier episodes that did not entail professional care nor loss of workdays.
Ryden[63]/7	Employees at a children's hospital and health center; N=84 cases and 168 matched controls	Cases: employees with reported LBP injuries while employed at a children's hospital and health center in 1983-1985. Controls: selected from the same population and matched by age, sex and department or physical requirements of the job.

Abbreviations: MQS, methodological quality score based on items on validity and precision; LBP, low back pain; OR, odds ratio, the corresponding 95% confidence interval are shown in parenthesis; NS, not significant.

Follow-up	Results
32 years, 4 measurements	Work (questionnaire 1985, outcome 1 and 2): job satisfaction (NS)

‡ 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.

§ The results for work-related risk factors from 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.

Results
Work (interview): satisfaction at work (NS)
Work multivariate (employee health records, adjusted for age, sex and department): problems at work [OR=0.67 (0.01-59.66)] Nonwork (employee health records, adjusted for age, sex and department): problems at home [OR=0.69 (0.18-2.68)]

Leino and Hänninen[52] did not consistently find an effect in the analyses in all subgroups, but low support had a statistically significant positive effect or no effect, both on low back symptoms and clinical findings. Finally, no effect was found in one high-quality study, except in men in whom a nonsignificant negative effect of low workplace support on long absences due to back pain was found.[48] The results were considered to indicate no effect, because no effect was found on short absences, the operationalization of back pain that is closest to self-reported symptoms. Because findings in four of five studies indicated a positive effect, application of the rating system showed that there is strong evidence for low social support in the workplace as a risk factor for back pain. The magnitude of the risk estimates (RR/OR) ranged from 1.3 to 1.9.

Job satisfaction

The effect of low job satisfaction was reported in seven high- and 2 low-quality studies.[31,41,47,48,56,60-62,64] In one high-quality study it was reported only that no statistically significant effect was found.[56] Results in another high-quality study indicated no effect of low job satisfaction.[48] Five high-quality studies found that low job satisfaction had a statistically significant positive effect.[31,41,47,60,62] Because results in five of six studies indicated a positive effect of low job satisfaction, application of the rating system showed that there is strong evidence for low job satisfaction as a risk factor. The magnitude of the risk estimates (RR/OR) ranged from 1.7 to 3.0.

Sensitivity analysis

Strong evidence of an effect was found for low social support in the workplace and low job satisfaction. When all the studies in which a nonsignificant effect for these exposures was found were considered as indicating no effect, the result for job satisfaction did not change. For low support in the workplace, this would mean that results in two studies indicated no effect and those in three indicated a positive effect, which would provide insufficient evidence of an effect of low social support in the workplace because of inconsistent findings.

Psychosocial factors in private life

The effect of psychosocial factors in private life was reported in only one high-quality study and two low-quality studies,[31,55,63] and the factors studied were very different. They included family support, presence of a close friend or neighbor, social contact, social participation, instrumental support, and emotional support. In general, in these studies it was reported only that no statistically significant effect was found. The only effect found was that high emotional support had a statistically significant positive effect for chronic low back pain in a group of elderly subjects.[55] Therefore, application of the rating system showed that there is insufficient evidence of an effect of psychosocial factors in private life.

Discussion

Selection of studies

Although efforts were made to find all published cohort and case-control studies, the possibility of selection and publication bias cannot be excluded. The exclusion of studies with a cross-sectional design is an important difference between this review and previously published reviews on the same topic. The main argument for the exclusion of this type of study is that temporality, the only inarguable and therefore necessary criterion for causality,[65] is not met in cross-sectional studies, in which exposure and outcome are assessed simultaneously.

Studies with a fairly broad spectrum of outcome measures were included in this review. Given the suggested explanations for the association between psychosocial work characteristics and musculoskeletal pain, there may be psychosocial factors that affect only the reporting of symptoms and sick leave.[4-7] In addition, different groups of back pain, classified based on characteristics such as, for example, the absence or presence of radiation, may have different causes. However, because of the limited number of studies and the heterogeneity in the assessment of back pain, it was not possible to specifically examine the association between psychosocial factors and different types of back pain, such as back pain with and without radiation, and different measures of back pain, such as back pain on survey, reports of back pain, and such consequences of back pain as sick leave, medical consultation or treatment and disability. Because of the limited number of studies, it was also not possible to examine the evidence available from case-control and cohort studies separately.

Quality of the studies

Based on the scoring on the criteria list the methodological quality of most studies (69%) was considered to be high. The quality of studies in working populations turned out to be generally higher than of studies in community-based populations.

None of the publications on any of the studies clearly demonstrated with reference to repeatability data that standardized methods of acceptable quality were used for the assessment of psychosocial factors at work. Only one study[48] made use of the Job Content Questionnaire[66] to measure psychosocial work characteristics. Although factors examined by different investigators were combined in the same category in this review, factors that seemed to have similar names could differ unexpectedly, because of differences in measurement methods or in the items included in the scale. Although most studies presented quantitative measures of effect for some of the factors studied, in many studies, effect estimates were missing for at least some of the psychosocial factors of interest.

A few aspects of the quality of the studies were not included in the criteria list but were observed during the scoring of the studies. For instance, the reviewed studies provide little insight into the effect of adjustment for certain covariates, because only one study showed the effect estimate for a certain exposure with and without adjustment for covariates.[48] The prevalence of back pain instead of the cumulative incidence was examined in some of the cohort studies, because the occurrence of back pain was assessed for only a part of the follow-up period.[49-54,61]

Assessment of evidence

The main difference between this review and previously published reviews on the same topic is the application of a systematic approach that includes explicitly defined criteria, on which the assessment of the strength of the evidence was based. As in the clinical literature, it is still unclear which items are especially important causes of bias and should therefore be included in the methodological quality assessment.[13] One of the specific problems encountered in this review of observational epidemiological studies, compared to reviews of clinical trials in which usually only one contrast is evaluated, is that the relatively broad objective of this review and most of the evaluated studies resulted in a relatively non-specific list of criteria. Another problem that arises from the rating system applied in this review of observational studies is that the synthetic approach can give a false impression of consistency across study results.

In spite of these limitations, in the authors' opinion, the use of a systematic approach with scoring of the quality of the studies and defining levels of evidence was appropriate in the present qualitative review. One important advantage is that the reader is given considerable insight into the process of assessment of the evidence. This makes it possible to repeat the analysis and to examine how the results are influenced if slight changes are made in the assessment of the findings or the methodological quality of the studies.

Evidence for psychosocial factors as risk factors for back pain

Strong evidence for a positive effect was found for low social support in the workplace and low job satisfaction. The results of the sensitivity analysis showed that insufficient evidence instead of strong evidence was found for low social support when nonsignificant findings were dealt with differently. This was because the effect found for social support in the workplace was of relatively low magnitude and nonsignificant in one of the four studies in which a positive effect was found.[47] The assessment of the evidence can also be changed by using a slightly different definition of high- and low-quality studies. The use of a cutoff point of 40% for the assessment of high-quality studies, implying that more studies are considered to be of high-quality, results also in insufficient evidence instead of strong evidence for social support in the workplace. The results for the other factors are not affected. The use of a cutoff point of 60% has no effect on the results for any of the factors studied.

In the only study in which no effect of low job satisfaction was found, the statistically significant association found in univariate analysis disappeared after adjustment for both prior back pain and psychosocial work characteristics such as demands, control and support.[48] Three of the five studies in which a positive effect of low job satisfaction was found had also adjusted for prior back pain, but not for other psychosocial work characteristics.[31,41,47] In none of the studies were the results adjusted for physical load at work. Therefore, the positive association between low job satisfaction and back pain may be due to an intercorrelation between psychosocial work characteristics and physical load on the one hand and job satisfaction on the other.

Insufficient evidence was found for either a high work pace or high qualitative demands, because of inconsistent findings. The contradictory findings for a high work pace[48,59] may be caused by a lack of or improper adjustment for physical load at work. The contradictory findings of the two studies on the effect of high qualitative demands may be because each study focuses on different aspects of qualitative demands, namely, conflicting demands[48] and high mental demands.[61] However, the studies also differ in their operationalization of back pain, the adjustment for confounding, and the period between the measurement of exposure and back pain. In one of the studies,[61] even the timing of the different measurements was not quite clear.

Insufficient evidence was found for an effect of job content, job control, or decision latitude, because the available information was too limited. However, the division into categories in this review is debatable. Job content and job control, the sub-dimensions of decision latitude, appear to be highly correlated.[67] If the assessment of the evidence was focused on all three categories together, strong evidence would have been found for the total group. This evidence would be based on one high-quality study in which a positive effect was found for both job content and job control separately,[52] and another study in which a positive effect of decision latitude was found.[48]

In general, it can be concluded that in many of the studies no adjustment had been made for physical load at work, and even if this factor was controlled for, in most cases a rough measure was used, or the adjustment was restricted to certain aspects of physical load at work. In the workplace a high correlation often exists between psychosocial factors and physical load.

Insufficient evidence was found for an effect of psychosocial factors in private life, simply because the data were very limited.

Comparison with the results of previous reviews

It is interesting to see how the results of this review compare with the conclusions drawn in other recently published reviews on the same topic.[4,7-10] Bongers et al.[4] concluded that there is evidence for monotonous work or poor work content and poor support by colleagues as risk factors for back pain. Burdorf and Sorock[10] concluded that job dissatisfaction and monotonous work were important factors. The results of Bernard et al.[8] showed that there was evidence for intensified work load as a risk factor, and limited evidence for low job control and job dissatisfaction.

The conclusions drawn in the various reviews appear to be rather heterogeneous. In all reviews, evidence was found for the effect of some of the psychosocial work characteristics, but there is no psychosocial work characteristic for which evidence was found in all reviews. The differences in the results of the present review, compared with those in other reviews, are mainly based on the fact that cross-sectional studies were excluded from this review. In the other reviews the evidence for (quantitative and qualitative) job demands,[8] monotonous work,[4,8,10] and job control[8] was based solely on the findings of cross-sectional studies. Furthermore, a difference in the interpretation of the results of the study of Bigos et al.[31,32] played an important role in the different result for social support in the workplace. In the review of Bernard[8] the findings were interpreted as indicating no effect of support, while in this review and in the review of Bongers et al.[4] the findings were interpreted as indicating a positive effect of low support.

The role of psychosocial factors in private life was also evaluated in one of the reviews,[9] and it was concluded that the few studies that analyzed the effects of life events or social relationships outside the work environment indicate that these are of minor importance. However, an effect of life events was found in several cross-sectional studies. In the present review, however, no case-control or cohort studies on the effect of life events were identified.

Having evaluated the strength of the evidence for both physical[17] and psychosocial factors as risk factors for back pain, using the same methods, the question arises of whether the findings indicated a difference in the evidence for physical and psychosocial factors. Strong or moderate evidence has been found for heavy physical work; lifting; bending, and twisting; and whole-body vibration at work. Unlike the results for psychosocial factors, these results were rather insensitive to slight changes in the assessment of the findings and the methodological quality of the studies and in agreement with the results of previous reviews on physical load.[17] This indicates that the body of evidence supporting the role of these physical load factors as risk factors for back pain is somewhat more consistent than that for the psychosocial factors.

Conclusions and recommendations

On the basis of the approach applied, strong evidence was found for a positive effect of low social support in the workplace and low job satisfaction. However, the result for low social support was sensitive to changes in the assessment of the findings and the methodological quality of the studies. The effect found for low job satisfaction may be a result of insufficient adjustment for psychosocial work characteristics and physical load at work. Insufficient evidence was found for an effect of a high work pace, high qualitative demands, low job content, low job control, and psychosocial factors in private life. However, the combined evaluation of studies on job content and job control, both aspects of decision latitude, led to strong evidence for low job decision latitude as a risk factor for back pain.

Results of further analysis of the available evidence led to the conclusion that investigators in future studies should adjust for all the different aspects of physical factors at work before more definite conclusions can be drawn on the effect of psychosocial work characteristics. Furthermore, researchers should examine more extensively the pathway of the associations between psychosocial work characteristics (such as job demands, job control and social support), physical load at work, job satisfaction, and back pain. Efforts should also be made to measure psychosocial factors in an identical manner in different studies. Concerning psychosocial factors in private life, there is a need for more longitudinal and case-control studies based on a similar set of factors, including life events.

Comparing the results of this and other reviews on psychosocial factors showed that although there was evidence for the effect of some psychosocial work characteristics in all reviews, the results were rather heterogeneous. The merit of the approach used in this review is that the reader is given much insight into the process of assessment of the evidence. The results of this review appeared to be rather sensitive to slight changes in the assessment of the findings or the methodological quality of the studies, considering the possibility of (residual) confounding, and a change in the division into categories of the psychosocial work characteristics. This leads to the conclusion that there seems to be evidence for an effect of psychosocial factors at work but that the evidence for the role of specific work-related psychosocial factors has not been established yet.

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Flexion and rotation of the trunk and lifting at work are risk factors for low back pain:

results of a prospective cohort study

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Abstract

The objective was to investigate the relationship between flexion and rotation of the trunk and lifting at work and the occurrence of low back pain. The research was part of a three-year prospective cohort study of risk factors for musculoskeletal symptoms among workers of 34 companies in the Netherlands. The study population consisted of 861 workers with no low back pain at baseline and complete data on the occurrence of low back pain during the three-year follow-up period. Physical load at work was assessed by means of analyses of video-recordings. Information on other risk factors and the occurrence of low back pain was obtained by means of self-administered questionnaires. An increased risk of low back pain was observed for workers who worked with the trunk in a minimum of 60 degrees of flexion for more than 5% of the working time (RR 1.5, 95% CI 1.0-2.1), for workers who worked with the trunk in a minimum of 30 degrees of rotation for more than 10% of the working time (RR 1.3, 95% CI 0.9-1.9), and for workers who lifted a load of at least 25 kilograms more than 15 times per working day (RR 1.6, 95% CI 1.1-2.3). It can be concluded that flexion and rotation of the trunk and lifting at work are moderate risk factors for low back pain, especially at greater levels of exposure.

Introduction

The effect of physical load at work on the occurrence of low back pain has been studied extensively during the past 20 years. Several reviews of the literature have reported that there is evidence that flexion and rotation of the trunk and lifting at work are risk factors for back pain.[1-3]

Although a number of articles have addressed the limited value of self-reported physical work load,[4,5] however, to date only two case-referent studies actually have quantified physical load at work.[6,7] Unfortunately, potential confounding by psychosocial work characteristics was not taken into account in the reported analyses of the data of these studies.[6,7] Most previous studies on the risk of work-related physical factors failed to assess and include in the analyses individual and psychosocial factors that also may be relevant in the aetiology of low back pain.[8] The Boeing study was the first long-term prospective cohort study that included physical, psychosocial, and individual factors.[9,10]

The present report on low back pain is part of the Study on Musculoskeletal disorders, Absenteeism, Stress, and Health (SMASH), a prospective cohort study among a working population that was initiated to identify risk factors for musculoskeletal disorders. The objective of the analyses described in this article was to determine whether flexion and rotation of the trunk and lifting at work are risk factors for the occurrence of low back pain and to explore the exposure-response relationship of these work-related physical factors with low back pain.

Materials and methods

Workers were recruited from 34 companies located throughout the Netherlands. The participating companies were asked to select workers who had been employed in their current job for at least one year and who were working 24 hours per week or more. Workers in blue-collar jobs as well as workers in white-collar jobs and caring professions were included in the study. The baseline measurements were carried out between March 1994 and March 1995 and consisted of three aspects: a self-administered questionnaire, assessment of the physical load at the workplace, and a physical examination. There was a three-year follow-up period.

At baseline, 1,789 (87%) of the 2,064 workers who were invited to participate completed the questionnaire, 1,738 of whom were eligible for participation in the study on risk factors for low back pain. Thirty workers were excluded because they had not been employed in their current job for at least one year or had a working week of less than 20 hours and therefore did not meet the inclusion criteria. A further 17 workers were excluded because they had another paid job for a substantial number of hours in addition to the job at the company from which they had been recruited, and 4 workers were excluded because they had had a work disability due to low back pain in the previous 12 months. For the longitudinal analysis described here, a subcohort of 1,192 workers with no low back pain at baseline was identified: workers who reported at baseline that they had not had regular or prolonged low back pain in the previous 12 months.

Data collection

All risk factors included in the analyses were measured at baseline. The physical load at work was assessed by means of video-recordings and force measurements at the workplace, according to a standard protocol.[a] Four video-recordings of all workers were made randomly during the course of one day. The duration of each video-recording was 10-14 minutes, depending on the variability of the worker's tasks. The project assistants who made the video-recordings classified all workers into groups with similar tasks and a similar physical load. Within each group, analyses of the posture, movement, and force exertion of one in four workers were made by means of observations from the video-recordings. The mean values for flexion and rotation of the trunk and lifting and sitting postures of the workers in each group for whom the video-recordings were analysed were assigned to all workers in the same group.

Assessment of the percentage of the working time spent in a sitting position and of the percentage of the working time spent with the trunk in a minimum of 30 or 60 degrees of flexion was based on continuous observations from the video-recordings. The categories of trunk flexion that were observed were defined as neutral (< 30 degrees), mild flexion (30-60 degrees), extreme flexion (60-90 degrees), and very extreme flexion (≥ 90 degrees). Assessment of the percentage of the working time spent with the trunk in rotation was based on multimoment observations from the four video-recordings per individual. The categories of trunk rotation were defined as neutral (< 30 degrees) and twisting (≥ 30 degrees) and were

[a] Available on request from the first author (in Dutch).

observed every 15 seconds. Assessment of the number of times workers lifted a load of any weight, or a load of at least 10 or 25 kilograms during a working day, was based on continuous observations from the video-recordings and on force measurements made at the workplace. The number of lifts during the period observed (4 times 10 or 14 minutes) was extrapolated to the number of lifts for an 8-hour working day.

Individual factors such as age, gender, level of education, and smoking habits were assessed on the basis of certain items in the self-administered questionnaire. One question was included for the assessment of exercise behaviour during leisure time.[11] Psychosocial work characteristics were measured by means of a Dutch version of Karasek's Job Content Questionnaire, and concerned the dimensions quantitative job demands, decision authority, skill discretion, supervisor support, and co-worker support.[12] The psychometric properties and the construction of the scales for these dimensions have been described by De Jonge et al.[13] for the data from the present study. Job security was assessed on the basis of one single question.[12] Driving a vehicle at work and during leisure time, as well as frequent flexion and/or rotation of the upper part of the body and moving heavy loads (> 25 kilograms) during leisure time, were assessed by means of the Loquest questionnaire.[14] Assessment of the body mass index was based on measurements of weight and height taken by a physiotherapist during the physical examination at baseline.

After each year of the follow-up period, the occurrence of low back pain and of workplace changes was assessed by means of a postal questionnaire. In the baseline and follow-up questionnaires, assessment of the occurrence of low back pain was based on an adaptation of the Nordic Questionnaire.[15] Cases of low back pain were defined for those workers who reported in at least one of the annual self-administered follow-up questionnaires that they had had regular or prolonged low back pain in the previous 12 months.

Statistical analysis

Univariate analyses were performed with the computer package Epi Info (Version 6.0). In these analyses, relative risks (RR) and corresponding 95 percent confidence intervals (95% CI) were calculated for the potential risk factors flexion and rotation of the trunk and lifting at work by comparing the cumulative incidence of low back pain between groups with different levels of exposure. The variables age, gender, smoking habits, body mass index, exercise behaviour during leisure time, quantitative job demands, decision authority, skill discretion, supervisor support, co-worker support, job security, moving heavy loads during leisure time, frequent flexion and/or rotation of the upper part of the body during leisure time, driving a vehicle during leisure time and at work, and the percentage of the working time spent in a sitting position were considered to be potential confounders. Therefore, it was checked whether these variables were actually univariately associated with the occurrence of low back pain with a Yates' corrected p-value of less than 0.25.[16,17] Variables that met this criterion were included in the multivariable analyses. Age and gender were included in the multivariable analyses, however, irrespective of the association with low back pain found in univariate analyses of this data set. In the univariate analyses, continuous independent variables were recoded as categorical variables using small intervals on the measurement scale of the variable (for example, intervals of 5% of the working time spent with the trunk in a minimum of 30 degrees of flexion) to determine whether there was a linear relationship with low back pain. Those variables that showed a nonlinear relationship with low back pain were divided into categories for further analysis. In general, small categories with similar relative risks were regrouped into a few larger categories, resulting in a division into 3-5 categories for most variables. Consistency of the categorization of related variables also was taken into account.

The presence of confounding was assessed by means of multivariable analyses. To prevent the occurrence of collinearity, the degree of interrelationship of the various risk factors selected for the multivariable analyses was checked. The Cox regression procedure in the SPSS computer package (Version 6.1.3), with a constant risk-period for all subjects, was applied for the estimation of adjusted relative risks.[18-20] Stepwise, the individual factors, psychosocial work characteristics, physical factors during leisure time, and physical factors at work that were selected on the basis of the results of the univariate analyses were added to a model that included only one of the work-related physical factors being studied at a time. To determine whether adjustment for the potential confounders influenced the results, it was checked whether the effect estimates for flexion and rotation of the trunk and lifting at work differed by more than 10% from the crude effect estimates.

The analyses were repeated for those workers who reported that no, or only minor changes in their work had occurred during the first and second follow-up periods. This selection reduced the likelihood of misclassification of exposure resulting from changes in the physical work environment with time. Workers whose work had changed because of back pain also were included in these analyses because the exclusion of these workers could result in a false decrease in the effect estimates. Moreover, to determine the presence or absence of a healthy worker effect, the analyses also were repeated for those workers who had been employed in their current job for 5 years or fewer at baseline.

Results

From the cohort of 1,192 workers, data on the occurrence of low back pain were available for 861 workers (72%) for all three annual follow-up measurements. Approximately 30% of the workers in this group were women. The mean age of the workers was 36 years, with an age-range of 18-59 years.

Crude relationships

The cumulative incidence of low back pain during the three-year follow-up period was 26.6% in the total group and 24.7% and 30.8% in men and women, respectively. For 835 workers, data on exposure to flexion and rotation of the trunk and lifting at work was available from video-based observations. Table 4.1 presents the results of the univariate analyses.

Table 4.1 Crude relationship of flexion and rotation of the trunk and lifting at work with low back pain

Risk factor	LBP	No LBP	Crude RR (95% CI) (n=835*)
Percentage of the working time trunk flexion ≥ 30°			
≤ 5% working time	107	319	1.00
5-10% working time	46	134	1.02 (0.75-1.37)
> 10% working time	70	159	1.22 (0.94-1.57)
Percentage of the working time trunk flexion			
≤ 5% working time ≥ 30°	107	319	1.00
5-10% working time ≥ 30°	46	134	1.02 (0.75-1.37)
> 10% working time ≥ 30° and ≤ 5% working time ≥ 60°	49	123	1.13 (0.85-1.51)
> 5% working time ≥ 60°	21	36	1.47 (1.01-2.14)
Percentage of the working time trunk rotation ≥ 30°			
≤ 5% working time	145	422	1.00
5-10% working time	59	151	1.10 (0.85-1.42)
> 10% working time	19	39	1.28 (0.86-1.90)
Number of lifts per 8-hour working day			
never	61	172	1.00
never ≥ 10 kg/working day	38	104	1.02 (0.72-1.45)
never ≥ 25 kg/working day	67	201	0.95 (0.71-1.29)
1-15 times ≥ 25 kg/working day	33	102	0.93 (0.65-1.35)
> 15 times ≥ 25 kg/working day	24	33	1.61 (1.11-2.34)
Number of lifts ≥ 25 kg per 8-hour working day			
never	166	477	1.00
1-15 times/working day	33	102	0.95 (0.68-1.31)
> 15 times/working day	24	33	1.63 (1.17-2.27)

Abbreviations: LBP, low back pain; RR, relative risk; CI, confidence interval.
* For 835 of the 861 workers, data was available on exposure to flexion and rotation of the trunk and lifting at work.

Both trunk flexion and lifting at work were statistically significantly associated with the occurrence of low back pain. The relationship between working with the trunk in a minimum of 60 degrees of flexion and low back pain was stronger than the relationship between working with the trunk in a minimum of 30 degrees of flexion and low back pain. The relative risk for working with the trunk in a minimum of 30 degrees of flexion did not increase with increasing duration of exposure. A slight increase in risk was found with increasing exposure to trunk rotation, but this relationship was not statistically significant. Because of the small number of workers who spent more than 10 percent of their working time with the trunk in a minimum of 60 degrees of flexion, or more than 15 percent of their working time with the trunk in rotation, it was not possible to determine whether there was a further increased risk at greater levels of exposure.

Lifting loads of less than 25 kilograms was not associated with an increased risk of low back pain. The risk of low back pain started to increase when a load of 25 kilograms or more was lifted more than 15 times per 8-hour working day. Further division of the highest exposure category of lifting showed a relative risk of 1.57 (95% CI 1.04-2.37) for lifting 25 kilograms or more 15 to 25 times per 8-hour working day and 1.74 (95% CI 1.06-2.88) for lifting a load of at least 25 kilograms more than 25 times per 8-hour working day, each compared with never lifting such a load.

Potential confounders of the studied relationships

Univariate analyses of the potential confounders showed that gender, exercise behaviour during leisure time, high quantitative job demands, low supervisor support, low co-worker support, moving heavy loads during leisure time, frequent flexion and rotation of the upper part of the body during leisure time, and driving a vehicle during leisure time and at work were univariately associated with low back pain with a p-value of less than 0.25. Therefore, these variables were included in the multivariable analyses of flexion and rotation of the trunk and lifting at work. It was predetermined to include age, independent of its association with low back pain. Decision authority and skill discretion were included because it was considered wise to include all related variables of psychosocial work characteristics.

Although working in a sitting position for more than 95% of the working time was associated with low back pain, with a p-value of less than 0.25, this variable was not included in the multivariable analyses because the percentage of the working time spent in a sitting position had a very strong negative correlation with lifting at work ($r = -0.76$). Moreover, the effects of flexion and rotation of the trunk and lifting at work were not adjusted for each other because the interrelationship between these exposures was very high in the study population. Correlation coefficients in the region of 0.60 and greater were found for the relationship between these three physical factors (data not shown).

The multivariable analyses of flexion and rotation of the trunk and lifting showed that adjustment for the selected variables did not influence the relative risks for the physical factors at work by more than 10% (Table 4.2). The confidence intervals of the relative risks estimated in multivariable analyses were wider than those of the relative risks resulting from univariate analyses (Table 4.1). This is because of the use of Cox regression, which produces adequate point estimates of the relative risk, but too conservative estimates of the confidence intervals.[19,20]

Change of work

Of the total group of 835 workers for whom complete data on flexion and rotation of the trunk and lifting at work was obtained from video-based observations, 724 workers (87%) reported that no, or only minor changes in their work had occurred or that the change in their work reported at the first or second follow-up measurement was related to back pain. In this subgroup, the effect estimates for the physical factors that were studied were somewhat higher, especially for trunk rotation, but the pattern of the relationships found remained the same (Table 4.3).

Table 4.2 Results from multivariable analyses for the relationship of flexion and rotation of the trunk and lifting at work with low back pain

Risk factor	Crude RR (95% CI)* (n=780)	Adjusted RR (95% CI)† (n=780)
Percentage of the working time trunk flexion ≥ 30°		
≤ 5% working time	1.00	1.00
5-10% working time	0.98 (0.68-1.41)	1.04 (0.70-1.54)
> 10% working time	1.17 (0.86-1.59)	1.19 (0.86-1.65)
Percentage of the working time trunk flexion		
≤ 5% working time ≥ 30°	1.00	1.00
5-10% working time ≥ 30°	0.98 (0.68-1.41)	1.05 (0.71-1.54)
> 10% working time ≥ 30° and ≤ 5% working time ≥ 60°	1.08 (0.77-1.53)	1.09 (0.76-1.58)
> 5% working time ≥ 60°	1.42 (0.88-2.30)	1.48 (0.90-2.42)
Percentage working time trunk rotation ≥ 30°		
≤ 5% working time	1.00	1.00
5-10% working time	1.10 (0.81-1.50)	1.08 (0.78-1.50)
> 10% working time	1.26 (0.77-2.06)	1.29 (0.77-2.15)
Number of lifts per 8-hour working day		
never	1.00	1.00
never ≥ 10 kg/working day	1.01 (0.66-1.53)	0.92 (0.60-1.42)
never ≥ 25 kg/working day	0.95 (0.67-1.36)	0.98 (0.67-1.42)
1-15 times ≥ 25 kg/working day	0.87 (0.56-1.35)	0.83 (0.52-1.33)
> 15 times ≥ 25 kg/working day	1.59 (0.98-2.60)	1.57 (0.90-2.75)
Number of lifts ≥ 25 kg per 8-hour working day		
never	1.00	1.00
1-15 times/working day	0.88 (0.60-1.31)	0.86 (0.57-1.30)
> 15 times/working day	1.62 (1.04-2.53)	1.62 (0.97-2.69)

Abbreviations: RR, relative risk; CI, confidence interval.

* Crude relative risk from Cox regression in the population with no missing values for gender, age, exercise behaviour during leisure time, quantitative job demands, decision authority, skill discretion, supervisor support, co-worker support, moving of heavy loads during leisure time, flexion and/or rotation of the upper part of the body during leisure time, driving a vehicle during leisure time and driving a vehicle at work.

† Relative risk from Cox regression, adjusted for the risk factors mentioned above.

Healthy worker effect

At baseline, 360 workers (43%) reported that they had been working in their current job for 5 years or fewer. The effect estimates for trunk rotation and lifting at work were somewhat greater in this subgroup than in the complete cohort, but the pattern of the relationships found remained the same for these variables (Table 4.3). For trunk flexion, the effect estimate for a minimum of 60 degrees of trunk flexion did not increase, but an increase in the effect estimate was observed for a minimum of 30 degrees of trunk flexion.

Table 4.3 Relationship of flexion and rotation of the trunk and lifting at work with low back pain: results of subgroup analyses

Risk Factor	Workers with no, or only minor changes in work Crude RR (95% CI) (n=724)	Workers employed ≤ 5 years in the current job at baseline Crude RR (95% CI) (n=360)
Percentage of the working time trunk flexion		
≤ 5% working time ≥ 30°	1.00	1.00
5-10% working time ≥ 30°	1.10 (0.80-1.52)	0.98 (0.61-1.57)
> 10% working time ≥ 30° and ≤ 5% working time ≥ 60°	1.20 (0.87-1.63)	1.53 (1.03-2.30)
> 5% working time ≥ 60°	1.72 (1.16-2.57)	1.55 (0.85-2.80)
Percentage of the working time trunk rotation ≥ 30°		
≤ 5% working time	1.00	1.00
5-10% working time	1.15 (0.87-1.52)	1.29 (0.89-1.87)
> 10% working time	1.57 (1.06-2.32)	1.75 (1.03-2.96)
Number of lifts per 8-hour working day		
never	1.00	1.00
never ≥ 10 kg/working day	0.91 (0.62-1.35)	0.82 (0.45-1.49)
never ≥ 25 kg/working day	0.99 (0.72-1.36)	0.94 (0.59-1.49)
1-15 times ≥ 25 kg/working day	0.85 (0.57-1.28)	1.07 (0.64-1.80)
> 15 times ≥ 25 kg/working day	1.79 (1.22-2.63)	1.98 (1.16-3.39)

Abbreviations: RR, relative risk; CI, confidence interval.

Discussion

Summary of findings

All exposures in this study showed a moderately strong relationship with the occurrence of low back pain. The degree of trunk flexion appeared to be a risk factor for low back pain. Extreme trunk flexion led to an increased risk of low back pain when the trunk was in a minimum of 60 degrees of flexion for more than 5% of the working time. The weight of a load also appeared to be a risk factor for low back pain. Lifting 25 kilograms or more increased the risk of low back pain when this occurred more than 15 times per working day, and a slight increase in risk was observed with a further increase in the frequency of lifting. In the initial analyses, the relationship of trunk rotation with low back pain was not so clear, but in the additional analyses, which included only those workers with no, or only minor changes in their work during the follow-up period, all relationships became somewhat stronger, and in the group of workers with the trunk in rotation for more than 10% of the working time, there was a definite increase in the risk of low back pain.

An important source of potential bias in occupational cohort studies is the healthy worker effect.[21] To minimize this form of bias, it would be better to study newly employed workers, but this was beyond the scope of the present study. An additional analysis of the group of workers who had been employed in their current job for 5 years or fewer, however, showed stronger associations with low back pain for the exposures under study, which indicates the presence of a healthy worker effect in the complete cohort.

Methodological strengths

The prospective design of the study made it possible to establish the existence of a temporal relationship, which is a necessary criterion for causality.[22] The physical load at the workplace was assessed on the basis of observations. Although, for reasons of efficiency, these measurements were not made at the individual level, they were made on a large scale.[23] Adjustments for individual factors, psychosocial work characteristics, and physical factors during leisure time were made in the analyses. The history of back pain, a variable that has been shown to be an important predictor of new episodes of low back pain,[8] was not included in the analyses reported here. In the population of this study that had no low back pain in the previous 12 months at baseline, 65.4 % of the workers reported ever having had low back pain at baseline, and this variable also was strongly associated with the occurrence of low back pain during the follow-up period (crude RR 2.74). It was decided not to adjust for a history of low back pain because prior low back pain also may be a result of the exposures under study, and therefore possibly an intermediate variable.[24] Additional adjustment for prior low back pain, however, appeared to have little or no influence on the effect estimates for the exposures under study (data not shown).

Limitations and potential sources of bias

The possibility of bias because of loss to follow-up exists in any cohort study. In the present study, the exposure to work-related physical factors was greater in those workers who were lost to follow-up. This probably is related to the fact that this group had a relatively low level of education. It is not possible to determine whether these differences have influenced the results of the analyses, because the relationship of exposure to work-related physical factors with the three-year cumulative incidence of low back pain in the workers who were lost to follow-up is unknown. The incidence of low back pain at the first follow-up, however, did not differ for those workers who were lost to follow-up after this specific measurement (data not shown).

In the present study, it was possible to identify a minimum level of exposure to flexion and rotation of the trunk and lifting at work above which the risk of low back pain started to increase. Because of the relatively small number of workers with exposure above this level, however, it was not possible to study the further course of the relationship of work-related physical exposures with low back pain at greater levels. Further, because of the strong correlation between flexion and rotation of the trunk and lifting at work in the study population, the independent causal effects of these exposures could not be separated.

Comparison with previous findings

Of special interest is comparison of the results of the present study with the results of the case-referent studies of Punnett et al.[6] and Norman et al.,[7] in which an observational method also was used to quantify the physical load at work. The present study confirms the finding of Punnett et al.[6] that flexion and rotation of the trunk as well as lifting at work are risk factors for low back pain. Further, Punnett et al.[6] also found that the risk increased with the degree of flexion. In their study, however, an exposure-response relationship with low back pain was found for both mild and severe flexion, and their effect estimates for flexion and rotation of the trunk were greater than those of the present study, even though lower cutoff points were used for the definition of mild flexion (21-45 degrees), severe (extreme) flexion (> 45 degrees) and trunk rotation (> 20 degrees). Punnett et al.[6] found an odds ratio of 2.2 for the effect of lifting a load of at least 10 pounds (4.54 kilograms) at least once per minute throughout the working day, which is equivalent to at least 480 times per 8-hour working day. In the present study, an effect of lifting only was found for heavier loads.

In the study of Norman et al.,[7] both trunk kinematic variables and external forces on the hands were associated with the risk of reporting low back pain at work. Crude odds ratios ranging from 1.4 to 2.4 were found. Unlike the study of Punnett et al.,[6] the study of Norman et al.[7] did include the assessment of possible psychosocial risk factors, but the analyses in the report of Norman et al.[7] focused on the biomechanical data of the study and did not include the psychosocial risk factors. In addition, no attempt was made to examine exposure-response relationships.

Comparison of the results of the present study with the results of the Boeing study is difficult, because in the Boeing study two different measures of heavy physical work were studied that did not resemble the operationalizations of physical load at work in the present study.[9,10] No statistically significant relationship was found between these measures of heavy physical work and reports of back pain.

When the results of the present study are compared with the results of previous prospective cohort studies on risk factors for low back pain, one has to be aware that relative risks were computed in the present study, whereas most previous cohort studies computed odds ratios using logistic regression. In the case of an outcome measure with a relatively high occurrence, such as low back pain (26.6% in the present study), odds ratios are overestimations of the relative risk.[18-20] For example, for lifting loads of at least 25 kilograms more than 15 times per working day, the present study found a relative risk of 1.6. If one estimates an odds ratio based on the same data, one finds an effect estimate of 2.1.

Conclusions

This is the first prospective study that has been carried out to investigate the relationship between flexion and rotation of the trunk and lifting at work and the occurrence of low back pain, in which the work-related physical factors were actually measured. In addition, individual factors, psychosocial work characteristics, and other physical factors were taken into account as potential confounders. The main conclusion that can be drawn from this study is that flexion and rotation of the trunk and lifting at work are moderate risk factors for low back pain. Extreme trunk flexion and lifting loads of 25 kilograms or more seem to be especially important.

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5

Psychosocial work characteristics and psychological strain in relation to low back pain:

results of a prospective cohort study

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Abstract

The objective was to investigate the relationship between psychosocial work characteristics and low back pain and the potential intermediate role of psychological strain variables in this relationship. The research was part of a prospective cohort study of risk factors for musculoskeletal symptoms. The study population consisted of 861 workers from 34 companies in the Netherlands who had no low back pain at baseline and for whom data on the occurrence of low back pain were obtained with annual questionnaires during a three-year follow-up period. Information on psychosocial work characteristics and psychological strain variables was collected using a questionnaire at baseline. After adjustment for individual factors and quantified physical load at work, nonsignificant relative risks ranging from 1.3 to 1.6 were observed for high quantitative job demands, high conflicting demands, low supervisor support and low co-worker support. Decision authority and skill discretion showed no relationship with low back pain. In general, the estimated relative risks for the psychosocial work characteristics were scarcely influenced by additional adjustment for job satisfaction, emotional exhaustion and sleeping difficulties. Based on a comparison with previous findings, it can be concluded that low social support, from either supervisors or co-workers, appears to be a risk factor for low back pain. Some indications of a relationship between high quantitative job demands and high conflicting demands and low back pain were also found, but have not been observed consistently in previous studies. Little evidence was found for an intermediate role of the psychological strain variables under study.

Introduction

The study of psychosocial work characteristics has become an important aspect of epidemiological studies on musculoskeletal symptoms among workers. Recently, several reviews of the literature on the relationship between psychosocial work characteristics and low back pain have been conducted.[1-5] Based on the results of these reviews, it seems that there is evidence for a relationship between psychosocial work characteristics, in general, and the occurrence of low back pain, but the role of specific psychosocial work characteristics and the causality of the observed relationships is not yet clear.[4,5]

Several explanations have been given for the relationship between psychosocial work characteristics and musculoskeletal symptoms. One of the suggestions is that the association is based on confounding by the effect of physical factors at work.[1,6,7] From this perspective, an important shortcoming of most previous studies on the risk of specific psychosocial work characteristics is that in these studies insufficient adjustment was made for physical load at work. Another hypothesis is that psychosocial work characteristics increase psychological strain, such as emotional exhaustion[8] which, in turn, may increase muscle tension or hormonal excretion. In the long term this may lead to organic changes and the development or aggravation of musculoskeletal symptoms, or it may lower the level of pain perception and thus increase symptom reporting.[1,6,7,9,10] This latter hypothesis implies that psychological strain would be an intermediate variable in the relationship between psychosocial work characteristics and the occurrence of low back pain. In the light of this hypothesis, not only emotional exhaustion[8] and sleeping difficulties,[11] but also job satisfaction, which is often grouped under the heading of psychosocial work characteristics in research on low back pain, can be regarded as a psychological strain variable.[12,13] No epidemiological study has been identified in which this has been investigated.

The main purpose of the analyses described in this article was to investigate the relationship between the psychosocial work characteristics of quantitative job demands, conflicting demands, decision authority, skill discretion, supervisor support and co-worker support and the occurrence of low back pain, taking into account the potential confounding effect of individual factors and physical load at work. An additional objective was to study the potential intermediate role of psychological strain in the relationship between psychosocial work characteristics and low back pain. The analyses are based on data from the Study on Musculoskeletal disorders, Absenteeism, Stress, and Health (SMASH), a prospective cohort study among a working population, which was initiated to identify risk factors for musculoskeletal disorders. The results concerning the relationship between physical load at work and low back pain are reported elsewhere.[14]

Subjects and methods

Workers were recruited from 34 companies located throughout the Netherlands. A prerequisite for participating companies was that no major reorganizations were planned for the next three years and that the turnover rate of the work-force was lower than 15 percent. Furthermore, the companies were asked to select workers who had been employed in their current job for at least one year and who were working 24 hours per week or more. Workers in blue-collar jobs as well as workers in white-collar jobs and caring professions were included in the study.

The baseline measurements were carried out between March 1994 and March 1995, and consisted of three aspects: a self-administered questionnaire, quantitative assessment of the physical load at the workplace, and a physical examination focused on the assessment of the functional capacity of the workers. There was a three-year follow-up period. Each year the occurrence of changes in work and of low back pain was assessed by means of a postal questionnaire.

At baseline, 1,789 (87 percent) of the 2,064 workers who were invited to participate completed the questionnaire, 1,738 of whom were eligible for participation in the study on risk factors for low back pain.[14] For the longitudinal analysis described in this paper, a subcohort of 1,192 workers with no low back pain at baseline was identified, consisting of workers who reported at baseline that they had not had regular or prolonged low back pain in the previous 12 months.

Data-collection

All risk factors included in the analyses were measured at baseline. Psychosocial work characteristics were measured by means of a Dutch version of Karasek's Job Content Questionnaire (JCQ),[15] and concerned the dimensions of quantitative job demands, decision authority, skill discretion, supervisor support and co-worker support, as determined in the Demand-Control-Support model developed by Karasek and colleagues.[16-18] The constructed scales were sum-scores of the individual items within the dimension at issue. The response options for the individual items ranged from one (strongly disagree) to four (strongly agree). Conflicting demands and job security were both assessed on the basis of one single item from the JCQ.[15] In the analyses, job security was only considered as a potential confounder. Potential intermediate psychological strain variables were also assessed by means of the self-administered baseline questionnaire. Three psychological strain variables were examined, i.e. job satisfaction, emotional exhaustion and sleeping difficulties. Job satisfaction was assessed by means of two different questions, one concerning job task enjoyment[19] and one concerning the general opinion about the job.[20] Emotional exhaustion was measured according to a seven-item sub-scale of the Dutch version of the Maslach Burnout Inventory.[8,21] In the present study one original item of this scale was omitted because it applies only to people-oriented jobs. Sleeping difficulties were assessed according to a three-item scale.[11] The psychometric properties and the construction of the scales for quantitative job demands, decision authority, skill discretion, supervisor support, co-worker support and emotional exhaustion have been described by De Jonge et al.,[13] based on data from the present study.

Individual factors that were considered to be potential confounders, i.e. age, gender, smoking habits, body mass index, exercise behaviour and coping skills, were mainly assessed by means of the self-administered questionnaire. One question was included for the assessment of exercise behaviour during leisure time.[22] Coping skills, i.e. active problem-solving, avoidance behaviour and social support-seeking, were assessed by means of the Utrecht Coping List.[23] Assessment of the body mass index was based on measurements of weight and height taken by a physiotherapist during the physical examination at baseline.

Work-related physical factors that were considered to be potential confounders were trunk flexion, lifting and driving a vehicle at work. The percentage of the working time spent with the trunk in a minimum of 30 or 60 degrees of flexion and the number of times workers lifted a load of any weight, or a load of at least 10 or 25 kilograms during a working day, were assessed by means of analyses of video-recordings and force measurements at the workplace. These measurements are described in more detail elsewhere.[14] Driving a vehicle at work was assessed by means of the Loquest questionnaire.[24]

In the baseline and follow-up questionnaires, assessment of the occurrence of low back pain was based on an adaptation of the Nordic Questionnaire.[25] Workers had to answer the question 'Have you in the previous 12 months had trouble (ache, pain, discomfort) in the low back?' with one of the following four response options: no, never; yes, sometimes; yes, regular; yes, prolonged. Cases of low back pain were defined as workers who reported, for at least one of the follow-up measurements, that they had had regular or prolonged low back pain in the previous 12 months.

Statistical analysis

The statistical analysis consisted of several steps. Univariate analyses were performed with the computer package Epi Info (Version 6.0). In these analyses, the various scales for psychosocial work characteristics were recoded as categorical variables using small intervals on the measurement scale of the variable to determine the relationship with low back pain. In general, small categories with similar relative risks were regrouped into a few larger categories, resulting in a division into three categories (low, medium, high). Relative risks (RR) and corresponding 95 percent confidence intervals (95% CI) were calculated for the psychosocial work characteristics under study by comparing the cumulative incidence of low back pain between groups with different levels of exposure. If the individual factors, work-related physical factors and other factors (job security) that were considered to be potential confounders were univariately associated with the occurrence of low back pain with a Yates' corrected p-value[26] of less than 0.25,[27] they were included in the multivariable analyses. However, age, gender, and the other psychosocial work characteristics under study were included in the multivariable analyses, irrespective of their univariate association with low back pain in this data set. For the psychosocial work characteristics, this decision was based on the fact that these variables are related.

The presence of confounding was assessed by means of multivariable analyses. To prevent the occurrence of collinearity, the degree of interrelationship between the psychosocial work characteristics under study and the other independent variables selected for the multivariable analyses was first checked. The Cox regression procedure in the SPSS computer package (Version 9.0) was applied for the estimation of adjusted relative risks, using a constant risk-period for all subjects.[28-30] The adjusted relative risks were determined in a full model with one of the psychosocial work characteristics, the individual factors, other psychosocial work characteristics and work-related physical factors that were selected on the basis of the results of the univariate analyses. To determine whether adjustment for the potential confounders influenced the results, it was checked whether the effect estimates for the psychosocial work characteristics included in the full model differed by more than 10 percent from the crude effect estimates. A stepwise procedure was used to construct the full model. This made it possible to determine whether the results were mainly influenced by adjustment for the group of individual factors, the group of other psychosocial work characteristics, or the group of work-related physical factors.

The multivariable analyses described above were repeated for those workers who reported that no, or only minor changes in their work had occurred during the first and second follow-up periods. This selection reduced the likelihood of misclassification of exposure resulting from changes in the work environment with time. Participants whose work had changed due to back pain were also included in these analyses, because excluding them could result in a false decrease in the effect estimates. Moreover, to determine the presence or absence of a healthy worker effect, the analyses were also repeated for those workers who had been employed in their current job for 5 years or fewer at baseline.

Furthermore, to investigate the intermediate role of the psychological strain variables of job satisfaction, emotional exhaustion and sleeping difficulties in the relationship between psychosocial work characteristics and low back pain, these variables were added to the full multivariable model one at a time. By performing these analyses the effect of the psychological strain variables on low back pain could be evaluated with adjustment for the psychosocial work characteristics under study and the potential confounders.[31,32] The degree of change in the effect estimates for the psychosocial work characteristics could also be evaluated.[31,32] If the effect estimates for the psychosocial work characteristics decreased by more than 10 percent after inclusion of a psychological strain variable, the existence of an intermediate role of this variable was considered to be likely.

Results

From the cohort of 1,192 workers, data on the occurrence of low back pain were available for 861 workers (72 percent) for all three annual follow-up measurements. Approximately 30 percent of the workers in this group were female. The mean age of the workers was 36 years, with an age-range of 18-59 years. The cumulative incidence of low back pain during the three-year follow-up period was 26.6 percent.

Crude relationships

Table 5.1 presents the results of the univariate analyses of the relationship between the psychosocial work characteristics and low back pain. The strongest relationships with low back pain were found for high quantitative job demands, low supervisor support, and low co-worker support, followed by high conflicting demands and low skill discretion. Most relationships were not, or only marginally statistically significant. Decision authority was not found to be related to low back pain.

Potential confounders of the studied relationships

Univariate analyses of the potential confounders showed that exercise behaviour during leisure time, active problem-solving, avoidance behaviour, social support-seeking, trunk flexion, lifting and driving a vehicle at work were univariately associated with low back pain with a p-value of less than 0.25. Therefore, these variables were included in the multivariable analyses of the psychosocial work characteristics under study. It was decided beforehand to include age, gender and the other psychosocial work characteristics under study, independent of their association with low back pain.

Table 5.1 Crude relationship between psychosocial work characteristics and the occurrence of low back pain

Risk factor	LBP	No LBP	Crude RR (95% CI)
Quantitative job demands			
low (score 6-11)	55	192	1.00
medium (score 12-16)	156	405	1.25 (0.95-1.63)
high (score 17-20)	18	34	1.55 (1.00-2.41)
Conflicting demands			
(strongly) disagree	152	437	1.00
agree	56	152	1.04 (0.80-1.36)
strongly agree	20	39	1.31 (0.90-1.92)
Decision authority			
high (score 10-12)	48	140	1.00
medium (score 7-9)	150	404	1.06 (0.80-1.40)
low (score 3-6)	29	84	1.01 (0.68-1.50)
Skill discretion			
high (score 17-20)	51	151	1.00
medium (score 12-16)	152	425	1.04 (0.79-1.37)
low (score 5-11)	26	56	1.26 (0.84-1.87)
Supervisor support			
high (score 13-16)	23	86	1.00
medium (score 11,12)	127	368	1.22 (0.82-1.80)
low (score 4-10)	79	176	1.47 (0.98-2.20)
Co-worker support			
high (score 13-16)	39	150	1.00
medium (score 11,12)	164	421	1.36 (1.00-1.85)
low (score 4-10)	25	57	1.48 (0.96-2.27)

Abbreviations: LBP, low back pain; RR, relative risk; CI, confidence interval.

The multivariable analyses of the relationship between the psychosocial work characteristics and low back pain showed that only the relative risk for low skill discretion changed by more than 10 percent after adjustment for the variables that were selected (table 5.2). The decrease in the estimated relative risk for low supervisor support was just under 10 percent. The changes in the estimated relative risks were mainly caused by adjustment for the other psychosocial work characteristics. In the case of supervisor support, the adjustment for co-worker support appeared to be especially important.

Change in work

In the subgroup of workers who reported that no, or only minor changes in their work had occurred, the adjusted relative risks for high quantitative job demands and medium and low supervisor support were slightly higher, compared with the relative risks in the complete cohort. No difference was observed in the relative risks for conflicting demands, decision authority, skill discretion or co-worker support (table 5.2).

Table 5.2 Results from multivariable analyses for the relationship between psychosocial work characteristics and the occurrence of low back pain

Risk factor	Crude RR (95% CI)* (n=768)	Adjusted RR (95% CI)† (n=768)	Workers with no, or only minor changes in work Adjusted RR (95% CI)† (n=669)	Workers employed ≤ 5 years in the current job at baseline Adjusted RR (95% CI)† (n=334)
Quantitative job demands				
low (score 6-11)	1.00	1.00	1.00	1.00
medium (score 12-16)	1.27 (0.92-1.75)	1.24 (0.89-1.71)	1.31 (0.91-1.89)	2.11 (1.17-3.81)
high (score 17-20)	1.52 (0.84-2.75)	1.41 (0.76-2.62)	1.56 (0.81-3.03)	2.49 (0.92-6.74)
Conflicting demands				
(strongly) disagree	1.00	1.00	1.00	1.00
agree	1.04 (0.75-1.43)	1.02 (0.73-1.43)	1.09 (0.76-1.56)	0.96 (0.56-1.67)
strongly agree	1.32 (0.80-2.18)	1.37 (0.81-2.32)	1.34 (0.75-2.39)	1.33 (0.52-3.37)
Decision authority				
high (score 10-12)	1.00	1.00	1.00	1.00
medium (score 7-9)	1.03 (0.73-1.44)	0.98 (0.66-1.45)	1.00 (0.65-1.54)	0.88 (0.45-1.71)
low (score 3-6)	1.05 (0.65-1.68)	0.98 (0.56-1.71)	0.99 (0.54-1.80)	1.00 (0.43-2.33)
Skill discretion				
high (score 17-20)	1.00	1.00	1.00	1.00
medium (score 12-16)	1.02 (0.73-1.42)	1.00 (0.67-1.49)	1.00 (0.65-1.55)	1.13 (0.58-2.18)
low (score 5-11)	1.22 (0.74-2.00)	0.97 (0.53-1.75)	0.85 (0.44-1.66)	1.01 (0.41-2.44)
Supervisor support				
high (score 13-16)	1.00	1.00	1.00	1.00
medium (score 11,12)	1.29 (0.82-2.03)	1.25 (0.75-2.07)	1.41 (0.79-2.50)	1.75 (0.78-3.95)
low (score 4-10)	1.43 (0.89-2.32)	1.29 (0.76-2.21)	1.41 (0.77-2.60)	1.88 (0.76-4.64)
Co-worker support				
high (score 13-16)	1.00	1.00	1.00	1.00
medium (score 11,12)	1.30 (0.90-1.86)	1.35 (0.90-2.02)	1.20 (0.79-1.83)	1.33 (0.74-2.41)
low (score 4-10)	1.54 (0.92-2.59)	1.65 (0.92-2.95)	1.68 (0.90-3.14)	1.32 (0.56-3.13)

Abbreviations: RR, relative risk; CI, confidence interval.

* Crude relative risk from Cox regression in the population with no missing values for gender, age, exercise behaviour during leisure time, active problem-solving, avoidance behaviour, social support-seeking, trunk flexion, lifting, driving a vehicle at work and the other psychosocial work characteristics mentioned in the table.

† Relative risk from Cox regression, adjusted for the risk factors mentioned above.

Healthy worker effect

In the subgroup of workers who reported that they had been working in their current job for 5 years or fewer at baseline, the adjusted relative risks for medium and high quantitative job demands were substantially higher than in the complete cohort. The crude relative risk for high quantitative job demands was even higher (RR 3.0, 95% CI 1.2-7.4). The change in the estimated relative risk was mainly caused by the adjustment for work-related physical factors. The relative risks for medium and low supervisor support were also substantially higher in this subgroup than in the complete cohort. The relative risk for low co-worker support was slightly lower than in the complete cohort. Univariately, the relative risk for low co-worker support was still higher. The decrease in the estimated relative risk for low co-worker support was mainly caused by the adjustment for supervisor support. No difference was observed in the relative risks for conflicting demands, decision authority or skill discretion (table 5.2).

Table 5.3 Relationship of job satisfaction, emotional exhaustion and sleeping difficulties with low back pain

Risk factor	LBP	No LBP	Adjusted RR (95% CI)*
Job task enjoyment			
(almost) always	110	337	1.00
often	96	240	1.13 (0.83-1.54)
never/sometimes	23	55	1.28 (0.77-2.14)
Job satisfaction, general opinion about the job			
good	117	412	1.00
reasonable	98	197	1.54 (1.14-2.08)
not good/moderate	14	22	1.75 (0.96-3.19)
Emotional exhaustion			
score 0	99	333	1.00
score 1	59	151	1.12 (0.79-1.59)
score 2, 3	48	112	1.15 (0.78-1.70)
score 4-7	23	32	1.70 (1.03-2.81)
Sleeping difficulties			
score 0	152	482	1.00
score 1	41	95	1.29 (0.88-1.88)
score 2	20	30	1.64 (1.00-2.68)
score 3	8	9	2.14 (0.98-4.64)

Abbreviations: LBP, low back pain; RR, relative risk; CI, confidence interval.

* *Relative risk from Cox regression, adjusted for* gender, age, exercise behaviour during leisure time, active problem-solving, avoidance behaviour, social support-seeking, trunk flexion, lifting, driving a vehicle at work, quantitative job demands, conflicting demands, decision authority, skill discretion, supervisor support and co-worker support.

Role of the psychological strain variables

Tables 5.3 and 5.4 show the results of the multivariable analyses for the relationship between psychosocial work characteristics and low back pain with the inclusion of psychological strain variables. It can be seen from table 5.3 that a statistically significant increased risk of low back pain was observed for workers whose opinion about their job in general was less than good, for workers with a high score on the scale for emotional exhaustion, and for workers with a high score on the scale for sleeping difficulties. No statistically significant increased risk was found for workers who reported that they never, or only sometimes enjoyed their job tasks.

It can be seen from table 5.4 that, in general, the estimated relative risks for the psychosocial work characteristics were scarcely influenced by adjustment for the psychological strain variables. Only the estimated relative risk for high quantitative job demands decreased by more than 10 percent after additional adjustment for the variable of general opinion about the job and after additional adjustment for emotional exhaustion. Therefore, an intermediate role of the psychological strain variables was not considered to be likely, at least not for the effect of conflicting demands, supervisor support and co-worker support. The psychosocial work characteristics of decision authority and skill discretion are not included in table 5.4 because no relationship was observed between these factors and low back pain, which is one of the conditions that must be met if an intermediate variable is to fulfil its role.[31,32]

Discussion

Summary of findings

The multivariable analyses showed that in the complete cohort and in the subgroup of workers with no, or only minor changes in their work, there was a 1.3 to 1.6-fold increased risk of low back pain for workers with high quantitative job demands, for workers with high conflicting demands, for workers with low supervisor support and for workers with low co-worker support. The adjusted relative risks for the relationships found were not, or only borderline statistically significant. This is partly due to the use of Cox regression which produces too large estimates of the standard errors which results in too conservative estimates of the confidence intervals.[29,30] No relationship with low back pain was found for low decision authority or low skill discretion.

An important source of potential bias in occupational cohort studies is the healthy worker effect.[33] To minimize this form of bias it would be better to study newly employed workers, but this was beyond the scope of the present study. Therefore, an additional analysis of the group of workers who had been employed in their current job for 5 years or fewer was performed. This analysis showed stronger associations with low back pain for medium and high quantitative job demands and for medium and low supervisor support.

Table 5.4 Results from multivariable analyses for the relationship between psychosocial work characteristics and low back pain with inclusion of potential intermediate variables

Risk factor	Adjusted RR (95% CI)* (n=768)	RR after additional adjustment for job task enjoyment (95% CI) (n=768)	RR after additional adjustment for general opinion about the job (95% CI) (n=767)	RR after additional adjustment for emotional exhaustion (95% CI) (n=766)	RR after additional adjustment for sleeping difficulties (95% CI) (n=762)
Quantitative job demands					
low (score 6-11)	1.00	1.00	1.00	1.00	1.00
medium (score 12-16)	1.24 (0.89-1.71)	1.24 (0.89-1.72)	1.22 (0.88-1.70)	1.18 (0.85-1.65)	1.21 (0.87-1.69)
high (score 17-20)	1.41 (0.76-2.62)	1.40 (0.75-2.60)	1.26 (0.67-2.36)	1.19 (0.62-2.29)	1.42 (0.76-2.66)
Conflicting demands					
(strongly) disagree	1.00	1.00	1.00	1.00	1.00
agree	1.02 (0.73-1.43)	1.02 (0.73-1.42)	1.01 (0.72-1.41)	1.02 (0.73-1.42)	1.01 (0.72-1.42)
strongly agree	1.37 (0.81-2.32)	1.37 (0.81-2.33)	1.40 (0.82-2.38)	1.33 (0.78-2.27)	1.35 (0.79-2.30)
Supervisor support					
high (score 13-16)	1.00	1.00	1.00	1.00	1.00
medium (score 11,12)	1.25 (0.75-2.07)	1.23 (0.74-2.04)	1.23 (0.74-2.05)	1.25 (0.75-2.06)	1.26 (0.75-2.11)
low (score 4-10)	1.29 (0.76-2.21)	1.25 (0.73-2.15)	1.17 (0.68-2.02)	1.23 (0.72-2.11)	1.30 (0.75-2.26)
Co-worker support					
high (score 13-16)	1.00	1.00	1.00	1.00	1.00
medium (score 11,12)	1.35 (0.90-2.02)	1.34 (0.90-2.01)	1.33 (0.89-1.99)	1.35 (0.90-2.01)	1.36 (0.91-2.04)
low (score 4-10)	1.65 (0.92-2.95)	1.60 (0.89-2.88)	1.56 (0.87-2.81)	1.60 (0.89-2.86)	1.59 (0.89-2.86)

Abbreviations: RR, relative risk; CI, confidence interval.

* Relative risk from Cox regression, adjusted for gender, age, exercise behaviour during leisure time, active problem-solving, avoidance behaviour, social support-seeking, trunk flexion, lifting, driving a vehicle at work, decision authority, skill discretion and the other psychosocial work characteristics mentioned in the table.

Moreover, a weaker association was found for low co-worker support. These results may indicate the presence of a healthy worker effect in the complete cohort. The results for supervisor support and co-worker support might also indicate that different types of support could be important during different stages of employment.

The results of the analyses with additional adjustment for a psychological strain variable do not indicate that the psychological strain variables of job satisfaction, emotional exhaustion and sleeping difficulties are intermediates in the relationship between high conflicting demands, supervisor support and co-worker support and low back pain. The general opinion about the job and emotional exhaustion may be intermediates in the relationship between high quantitative job demands and low back pain. For a variable to be considered as an intermediate variable several conditions must be met.[31,32] Previous analyses of the data from the present study have shown that there is a relationship between the psychosocial work characteristics of high job demands, low supervisor support and low co-worker support and the psychological strain variables of job task enjoyment and emotional exhaustion.[13] In the present analyses, the psychological strain variables themselves, except for the operationalization of job satisfaction in terms of job task enjoyment, were statistically significantly associated with low back pain, and are therefore independent risk factors for the occurrence of low back pain. The assessment of the influence of additional adjustment for the psychological strain variables on the effect estimates for the psychosocial work characteristics was complicated, due to the small magnitude of the observed effects for the psychosocial work characteristics.

The results of this study do not support the hypothesis that the association between psychosocial work characteristics and low back pain is based on confounding by the effect of physical factors at work. Adjustment for work-related physical factors had scarcely any effect on the estimated relative risks in the complete cohort. However, again no strong conclusions can be based on this observation, due to the small magnitude of the observed effects for the psychosocial work characteristics. In the subgroup of workers who had been employed in their current job for 5 years or fewer at baseline, a stronger crude effect was observed for high quantitative job demands. Adjustment for work-related physical factors appeared to affect the magnitude of this effect, suggesting that part of the crude association was due to an association between high physical load and high job demands in this subgroup. However, a statistically significant relative risk remained.

Methodological strengths and limitations

The prospective design of this study made it possible to study the temporal relationship between psychosocial work characteristics and low back pain. Moreover, in addition to adjustment for individual factors and other psychosocial work characteristics, a thorough adjustment for work-related physical factors was possible, based on actual quantification of the physical load at the workplace. Both aspects strengthen the concept that the associations that were found may be causal relationships.

The possibility of bias due to selective loss to follow-up cannot be excluded. In this study the percentage of workers in the reference category of conflicting demands was lower in the group that was lost to follow-up. Relatively more workers in this group reported low decision authority and low skill discretion (data not shown). This is probably related to the fact that the group that was lost to follow-up had a relatively low level of education (data not shown). However, no selectivity in the loss to follow-up was found with respect to quantitative job demands, supervisor support or co-worker support.

Due to the selection of workers with no low back pain at baseline and the necessity to have data on the occurrence of low back pain for all follow-up measurements, a relatively small proportion of the original cohort of 1,738 workers was included in the present analyses. As a result the statistical power to detect weak associations (relative risk in the order of 1.5) was limited.

In this study, it was decided to use a cumulative measure of the occurrence of low back pain over the three-year follow-up period. This means that the course of low back pain over the follow-up period was not taken into account in these analyses. Further analyses could be performed to study more specifically the influence of psychosocial work characteristics on the course of low back pain.

Comparison with previous findings

Due to the small magnitude of the observed effects for the psychosocial work characteristics and the lack of clearly statistically significant effects, it is difficult to draw firm conclusions based on the results of the present study. Therefore, comparison of the findings of the present study with previous findings is especially important. Of special interest is comparison of the results of the present study with the results of other cohort studies that were restricted to a population with no low back pain at baseline and case-control studies that excluded during enrolment subjects with low back pain in the previous months. The findings of various studies investigating the risk of high quantitative job demands are inconsistent. One study, the MUSIC Study, reported no effect of high quantitative job demands on care-seeking for low back pain among nursing personnel,[34] one study only reported that no statistically significant association was found[35] and one study reported an increased risk of sciatic pain,[36] in agreement with the present study.

One other prospective cohort study, the Whitehall study, examined the effect of conflicting demands.[37] However, this study was not restricted to subjects with no low back pain at baseline, and focused on the occurrence of absenteeism from work due to back pain. It was found that conflicting demands were only a risk factor for short absences from work due to back pain in men. An additional exploratory analysis of the data from the present study also showed that the risk of low back pain due to conflicting demands seems to be stronger in men than in the complete cohort (data not shown).

With regard to decision authority and skill discretion, the MUSIC Study reported that no effect was found on care-seeking for low back pain among a subcohort of nursing personnel.[34] However, the analyses of the total population of this study showed that low skill discretion was associated with care-seeking for low back pain in men.[38] Another study only reported that no statistically significant association was found between skill discretion and low back pain.[35]

Three studies have examined the effect of social support, a combination of supervisor and co-worker support.[34,36,38,39] These studies all reported an increased risk of low back pain for low social support,[34,36,39] except for the MUSIC Study in the total population.[38] Two prospective cohort studies that were not restricted to a population with no low back pain at baseline examined the individual effects of supervisor and co-worker support.[19,40] One study found an effect of both supervisor and co-worker support,[19] and the other found an effect of low supervisor support and no effect of co-worker support.[40] However, the fact that low supervisor support, as opposed to low co-worker support, was especially important in the latter study might be related to the nature of the job of transit operator.[40] On the basis of the main analyses of the present study, co-worker support seems to be more important than supervisor support. However, in the subgroup of workers who had been employed in their current job for 5 years or fewer at baseline the relative importance was reversed. Although it remains to be seen whether supervisor support and co-worker support are equally important, it is clear that far more consistent results have been found for low social support than for the other psychosocial work characteristics. This is also reported in a recent review on the relationship between psychosocial work characteristics and low back pain.[4] The magnitude of the observed relative risks in the present study also lies in the range of observed risk estimates for previous studies as reported in this review.[4]

The authors are not aware of any other study that has examined the potential intermediate role of psychological strain variables with methods similar to those used in the present study. However, the direct effect of job dissatisfaction has been studied extensively. In these studies job dissatisfaction has always been considered to pertain to the group of psychosocial work characteristics. Various studies have reported an increased risk of low back pain in relation to low job satisfaction.[35,37,39] From the present study, it appears that if an effect of job dissatisfaction does exist, it is probably independent of the effect of psychosocial work characteristics. An effect of low job satisfaction was found for only one of the two measures of job satisfaction that were used in the present study, but this may be explained by the presence of selectivity in the loss to follow-up with respect to job task enjoyment (data not shown).

Conclusions

Whereas only moderate, and not statistically significant associations were found between low supervisor and low co-worker support and the occurrence of low back pain, based on the comparison with previous findings, it seems likely that low social support is, indeed, a risk factor for the occurrence of low back pain. Based on the results of the present study, some indications of a relationship between high quantitative job demands and high conflicting demands and low back pain are also present. However, the relationship between these variables and low back pain has not been observed consistently in other studies. In the present study, no relationship was observed between low decision authority or low skill discretion and the occurrence of low back pain.

The results of this study do not support the hypothesis that the psychological strain variables of job satisfaction, emotional exhaustion and sleeping difficulties play an intermediate role in the relationship between conflicting demands, supervisor support and co-worker support and low back pain. The general opinion about the job and emotional exhaustion may be intermediates in the relationship between high quantitative job demands and low back pain. However, it is not possible to draw strong conclusions on this subject, because this is the first study which examined this hypothesis. In addition, the small magnitude of the observed effects for the psychosocial work characteristics complicated the examination of the potential intermediate role of psychological strain variables.

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6

High physical work load, low job satisfaction and low social support increase the risk of sickness absence due to low back pain:

results of a prospective cohort study

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Abstract

The objective was to determine whether physical and psychosocial load at work influence sickness absence due to low back pain. The research was a part of a three-year prospective cohort study on risk factors for musculoskeletal disorders. Workers from 21 companies located throughout the Netherlands participated in the part of this study on sickness absence due to low back pain. The study population consisted of 732 workers with no sickness absences of 3 days or longer due to low back pain in the three months prior to the baseline survey and complete data on the reasons for absences during the follow-up period. Physical load at work was assessed by means of analyses of video-recordings. Baseline information on psychosocial work characteristics was obtained by means of a questionnaire. Data on sickness absence were collected from company records. The main outcome measure was the rate of sickness absences of 3 days or longer due to low back pain during the follow-up period. After adjustment of the work-related physical and psychosocial factors for each other and for other potential determinants, statistically significant rate ratios ranging from 2.0 to 3.2 were found for trunk flexion, trunk rotation, lifting and low job satisfaction. A dose-response relationship was found for trunk flexion, but not for trunk rotation or lifting. Statistically nonsignificant rate ratios of approximately 1.4 were observed for low supervisor support and low co-worker support. Quantitative job demands, conflicting demands, decision authority and skill discretion showed no relationship with sickness absence due to low back pain. It can be concluded that flexion and rotation of the trunk, lifting and low job satisfaction are risk factors for sickness absence due to low back pain. Some indications of a relationship between low social support, either from supervisor or co-worker, and sickness absence due to low back pain are also present.

Introduction

Low back pain is a major health problem, not only because of the high prevalence and incidence of low back problems,[1] but also because of the important consequences in terms of disability, the utilization of health services, and sickness absence. This results in high costs. In 1991, the total cost of back pain to society in the Netherlands was estimated to be 1.7% of the gross national product.[2] More than half of the total cost was due to sickness absence related to back pain.[2] Back pain also accounts for large numbers of lost workdays in other countries.[3-5]

The relationship between physical and psychosocial load at work, and the occurrence of low back pain has been the subject of many studies. However, most of these studies did not actually quantify the physical load at work, or assess both physical and psychosocial load at work. Moreover, hardly any of these studies focused specifically on sickness absence due to low back pain as outcome measure. Two recent reviews[6,7] identified 32 cohort and case-control studies on the effect of physical and psychosocial factors on low back pain, 4 of which investigated their relationship with sickness absence due to low back pain.[8-11] Only 2 studies collected data on sickness absence from sick leave records, but these studies did not include an assessment of the physical load at work.[9,10]

The objective of the analyses presented in this paper was to determine whether physical and psychosocial load at work influence company-registered sickness absence due to low back pain.

Participants and methods

Study population

For the Study on Musculoskeletal disorders, Absenteeism, Stress, and Health (SMASH), workers were recruited from 34 companies located throughout the Netherlands. The participating companies were asked to select workers who had been employed in their current job for at least one year and who were working 24 hours per week or more. Workers in blue-collar jobs, as well as workers in white-collar jobs and caring professions were included in the study. At baseline, 1,789 (87%) of the 2,064 workers who were invited to participate completed the questionnaire, 1,738 of whom were eligible for participation in the part of the study focusing on risk factors for low back pain.[12]

Baseline survey

Between March 1994 and March 1995 the participants completed a questionnaire and underwent a physical examination. The questionnaire included questions on age, gender, smoking habits, exercise behaviour,[13] and coping skills.[14] Body mass index was assessed during the physical examination.

Psychosocial work characteristics were assessed by means of a Dutch version of Karasek's Job Content Questionnaire (JCQ),[15] which includes dimensions on quantitative job demands, decision authority, skill discretion, supervisor support, and co-worker support. Conflicting demands and job security were both assessed on the basis of one single item from the JCQ.[15] Job satisfaction was assessed by one question concerning general opinion about the job.[16]

Trunk flexion, trunk rotation and lifting of loads at work were assessed by analyses of video-recordings and force measurements at the workplace. These measurements are described in more detail elsewhere.[12] Driving a vehicle at work and physical factors during leisure time were assessed by means of the Loquest questionnaire.[17]

Follow-up and sickness absence

Adequate data on sickness absence were provided by 21 of the 34 participating companies. 1,080 (89%) of the 1,213 participating workers from these 21 companies had given their informed consent for a follow-up based on their sick leave records. Annually, from the start of the study, the companies provided the first and last dates of all (complete and partial) sickness absences to the end of 1997. If available, the reasons for absence were provided by the companies and/or by the physicians of the Occupational Health Services. In addition, the physicians coded the reasons for absence according to an adapted Dutch version[18] of the International Classification of Diseases (ICD).[19] The following diagnoses were considered to constitute sickness absence due to low back pain: lumbosacral spondylosis and spondylosis of unspecified site (ICD numbers 721, 721.3, 721.42, 721.9), lumbar intervertebral disc disorders and intervertebral disc disorders of unspecified site (ICD numbers 722, 722.10, 722.2, 722.52, 722.6, 722.73, 722.9), other and unspecified back disorders (ICD numbers 724, 724.2, 724.3, 724.4, 724.5, 724.9).

The main measure of sickness absence used in the present study was the rate of sickness absences of 3 days or longer due to low back pain. For each employee, the number of absences of 3 days or longer due to low back pain during the follow-up period was computed, and the overall person-time at risk (excluding time spent on sick leave) was calculated in person-years.[20] Workers with a follow-up period of less than 6 months (n=20) and workers with sickness absences due to low back pain of 3 days or longer in the three months prior to the baseline measurement (n=30), or with missing data on the reasons for absences during this period (n=42) were excluded from the analyses in this study. This resulted in a final cohort of 988 workers.

Statistical analysis

Poisson regression models were used to calculate rate ratios (RR) and corresponding likelihood ratio-based 95% confidence intervals (95% CI).[20] The analyses were carried out with the statistical package SAS (Version 6.12). The division into categories of the work-related physical and psychosocial factors under study was the same as that used for the analyses of the relationship of these factors with self-reported low back pain, reported elsewhere.[12,21]

Confounding was adjusted for in multivariable analyses. To prevent collinearity it was checked whether the work-related physical factors, psychosocial factors and the other independent variables had a correlation coefficient ≤ 0.50. The adjusted rate ratios were determined in a full model including one of the risk factors under study, the individual factors, (other) psychosocial work characteristics, physical factors during leisure time and (other) work-related physical factors.

To determine the presence or absence of a healthy worker effect, the multivariable analyses described above were repeated for those workers who had been employed in their current job for 5 years or fewer at baseline. Moreover, since risk factors for sickness absence (or the size of their effect) may differ for absences of different duration, the multivariable analyses were also repeated separately for short (3-7 days) and long absences (> 7 days).

Results

From the cohort of 988 workers, data on the reasons for all absences of 3 days or longer during the follow-up period were available for 732 workers (74%). Approximately 25% of the workers in this group were female. The mean age of the workers was 36.4 (range 18-59) years. The mean period of follow-up of sickness absences in this group was 37 (range 7-44) months. Table 6.1 shows the rates and number of absences of 3 days or longer due to low back pain according to age and gender. The rate of sickness absence due to low back pain was approximately twice as high among men as among women. Thirty-three percent of all workers who were absent due to back pain during the follow-up were absent more than once for this reason.

Table 6.1 Rates and number of absences of 3 days or longer due to low back pain according to age and gender (n=732)

	Men		Women	
	Number of absences	Rate (Number of absences/ 100 person-years)	Number of absences	Rate (Number of absences/ 100 person-years)
18-25 years	15	12.44	6	4.75
26-30 years	34	11.68	5	4.57
31-35 years	41	12.49	6	9.84
36-40 years	37	11.16	1	2.07
41-45 years	24	10.21	4	6.32
> 45 years	34	10.53	7	7.83
Total	185	11.35	29	5.82

Table 6.2 shows the effect of work-related physical factors on sickness absence due to low back pain. Trunk flexion, as well as trunk rotation and lifting at work, were statistically significantly associated with the occurrence of sickness absence due to low back pain. A dose-response relationship was found for trunk flexion, but not for trunk rotation or lifting. For lifting, the initial dose-response relationship that was observed in the crude analysis disappeared after adjustment for confounders. The effects of flexion and rotation of the trunk and lifting at work were not adjusted for each other for reasons of collinearity. In the subgroup of workers who reported that they had been working in their current job for 5 years or fewer at baseline, the adjusted rate ratios for all work-related physical factors under study were higher than those in the complete cohort.

Table 6.2 Rate ratios of absences of 3 days or longer due to low back pain according to work-related physical factors

Risk factor	Number of absences	Number of workers	Crude RR (95% CI)* (n=635)	Adjusted RR (95% CI)† (n=635)	Workers employed ≤ 5 years in the current job at baseline Adjusted RR (95% CI)† (n=265)
Percentage of the working time trunk flexion ≥ 30°					
≤ 5% working time	75	441	1.00	1.00	1.00
5-10% working time	32	116	1.75 (1.12-2.67)	1.36 (0.83-2.21)	0.90 (0.39-1.97)
10-15% working time	32	67	2.83 (1.81-4.32)	2.03 (1.19-3.40)	3.01 (1.23-7.27)
15-20% working time	24	35	4.02 (2.40-6.45)	3.24 (1.80-5.69)	9.16 (2.44-33.0)
> 20% working time	21	43	3.01 (1.80-4.84)	2.33 (1.32-3.97)	1.69 (0.46-5.42)
Percentage of the working time trunk flexion					
≤ 5% working time ≥ 30°	75	441	1.00	1.00	1.00
5-10% working time ≥ 30°	32	116	1.75 (1.12-2.67)	1.37 (0.83-2.21)	0.93 (0.40-2.05)
> 10% working time ≥ 30° and ≤ 5% working time ≥ 60°	48	97	2.91 (1.97-4.25)	2.27 (1.45-3.52)	3.15 (1.33-7.41)
> 5% working time ≥ 60°	29	48	3.65 (2.31-5.62)	2.65 (1.59-4.32)	3.59 (1.36-9.27)
Percentage working time trunk rotation ≥ 30°					
≤ 5% working time	106	544	1.00	1.00	1.00
5-10% working time	69	125	2.90 (2.11-3.97)	2.12 (1.45-3.07)	2.78 (1.36-5.67)
> 10% working time	9	33	1.65 (0.78-3.10)	1.10 (0.49-2.21)	0.33 (0.02-2.02)
Number of lifts per 8-hour working day					
never	32	251	1.00	1.00	1.00
never ≥ 10 kg/working day	27	112	2.31 (1.35-3.92)	2.47 (1.42-4.29)	3.10 (1.13-8.80)
never ≥ 25 kg/working day	65	208	2.76 (1.78-4.39)	2.32 (1.41-3.89)	2.46 (1.02-6.48)
1-15 times ≥ 25 kg/working day	37	82	3.60 (2.18-5.99)	2.27 (1.25-4.14)	2.06 (0.69-6.30)
> 15 times ≥ 25 kg/working day	23	49	3.81 (2.14-6.68)	2.18 (1.07-4.37)	2.77 (0.81-9.56)

Abbreviations: RR, rate ratio; CI, confidence interval.

* Crude rate ratio from Poisson regression in the population with no missing values for gender, age, smoking habits, body mass index, exercise behaviour during leisure time, coping skills, quantitative job demands, conflicting demands, decision authority, skill discretion, supervisor support, co-worker support, job security, job satisfaction, moving of heavy loads during leisure time, flexion and/or rotation of the upper part of the body during leisure time, driving a vehicle during leisure time and driving a vehicle at work.

† Rate ratio from Poisson regression, adjusted for the risk factors mentioned above.

Table 6.3 Rate ratios of absences of 3 days or longer due to low back pain according to psychosocial work characteristics

Risk factor	Number of absences	Number of workers	Crude RR (95% CI)* (n=635)	Adjusted RR (95% CI)† (n=635)	Workers employed ≤ 5 years in the current job at baseline *Adjusted RR (95% CI)†* (n=265)
Quantitative job demands					
low (score 6-11)	59	200	1.00	1.00	1.00
medium (score 12-16)	137	472	0.95 (0.68-1.33)	1.02 (0.71-1.48)	1.06 (0.57-2.06)
high (score 17-20)	15	51	0.92 (0.42-1.77)	0.68 (0.30-1.40)	1.62 (0.36-6.03)
Conflicting demands					
(strongly) disagree	133	472	1.00	1.00	1.00
agree	54	199	1.02 (0.72-1.43)	0.76 (0.52-1.10)	0.53 (0.26-1.06)
strongly agree	17	49	1.28 (0.67-2.22)	1.20 (0.61-2.19)	0.43 (0.10-1.52)
Decision authority					
high (score 10-12)	35	159	1.00	1.00	1.00
medium (score 7-9)	155	467	1.58 (1.05-2.49)	1.17 (0.70-2.02)	4.29 (1.39-16.5)
low (score 3-6)	24	98	1.27 (0.70-2.28)	0.69 (0.34-1.40)	1.58 (0.36-7.58)
Skill discretion					
high (score 17-20)	41	165	1.00	1.00	1.00
medium (score 12-16)	129	473	*1.12 (0.76-1.68)*	*0.85 (0.52-1.42)*	*0.61 (0.25-1.59)*
low (score 5-11)	44	87	2.08 (1.29-3.37)	1.10 (0.58-2.10)	0.65 (0.19-2.24)

Table 6.3 Continued

Risk factor	Number of absences	Number of workers	Crude RR (95% CI)* (n=635)	Adjusted RR (95% CI)† (n=635)	Workers employed ≤ 5 years in the current job at baseline Adjusted RR (95% CI)† (n=265)
Supervisor support					
high (score 13-16)	20	90	1.00	1.00	1.00
medium (score 11,12)	111	427	0.95 (0.58-1.63)	1.06 (0.60-1.97)	1.81 (0.66-5.73)
low (score 4-10)	82	207	1.61 (0.98-2.79)	1.43 (0.77-2.74)	3.59 (1.20-12.3)
Co-worker support					
high (score 13-16)	34	144	1.00	1.00	1.00
medium (score 11,12)	141	498	0.96 (0.65-1.47)	0.97 (0.62-1.56)	0.65 (0.30-1.46)
low (score 4-10)	38	81	2.02 (1.23-3.32)	1.46 (0.82-2.61)	1.12 (0.37-3.31)
Job satisfaction					
good	104	430	1.00	1.00	1.00
reasonable	85	251	1.21 (0.86-1.67)	1.06 (0.74-1.53)	0.75 (0.39-1.42)
not good/moderate	24	45	2.39 (1.43-3.79)	1.95 (1.08-3.39)	2.04 (0.72-5.49)

Abbreviations: RR, rate ratio; CI, confidence interval.

* Crude rate ratio from Poisson regression in the population with no missing values for gender, age, smoking habits, body mass index, exercise behaviour during leisure time, coping skills, moving of heavy loads during leisure time, flexion and/or rotation of the upper part of the body during leisure time, driving a vehicle during leisure time, trunk flexion, lifting, driving a vehicle at work, job security and the other psychosocial work characteristics mentioned in the table.

† Rate ratio from Poisson regression, adjusted for the risk factors mentioned above.

Table 6.4 Rate ratios of short (3-7 days) and long (> 7 days) absences due to low back pain according to work-related physical factors

Risk factor	Short absenteeism		Long absenteeism	
	Number of absences *3-7 days* (Number of workers*)	Adjusted RR *(95% CI)†* (n=688)	Number of absences *> 7 days* (Number of workers*)	Adjusted RR *(95% CI)† (n=751)*
Percentage of the working time trunk flexion ≥ 30°				
≤ 5% working time	31 (465)	1.00	59 (523)	1.00
5-10% working time	15 (127)	1.56 (0.74-3.20)	22 (144)	1.07 (0.59-1.89)
10-15% working time	11 (78)	1.35 (0.55-3.07)	39 (85)	3.21 (1.91-5.34)
15-20% working time	6 (38)	2.18 (0.74-5.60)	18 (38)	3.66 (1.86-6.91)
> 20% working time	7 (51)	1.17 (0.43-2.82)	17 (50)	2.93 (1.55-5.33)
Percentage of the working time trunk flexion				
≤ 5% working time ≥ 30°	31 (465)	1.00	59 (523)	1.00
5-10% working time ≥ 30°	15 (127)	1.59 (0.76-3.26)	22 (144)	1.07 (0.59-1.88)
> 10% working time ≥ 30° and ≤ 5% working time ≥ 60°	16 (107)	1.69 (0.80-3.47)	48 (116)	3.08 (1.90-4.96)
> 5% working time ≥ 60°	8 (60)	1.15 (0.46-2.63)	26 (57)	3.49 (2.03-5.89)
Percentage working time trunk rotation ≥ 30°				
≤ 5% working time	43 (582)	1.00	84 (648)	1.00
5-10% working time	21 (134)	1.52 (0.78-2.89)	56 (147)	2.30 (1.51-3.47)
> 10% working time	6 (43)	1.04 (0.37-2.56)	15 (45)	2.54 (1.30-4.71)
Number of lifts per 8-hour working day				
never	14 (259)	1.00	20 (281)	1.00
never ≥ 10 kg/working day	12 (118)	2.68 (1.13-6.46)	27 (152)	3.19 (1.72-6.01)
never ≥ 25 kg/working day	21 (232)	1.46 (0.64-3.44)	54 (246)	2.99 (1.68-5.54)
1-15 times ≥ 25 kg/working day	18 (92)	2.46 (0.96-6.41)	30 (99)	2.78 (1.40-5.58)
> 15 times ≥ 25 kg/working day	5 (58)	0.89 (0.24-2.89)	24 (62)	3.26 (1.52-6.98)

Abbreviations: RR, rate ratio; CI, confidence interval.

* From the cohort of 988 workers, data on the reasons for all absences of 3-7 days were available for 789 workers and data on the reasons for all absences of more than 7 days were available for 878 workers.

† Rate ratio from Poisson regression, adjusted for gender, age, smoking habits, body mass index, exercise behaviour during leisure time, coping skills, quantitative job demands, decision authority, skill discretion, supervisor support, co-worker support, job security, job satisfaction, moving of heavy loads during leisure time, flexion and/or rotation of the upper part of the body during leisure time, driving a vehicle during leisure time and driving a vehicle at work.

Table 6.5 Rate ratios of short (3-7 days) and long (> 7 days) absences due to low back pain according to psychosocial work characteristics

Risk factor	Short absenteeism		Long absenteeism	
	Number of absences 3-7 days (Number of workers*)	Adjusted RR (95% CI)† (n=688)	Number of absences > 7 days (Number of workers*)	Adjusted RR (95% CI)† (n=751)
Quantitative job demands				
low (score 6-11)	30 (217)	1.00	47 (235)	1.00
medium (score 12-16)	44 (507)	0.60 (0.34-1.06)	117 (570)	1.13 (0.76-1.70)
high (score 17-20)	3 (56)	0.10 (0.01-0.57)	13 (63)	0.86 (0.37-1.80)
Conflicting demands				
(strongly) disagree	51 (508)	1.00	113 (563)	1.00
agree	20 (216)	0.77 (0.40-1.39)	45 (243)	0.75 (0.49-1.11)
strongly agree	5 (53)	1.49 (0.49-3.67)	13 (58)	0.93 (0.40-1.89)
Decision authority				
high (score 10-12)	12 (157)	1.00	32 (176)	1.00
medium (score 7-9)	58 (505)	0.97 (0.46-2.20)	124 (539)	1.32 (0.75-2.41)
low (score 3-6)	7 (110)	0.44 (0.13-1.37)	24 (144)	0.80 (0.37-1.72)
Skill discretion				
high (score 17-20)	16 (174)	1.00	31 (185)	1.00
medium (score 12-16)	51 (515)	0.83 (0.39-1.84)	107 (566)	0.84 (0.48-1.51)
low (score 5-11)	10 (93)	1.27 (0.44-3.61)	42 (118)	1.19 (0.59-2.46)

Table 6.5 Continued

Risk factor	Short absenteeism		Long absenteeism	
	Number of absences 3-7 days (Number of workers*)	Adjusted RR (95% CI)† (n=688)	Number of absences > 7 days (Number of workers*)	Adjusted RR (95% CI)† (n=751)
Supervisor support				
high (score 13-16)	6 (92)	1.00	17 (98)	1.00
medium (score 11,12)	38 (457)	1.83 (0.70-5.55)	99 (508)	0.77 (0.42-1.49)
low (score 4-10)	33 (232)	2.89 (1.06-8.94)	63 (262)	0.77 (0.39-1.59)
Co-worker support				
high (score 13-16)	14 (153)	1.00	26 (165)	1.00
medium (score 11,12)	48 (541)	0.67 (0.34-1.38)	123 (599)	1.07 (0.65-1.82)
low (score 4-10)	13 (85)	0.88 (0.36-2.17)	30 (101)	1.49 (0.79-2.87)
Job satisfaction, general opinion about the job				
good	40 (461)	1.00	91 (517)	1.00
reasonable	29 (273)	1.01 (0.57-1.78)	71 (303)	1.00 (0.68-1.46)
not good/moderate	8 (49)	1.45 (0.50-3.63)	17 (50)	2.13 (1.09-3.95)

Abbreviations: RR, rate ratio; CI, confidence interval.

* From the cohort of 988 workers, data on the reasons for all absences of 3-7 days were available for 789 workers and data on the reasons for all absences of more than 7 days were available for 878 workers.

† Rate ratio from Poisson regression, adjusted for gender, age, smoking habits, body mass index, exercise behaviour during leisure time, coping skills, moving of heavy loads during leisure time, flexion and/or rotation of the upper part of the body during leisure time, driving a vehicle during leisure time, trunk flexion, lifting, driving a vehicle at work, job security and the other psychosocial work characteristics mentioned in the table.

Table 6.3 shows the effect of psychosocial work characteristics on sickness absence due to low back pain. After adjustment for confounders, a statistically significant increased rate ratio was only found for low job satisfaction. The rate ratios for low supervisor support and low co-worker support remained increased after adjustment for potential confounders, but were no longer statistically significant. In the subgroup of workers who reported that they had been working in their current job for 5 years or fewer at baseline, the adjusted rate ratio for low supervisor support was substantially higher than in the complete cohort. Moreover, a clearly increased rate ratio was found for medium decision authority, which showed no relationship with sickness absence due to low back pain in the complete cohort.

Tables 6.4 and 6.5 show the effect of work-related physical factors and psychosocial work characteristics on short and long absences due to low back pain, separately. The work-related physical factors had a stronger relationship with long absences than with short absences. With regard to the psychosocial work characteristics, the strongest relationship with short absences was found for low supervisor support, and the strongest relationship with long absences was found for low job satisfaction.

Discussion

In this longitudinal study, rate ratios ranging from 2.0 to 3.2 were observed for the relationship of trunk flexion, trunk rotation and lifting at work with sickness absence due to low back pain. Trunk flexion showed a dose-response relationship with increasing duration and also, although less clear, with an increasing degree of trunk flexion. Lifting loads of any weight increased the risk of sickness absence due to low back pain. No increase in risk was observed with increasing frequency of lifting, or with increasing weight of the load lifted. Due to the strong correlation between flexion and rotation of the trunk and lifting at work in the study population, the independent effects of these exposures could not be assessed. The associations of trunk flexion, trunk rotation and lifting at work with sickness absence due to low back pain were stronger than the associations of these factors with self-reported low back pain found in the same study (relative risks of approximately 1.5).[12] Moreover, the risk started to increase at lower levels of exposure.

Rate ratios ranging from 1.4 to 2.0 were observed for low supervisor support, low co-worker support and low job satisfaction. The adjusted rate ratios for supervisor and co-worker support were not statistically significant. Quantitative job demands, conflicting demands, decision authority and skill discretion showed no relationship with sickness absence due to low back pain in the complete cohort. The strength of the associations of low supervisor support, low co-worker support and low job satisfaction with sickness absence due to low back pain was similar to that of the association of these factors with self-reported low back pain found in the same study.[21]

The analysis of the group of workers who had been employed in their current job for 5 years or fewer at baseline showed stronger associations with sickness absence due to low back pain for the work-related physical factors under study, for medium decision authority, and for low supervisor support. A weaker association was found for low co-worker support. These results may indicate the presence of a healthy worker effect in the complete cohort. The results for supervisor support and co-worker support are similar to the results of the analyses of the relationship with self-reported low back pain in the same subgroup.[21] Comparison of complete cohort and subgroup results might indicate that different types of support are important during different stages of employment. The separate analyses for short and long absences showed the strongest associations for the relationships between long absences and trunk flexion, trunk rotation, lifting and low job satisfaction, and for the relationship between short absences and low supervisor support.

Selectiveness in the permission obtained for the collection of data from sick leave records might be a source of bias in this study. The percentage of workers with low back pain in the 12 months prior to baseline, and in the highest exposure category of the work-related physical factors under study, was higher among the group of workers who did not give consent for the collection of data on their sickness absence than among the group of workers who did (data not shown). This may explain the decline in the rate ratio in the highest exposure category of a minimum of 30 degrees of trunk flexion and trunk rotation.

Three other prospective cohort studies also collected data on sickness absence from company records.[9,10,22] The present study confirms the findings of Wickström and Pentti,[22] who reported a rate ratio of 2.6 for the relationship between self-reported exposure to harmful biomechanical loads at work and sickness absence due to back pain. They also found a rate ratio of 1.7 for the relationship between sickness absence due to back pain and a lack of recognition and respect at work, one of the aspects of lack of social support. Rossignol et al.[10] examined the effect of boredom at work and job satisfaction on sickness absence due to back pain. They only observed an effect of low job satisfaction. The Whitehall study investigated the effect of psychosocial work characteristics on short and long absences due to low back pain.[9] Low decision latitude, a combined measure of decision authority and skill discretion, showed the most consistent effects. The fact that this result was not confirmed in the present study might be explained by the lack of adjustment for physical load at work in the Whitehall study, or by the fact that the Whitehall study population only included office workers.

The findings from the present study are in agreement with the results of two recent reviews of the literature on physical and psychosocial risk factors for low back pain, which also showed that the evidence for trunk flexion and rotation, manual materials handling, low social support and low job satisfaction as risk factors for low back pain is the strongest.[6,7]

The main conclusion which can be drawn from this study is that the work-related physical factors of flexion and rotation of the trunk and lifting at work are risk factors for sickness absence due to low back pain. Of the psychosocial work characteristics under study, low job satisfaction was found to be a risk factor for sickness absence due to low back pain. Some indications of a relationship between low social support, either by supervisor or co-worker, and sickness absence due to low back pain are also present. The other psychosocial work characteristics were not found to be related to sickness absence due to low back pain in the present study.

The results suggest that high physical load is more strongly related to increased sickness absence due to low back pain than high psychosocial load. Furthermore, high physical load seems to be more strongly related to sickness absence due to low back pain than to low back complaints. This implies that decreasing the physical load at work, especially for workers with low back complaints, may be an important tool in the prevention of sickness absence due to low back pain. In addition, improving job satisfaction and social support at work may also contribute to the prevention of sickness absence due to low back pain.

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7

Comparison of conventional regression and generalized estimating equations (GEE) for the analysis of longitudinal data:

an application to work-related risk factors for low back pain

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Abstract

The objective was to compare the results of conventional regression and generalized estimating equations (GEE) analysis, using data from a prospective cohort study on work-related risk factors for low back pain which included three annual follow-up measurements. In a conventional logistic regression model, physical and psychosocial risk factors at baseline were related to the cumulative incidence of low back pain during the three-year follow-up period. In a GEE logistic model, repeated measurements of the physical and psychosocial risk factors were related to low back pain reported at one measurement point later. The conventional regression model showed a statistically significant effect of flexion and/or rotation of the upper part of the body (OR 1.8, 95% CI 1.2-3.0), but not of moving heavy loads (OR 1.4, 95% CI 0.7-3.1). The GEE model showed a statistically significant effect of both flexion and/or rotation of the upper part of the body (OR 2.2, 95% CI 1.5-3.2) and moving heavy loads (OR 1.6, 95% CI 1.0-2.6). With both methods no statistically significant associations with low back pain were found for the psychosocial work characteristics, but the GEE model showed weaker odds ratios for these variables than the conventional regression model. The results show that there are differences between the two analytical methods in both the magnitude and the precision of the observed odds ratios.

Introduction

In occupational health research on work-related risk factors for musculoskeletal symptoms there is an increasing awareness that prospective cohort studies are necessary to obtain more insight into the temporal relationship between work-related risk factors and health outcomes.[1-4] Conventional analyses of these studies mainly focus on examination of the relationship between exposure measured at baseline and the occurrence of the health outcome of interest during a specified follow-up period. However, changes at the workplace may invalidate baseline data, and repeated measurements of exposure should therefore be considered. A recent review of studies on physical risk factors for back pain showed that hardly any cohort studies incorporated repeated measurements of exposure, although there were many studies with an extremely long follow-up period during which the exposure could have changed considerably.[5]

Repeated measurements can be made of both exposures and outcomes. The most widely applied modelling approach for repeated measurements is the generalized estimating equation (GEE) method developed by Liang and Zeger.[6] The GEE method extends conventional regression analysis, taking into account the correlation between repeated measurements. Data on a person at a certain time during follow-up are included, whether or not data on that person is missing at other times. The GEE method can be applied to a wide range of familiar models, including linear and logistic regression, which means that the method is suitable for the analysis of both continuous and dichotomous outcome variables. In addition, both time-dependent and time-independent covariates can be included.[6-8] Gender is a typical example of a time-independent variable. All variables that are subject to change are, in principle, time-dependent.

The Study on Musculoskeletal disorders, Absenteeism, Stress, and Health (SMASH) is a three-year prospective cohort study among a working population, which was initiated to identify risk factors for musculoskeletal disorders. In this study, repeated measurements were made of both exposures and outcomes. In previous reports on the study, conventional analyses were performed, relating work-related risk factors at baseline to the cumulative incidence of low back pain reported during the follow-up period.[9,10] The objective of the study described in this paper was to compare the results of conventional regression with the results of GEE analysis, to find out whether the GEE method produces different parameter and standard error estimates. For this purpose, both analytical methods were applied to examine the relationship between selected work-related physical and psychosocial risk factors and the occurrence of low back pain.

Participants and methods

Study population

For the SMASH study, workers were recruited from 34 companies located throughout the Netherlands. The participating companies were asked to select workers who had been employed in their current job for at least one year and who were working for 24 hours per week or more. Workers in blue-collar jobs, as well as workers in white-collar jobs and caring professions were included in the study.

At baseline, 1,789 (87%) of the 2,064 workers who were invited to participate, completed the questionnaire. Of these, 1,738 were eligible for participation in the part of the study focusing on risk factors for low back pain.[9] For the analyses described in this paper, a cohort of 1,192 workers with no low back pain at baseline was identified, consisting of workers who reported at baseline that they had not had regular or prolonged low back pain in the previous 12 months.[9,10]

Baseline survey

Between March 1994 and March 1995 the participants completed a questionnaire and underwent a physical examination. The questionnaire included questions on the individual factors of age, gender, smoking habits, exercise behavior,[11] and coping skills.[12] Assessment of the body mass index was based on measurements of weight and height taken by a physiotherapist during the physical examination.

Psychosocial work characteristics were assessed by means of a Dutch version of Karasek's Job Content Questionnaire (JCQ) which includes dimensions on quantitative job demands, decision authority, skill discretion, supervisor support, and co-worker support.[13] Conflicting demands were assessed on the basis of one single item from the JCQ.[13]

Flexion and/or rotation of the upper part of the body and moving heavy loads (> 25 kilograms) at work were assessed by means of the Loquest questionnaire.[14] Driving a vehicle at work was also assessed with this questionnaire, and aspects of physical load during leisure time were assessed on the basis of questions comparable to those used to assess the physical load at work.[14]

Assessment of the occurrence of low back pain was based on an adaptation of the Nordic Questionnaire.[15] Workers had to answer the question 'Have you had trouble (aches, pain, discomfort) in the low back in the previous 12 months?' with one of the following four response options: no, never; yes, sometimes; yes, regularly; yes, prolonged. A case of low back pain was defined if a worker reported regular or prolonged low back pain in the previous 12 months.

Follow-up

After the baseline survey there was a follow-up period of three years, and each year the workers received a self-administered questionnaire by post. In these questionnaires, the same questions as in the baseline questionnaire were asked to assess exercise behaviour, psychosocial work characteristics, physical load at work and during leisure time, and the occurrence of low back pain in the previous 12 months.

Statistical analysis

Two analytical methods were used: conventional regression and GEE. Both methods were carried out with Proc Genmod in the statistical package SAS (Version 6.12),[16] and since the outcome variable low back pain is dichotomous, the link-function in Proc Genmod was always specified as logistic. Figure 7.1 illustrates the models that were analysed with the two methods. In the conventional regression model, the baseline measurements of work-related physical risk factors (i.e. flexion and/or rotation of the upper part of the body and moving heavy loads) and work-related psychosocial risk factors (i.e. quantitative job demands, conflicting demands, supervisor support, and co-worker support) were related to the cumulative incidence of low back pain reported during the three-year follow-up period. In this analysis, a case of low back pain was defined if a worker reported, in at least one of the annual self-administered follow-up questionnaires, regular or prolonged low back pain in the previous 12 months. Using GEE,[6] two different models were analysed. In GEE model 1, all risk factors and covariates were assumed to be time-independent, which means that only data from the baseline measurement were used, as in the conventional regression analysis. These baseline measurements were related to low back pain reported at the three different follow-up points. In GEE model 2, all risk factors were time-dependent. Most covariates were also time-dependent, except for age and gender and the covariates that were only measured at baseline (i.e. smoking habits, coping skills and body mass index). GEE model 2 was also a time-lag model, implying that the repeated measurements of the risk factors studied were related to low back pain reported at one measurement point later.[8] Given the fact that in the present study data on the occurrence of low back pain collected at each measurement point concerned

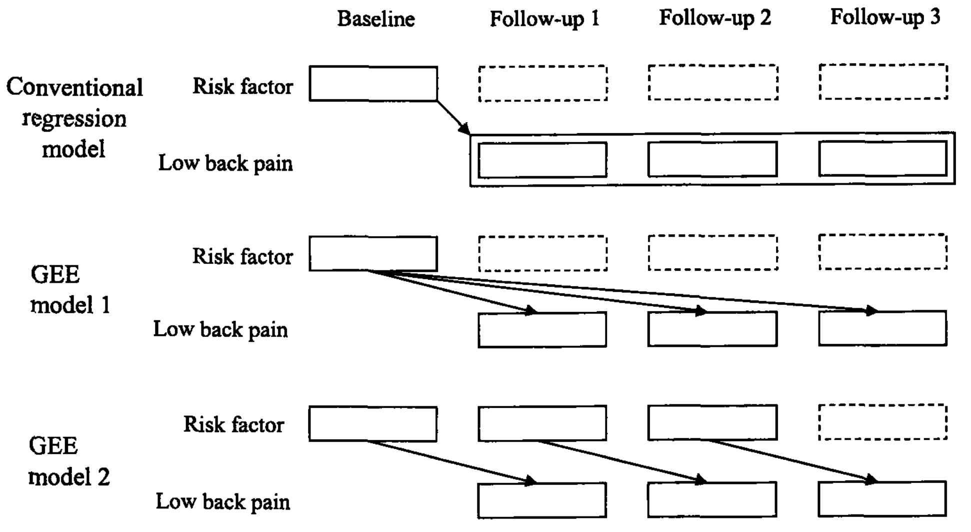

Figure 7.1 Illustration of the different models that were analysed with conventional regression and generalized estimating equations (GEE)

the previous 12 months, the use of a time-lag model was necessary to take into account the temporal sequence of cause and effect. GEE model 2 was considered a priori to be the most appropriate model for both the physical and the psychosocial risk factors studied, because it takes into account the time-varying nature of both the outcome and the exposure. GEE model 1 was also analysed to obtain insight into the separate effects of taking into account the time-varying nature of the outcome and the exposure. In the analyses of both GEE models, the working correlation structure for the repeated measurements of the outcome variable was specified as exchangeable, implying that all correlations of the outcome variable were assumed to be equal, irrespective of the time-period between the measurements.[6,8]

In univariate analyses, performed with both analytical methods, crude odds ratios (OR) with corresponding 95% confidence intervals (95% CI) were calculated for the risk factors studied. Adjusted odds ratios were determined in a full model, including the work-related physical and psychosocial risk factors and the individual factors, other psychosocial work characteristics, other work-related physical factors, and physical factors during leisure time that were considered as covariates. Both univariate and multivariable GEE models always included a linear time-effect (from 0 to 2).

Results

Table 7.1 shows the data on reported low back pain for each follow-up measurement separately and combined. From the cohort of 1,192 workers with no low back pain in the previous 12 months at baseline, data on the occurrence of low back pain were available for 861 workers (72%) for all three annual follow-up measurements. These data were used for the analyses with the conventional regression method. The cumulative incidence of low back pain in this group during the three-year follow-up period was 26.6%. Only 2.6% of the workers reported regular or prolonged low back pain in the previous 12 months at all three follow-up measurements.

From the cohort of 1,192 workers, data on the occurrence of low back pain were available for 1,116 workers (94%) for at least one of the follow-up measurements. These data were used for the analyses with the GEE method. At each follow-up measurement, approximately 12% of the workers reported they had had regular or prolonged low back pain in the previous 12 months.

Table 7.1 Low back pain reported at the annual follow-up measurements in the cohort of workers with no low back pain in the previous 12 months at baseline (n=1,192)

Measurement	Low back pain	Missing data (n)
Follow-up 1	10.9%	131
Follow-up 2	12.4%	123
Follow-up 3	12.6%	92
Cumulative	26.6%	331

Table 7.2 shows the results for the work-related physical risk factors studied. A comparison of the crude results from the two GEE models with the crude results from the conventional regression model shows that for the medium and the highest level of flexion and/or rotation of the upper part of the body the odds ratios in GEE model 1 were of the same magnitude, whereas the odds ratios in GEE model 2 were higher. In GEE model 2 a dose-response relationship was also observed. For the highest level of moving heavy loads the odds ratios were somewhat higher in both GEE models, while for the medium level of moving heavy loads, the odds ratios in the GEE models were slightly lower. A comparison between the adjusted odds ratios resulting from the different analyses shows a similar pattern for both flexion and/or rotation of the upper part of the body and moving heavy loads. In general, the 95% confidence intervals were found to be relatively smaller in the GEE analyses than in the conventional regression analysis. With the latter method, a statistically significant relationship with low back pain was found for flexion and/or rotation of the upper part of the body, but not for moving heavy loads, while with the GEE method a (borderline) statistically significant relationship with low back pain was found for both flexion and/or rotation of the upper part of the body and moving heavy loads.

Table 7.2 Results concerning the relationship between work-related physical factors and the occurrence of low back pain from multivariable analyses with conventional regression and generalized estimating equations (GEE)*

Risk factor	Crude OR (95% CI)†			Adjusted OR (95% CI)‡		
	Conventional regression model (n=786)	GEE model 1 (n=999)	GEE model 2 (n=1024)	Conventional regression model (n=786)	GEE model 1 (n=999)	GEE model 2 (n=1024)
Flexion and/or rotation of the upper part of the body						
seldom or never/sometimes	1.00	1.00	1.00	1.00	1.00	1.00
quite often	1.13 (0.79-1.62)	1.22 (0.89-1.68)	1.64 (1.26-2.12)	1.07 (0.72-1.58)	1.21 (0.86-1.69)	1.57 (1.20-2.05)
very often	1.90 (1.24-2.91)	1.85 (1.31-2.62)	2.31 (1.62-3.30)	1.84 (1.15-2.95)	1.87 (1.29-2.72)	2.18 (1.49-3.20)
Moving heavy loads (> 25 kg)						
seldom or never/sometimes	1.00	1.00	1.00	1.00	1.00	1.00
quite often	1.24 (0.80-1.93)	1.10 (0.75-1.59)	0.83 (0.57-1.20)	1.15 (0.71-1.84)	1.01 (0.68-1.49)	0.80 (0.55-1.15)
very often	1.44 (0.71-2.95)	1.60 (0.94-2.74)	1.72 (1.12-2.63)	1.44 (0.67-3.10)	1.63 (0.95-2.81)	1.62 (1.03-2.56)

Abbreviations: OR, odds ratio; CI, confidence interval.

* The different models that were analysed are illustrated in Figure 7.1.

† Crude odds ratio in the population with no missing values for gender, age, smoking habits, body mass index, exercise behaviour during leisure time, coping skills, quantitative job demands, conflicting demands, decision authority, skill discretion, supervisor support, co-worker support, moving heavy loads during leisure time, flexion and/or rotation of the upper part of the body during leisure time, driving a vehicle during leisure time, driving a vehicle at work.

‡ Adjusted odds ratio, adjusted for the risk factors mentioned above.

Table 7.3 Results concerning the relationship between psychosocial work characteristics and the occurrence of low back pain from multivariable analyses with conventional regression and generalized estimating equations (GEE)*

Risk factor	Crude OR (95% CI)†			Adjusted OR (95% CI)‡		
	Conventional regression model (n=786)	GEE model 1 (n=999)	GEE model 2 (n=1024)	Conventional regression model (n=786)	GEE model 1 (n=999)	GEE model 2 (n=1024)
Quantitative job demands						
low (score 6-11)	1.00	1.00	1.00	1.00	1.00	1.00
medium (score 12-16)	1.43 (0.99-2.07)	1.03 (0.75-1.41)	1.10 (0.86-1.42)	1.33 (0.90-1.97)	0.95 (0.68-1.31)	1.00 (0.76-1.30)
high (score 17-20)	1.87 (0.93-3.76)	1.72 (0.95-3.14)	1.43 (0.90-2.25)	1.46 (0.68-3.13)	1.36 (0.70-2.61)	1.13 (0.70-1.82)
Conflicting demands						
(strongly) disagree	1.00	1.00	1.00	1.00	1.00	1.00
agree	1.08 (0.75-1.57)	1.22 (0.89-1.67)	1.21 (0.94-1.56)	1.00 (0.67-1.49)	1.17 (0.84-1.63)	1.16 (0.90-1.51)
strongly agree	1.53 (0.84-2.79)	1.29 (0.77-2.16)	1.03 (0.60-1.79)	1.61 (0.84-3.07)	1.33 (0.79-2.23)	0.92 (0.52-1.61)
Supervisor support						
high (score 13-16)	1.00	1.00	1.00	1.00	1.00	1.00
medium (score 11,12)	1.42 (0.84-2.40)	1.10 (0.71-1.71)	1.09 (0.73-1.60)	1.39 (0.76-2.53)	1.06 (0.64-1.77)	0.99 (0.67-1.48)
low (score 4-10)	1.69 (0.97-2.94)	1.33 (0.84-2.11)	1.57 (1.04-2.37)	1.48 (0.78-2.80)	1.13 (0.66-1.93)	1.33 (0.86-2.05)
Co-worker support						
high (score 13-16)	1.00	1.00	1.00	1.00	1.00	1.00
medium (score 11,12)	1.36 (0.91-2.05)	1.24 (0.86-1.79)	1.14 (0.83-1.57)	1.53 (0.95-2.46)	1.44 (0.95-2.19)	1.16 (0.83-1.63)
low (score 4-10)	1.68 (0.91-3.10)	1.45 (0.86-2.44)	1.39 (0.88-2.22)	1.78 (0.88-3.60)	1.59 (0.89-2.83)	1.26 (0.77-2.05)

Abbreviations: OR, odds ratio; CI, confidence interval.

* The different models that were analysed are illustrated in Figure 7.1.

† *Crude odds ratio in the population with no missing values for gender, age, smoking habits, body mass index, exercise behaviour during leisure time, coping skills,* moving heavy loads during leisure time, flexion and/or rotation of the upper part of the body during leisure time, driving a vehicle during leisure time, moving heavy loads at work, flexion and/or rotation of the upper part of the body at work, driving a vehicle at work, and the other psychosocial work characteristics mentioned in the table.

‡ Adjusted odds ratio, adjusted for the risk factors mentioned above.

Table 7.3 shows the results for the work-related psychosocial risk factors studied. A comparison of the crude results from the two GEE models with the crude results from the conventional regression model shows that for both medium and high quantitative job demands the odds ratios in GEE models 1 and 2 were lower, with the lowest odds ratio for high quantitative demands found in GEE model 2. For high conflicting demands, the odds ratios in GEE models 1 and 2 were also lower, while for the medium level of conflicting demands the odds ratios in the GEE models were slightly higher. For medium and low supervisor and co-worker support, lower odds ratios were found in both GEE models. A comparison between the adjusted odds ratios resulting from the different models shows a similar pattern for the work-related psychosocial risk factors. Again, the 95% confidence intervals were relative smaller in the GEE analyses. After adjustment for potential confounders, no statistically significant relationship with reported low back pain was found for any of the work-related psychosocial risk factors studied.

Discussion

Summary and interpretation of findings

In this article, two different analytical methods were applied to longitudinal data from a prospective cohort study on work-related risk factors for musculoskeletal symptoms. For the work-related physical factors studied, higher odds ratios were obtained in the analysis of GEE model 2, which was considered a priori to be the most appropriate, than in the analysis of the conventional regression model. The fact that the analysis of GEE model 1 showed odds ratios for flexion and/or rotation of the upper part of the body similar to those found in the conventional regression model, suggests that the increase in the odds ratios for this risk factor in GEE model 2 is not caused by taking into account the time-varying nature of the outcome. In the case of flexion and/or rotation of the upper part of the body, changes in exposure have apparently occurred. An analysis of the data on exposure obtained from the different measurements shows that only 49% of workers reported the same level of exposure for flexion and/or rotation of the upper part of the body at baseline and the first two follow-up measurements.

With regard to moving heavy loads, the differences between the GEE models and the conventional regression model were smaller. The analysis of GEE model 1 showed that taking into account the time-varying nature of the outcome had a small effect on the odds ratios for moving heavy loads. The small increase in the odds ratio for the highest level of moving heavy loads could mean that frequently moving heavy loads has more influence on workers who reported low back pain at more than one of the follow-up measurements than on workers who reported low back pain at only one of the follow-up measurements. However, one has to be aware that taking into account the time-varying nature of the outcome is not the only difference between GEE model 1 and the conventional regression model. GEE model 1 also included a number of workers who were not included in the conventional regression model, because of missing data on the outcome for at least one of the follow-up measurements. The effect of taking into account the time-varying nature of the exposure was smaller for moving heavy loads than for flexion and/or rotation of the upper part of the body. This can be concluded from the similarity between the adjusted odds ratios of GEE model 2 and GEE model 1. This can be explained by the relative stability of the variable of moving heavy loads over the follow-up period. For this variable, 76% of workers reported the same level of exposure at baseline and the first two follow-up measurements.

In comparison with the results for the work-related physical factors, the results for the psychosocial work characteristics were rather heterogeneous. In addition, no clear evidence of a relationship between any of the psychosocial work characteristics studied and reported low back pain was found with either the conventional regression method or the GEE method. Therefore, the possibility of making inferences based on the observed differences between the models was limited. In general, in the analysis of GEE model 2, the model that was considered a priori to be the most appropriate, weaker associations for the psychosocial work characteristics were found than in the analysis of the conventional regression model. For all psychosocial work characteristics, the results of GEE model 1 showed that taking into account the time-varying nature of the outcome resulted in a decrease in the odds ratios. For both high quantitative job demands and high conflicting demands, the analysis of GEE model 2 showed that when the time-varying nature of the exposure was also taken into account, the odds ratios for these psychosocial work characteristics decreased further towards the neutral value. With regard to the social support variables, comparison of GEE model 2 with GEE model 1 showed that taking into account the time-varying nature of the exposure led to an increase in the odds ratio for low supervisor support, whereas the odds ratio for low co-worker support remained approximately the same. Apparently, the influence of taking into account the time-varying nature of the exposure is not the same for all psychosocial work characteristics. This cannot be explained by differences in the stability of these variables over the follow-up period. For all psychosocial work characteristics, only approximately half of the workers reported the same level of exposure at baseline and the first two follow-up measurements.

In addition to differences in the magnitude of the odds ratios, differences in the precision of the odds ratios for both the physical and the psychosocial factors were also observed. The confidence intervals of the odds ratios resulting from the GEE analyses were smaller than those of the odds ratios resulting from the conventional regression analysis. This can be explained by the fact that all available outcome data can be included in the GEE method. In the present study, 861 workers with data on the occurrence of low back pain for all three annual follow-up measurements were included in the conventional regression analysis, while 1,116 workers with data on the occurrence of low back pain for at least one of the follow-up measurements could be included in the GEE analyses. For the majority of these workers, more than one observation was also included in the analyses, which resulted in even more power. Only for moving heavy loads did the increase in power result in a different conclusion with regard to the presence of a statistically significant relationship with low back pain.

Limitations and potential sources of bias

Only the two GEE models included in the present analysis were taken into consideration, although other possibilities do exist. The time-lag model, the preferred model for the present data, takes into account the temporal sequence of cause and effect, and this model can also be extended to models with different time-lags. By repeatedly measuring exposure and outcome, the biologically relevant exposure window at some fixed interval of time relative to the outcome event can be defined.[7] The length of the exposure window and its temporal position relative to the outcome event will depend on the supposed causal mechanism for the exposure of interest. When the understanding of disease aetiology is too limited to specify a credible temporal relationship, different time-lags can be studied to obtain more insight into the hypothesized relationships.[17] It is beyond the scope of this paper to examine all these possibilities, but it is clear that modelling approaches such as the GEE method, make it feasible to explore these issues in the context of epidemiological cohort studies with repeated measurements of exposure and health data.[18] One can imagine that, especially with regard to the psychosocial work characteristics, the postulation of different time-lags could provide insight into the nature of the relationship of these variables with low back pain. The inclusion of an appropriate time-lag is especially important for exposures that are relatively unstable. The psychosocial work environment is clearly subject to change. It can be hypothesized that changes in the psychosocial work environment occur even more frequently than changes in the physical work environment, and that psychosocial work characteristics may have a more short-term effect on low back pain. Consequently, shorter intervals between the repeated measurements would be necessary to make an adequate assessment of the role of psychosocial work characteristics.

The GEE analyses reported in the present paper were performed using an exchangeable working correlation matrix. This structure was chosen, because it is the most neutral option, and also because the relatively short follow-up period of this study and the identical duration of the intervals between the repeated measurements does not warrant the use of a more specific correlation structure, such as a stationary m-dependent or autoregressive structure.[8] In general, the choice for the correlation structure has to be based on the correlation of the repeated outcome measures in the dataset. However, in case of a binary outcome, the value of a correlation coefficient as a measure of association is limited. Fortunately, the GEE analysis is known to be quite robust for the choice of a "wrong" correlation structure.[6] Therefore, the analyses were not performed with a different correlation structure.

A potential bias that is specifically related to longitudinal studies in which both exposure variables and outcome variables are allowed to vary over time, is feedback bias, which implies that earlier outcomes may affect subsequent exposures.[7] As explained by Eisen, the GEE method can not control for this bias.

A specific limitation of the analyses of work-related physical risk factors described in the present paper is that all measurements were based on self-reports. In the SMASH study, physical load at work was also quantified by means of analyses of video-recordings. However, since these measurements were not repeated at the annual follow-up measurements, these data are not included in this paper. In general, the results of the present analyses, based on self-reported measures of physical load at work, are in accordance with the results of the previously reported analyses of quantified measures based on the observations of baseline video-recordings.[9]

Conclusion

In conclusion, the results of this study clearly show that there are differences between the two analytical methods applied, in both the magnitude and the precision of the calculated odds ratios. Compared with conventional regression analysis, the GEE analysis with a time-lag model, in which the time-varying nature of both the exposure and the outcome is taken into account, revealed stronger associations for the work-related physical risk factors studied and weaker associations for the psychosocial work characteristics. Moreover, for moving heavy loads, conclusions on the presence or absence of a statistically significant relationship with low back pain differed, depending on the analytical method used. The analyses of another model with the GEE method provided insight into the causes of the differences between the conventional regression analysis and the GEE analysis. Taking into account the time-varying nature of both the outcome and the exposure appeared to have an influence.

This paper clearly demonstrates that in the design and analysis of prospective cohort studies on work-related risk factors for musculoskeletal symptoms, the incorporation of repeated measurements of both exposure and outcome should be considered. To encourage researchers to carry out such studies, discussions should be initiated to determine the appropriate intervals between the repeated measurements and also the appropriate number of repeated measurements needed to study both work-related physical and, in particular, psychosocial risk factors for low back pain.

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8

General discussion

In this final chapter, the main findings are summarized in the context of the research questions posed in the Introduction (Chapter 1). Although some limitations of the studies have already been discussed in the preceding chapters, attention is also paid to some general methodological issues concerning the systematic reviews and the prospective cohort study. The discussion of some of these issues includes the presentation of results from additional analyses. The final conclusions of this thesis, implications for prevention, and recommendations for future research are addressed in the last section of the chapter.

Summary of findings

Which work-related physical factors are risk factors for low back pain?

This question was addressed in the systematic review described in Chapter 2 and in the analyses of data from the Study on Musculoskeletal disorders, Absenteeism, Stress, and Health (SMASH) presented in Chapters 4, 6 and 7. According to the systematic review, there was strong evidence that manual materials handling, bending and twisting, and whole-body vibration are risk factors for low back pain. Moderate evidence was found that patient handling and heavy physical work are risk factors for low back pain. No evidence (labelled as insufficient evidence in Chapter 3) was found for an effect of standing or walking and sitting, either because of contradictory findings or because the available information was too limited. The analyses of data from SMASH focused on quantified measures of flexion and rotation of the trunk and lifting at work. In Chapter 4 it was shown that these factors are moderate risk factors (relative risks of approximately 1.5) for self-reported low back pain. In Chapter 6 it was shown that flexion and rotation of the trunk and lifting at work also increase the risk of sickness absence due to low back pain. The results reported in Chapter 7, in which generalised estimating equations (GEE) analysis was used to relate the repeated self-reported measurements of work-related physical factors to the repeated measurements of self-reported low back pain, are in accordance with the results reported in Chapter 4. A statically significant relationship with low back pain was found for flexion and/or rotation of the upper part of the body as well as for moving heavy loads.

The analyses of the data from SMASH also included an investigation of the exposure-response relationship between flexion and rotation of the trunk and lifting at work and low back pain. In Chapter 4 it was possible to identify a minimum level of exposure to flexion and rotation of the trunk and lifting at work, above which the risk of self-reported low back pain started to increase. Extreme trunk flexion and lifting loads of 25 kilograms or more seemed to be especially important. Trunk rotation led to an increased risk of low back pain for workers with the trunk in rotation for more than 10% of the working time. Due to the relatively small number of workers with exposure above these levels, it was not possible to study the further course of the relationship of these factors with self-reported low back pain at greater levels of exposure. In Chapter 6, trunk flexion was found to have an exposure-response relationship with sickness absence due to low back pain, with increasing duration and also, although less clear, with an increasing degree of trunk flexion. No exposure-response relationship with sickness absence due to low back pain was observed for trunk rotation or lifting. In the GEE analysis described in Chapter 7, an exposure-response relationship was observed between self-reported flexion and/or rotation of the upper part of the body and self-reported low back pain.

In conclusion, the findings of both the systematic review and SMASH suggest that flexion and rotation of the trunk and lifting at work are risk factors for low back pain. When adding the present study to the review, no change was found in the levels of evidence for flexion and rotation of the trunk and lifting at work. The systematic review not only showed strong evidence for flexion and rotation of the trunk and lifting, but also provided strong evidence that whole-body vibration is a risk factor for low back pain, and moderate evidence that patient handling and heavy physical work are risk factors for low back pain. In the analyses of the data from SMASH a clear exposure-response relationship with low back pain was observed for trunk flexion, but not for trunk rotation and lifting.

Which psychosocial work characteristics are risk factors for low back pain?

This question was also addressed in a systematic review and in the analyses of data from SMASH. In the systematic review described in Chapter 3, strong evidence was found for a positive effect of low social support in the workplace and low job satisfaction. Insufficient evidence (labelled as no evidence in Chapter 2) was found for an effect of a high work pace, high qualitative jobs demands, low job content and low job control, either because of contradictory findings or because the available information was too limited. However, since the results of the review appeared to be sensitive to slight changes in the methods used, the final conclusion was that there seems to be evidence for an effect of psychosocial work characteristics, but that evidence for specific factors has not yet been established.

In the analyses of data from SMASH presented in Chapter 5, only moderate (relative risks of approximately 1.5) and not statistically significant associations were found between high quantitative job demands, high conflicting demands, low supervisor support and low co-worker support, on the one hand, and self-reported low back pain on the other. Based on a comparison with the findings of previous studies that were included in the systematic review and the results of more recent studies, it was concluded that it seems likely that low social support is, indeed, a risk factor for the occurrence of low back pain. A relationship between high quantitative job demands or high conflicting demands and low back pain has not consistently been observed in other studies. No relationship was found between low decision authority or low skill discretion and self-reported low back pain. The results for low job satisfaction depended on the operationalization of this variable. When operationalized in terms of general opinion about the job, job satisfaction was found to be a risk factor for self-reported low back pain. Job task enjoyment was not related to self-reported low back pain.

In Chapter 6, job satisfaction operationalized in terms of general opinion about the job was also found to be a risk factor for sickness absence due to low back pain. Some indications of a relationship between low social support, from either supervisor or co-worker, and sickness absence due to low back pain were also present. High quantitative job demands, high conflicting demands, low decision authority and low skill discretion were not found to be related to sickness absence due to low back pain.

In Chapter 7, in which GEE analysis was used to relate repeated measurements of quantitative job demands, conflicting demands, supervisor support and co-worker support to the repeated measurements of self-reported low back pain, weaker associations for these psychosocial work characteristics were found than in Chapter 4. Consequently, no evidence of a relationship between any of the psychosocial work characteristics studied and self-reported low back pain was found in this analysis.

In conclusion, the results of both the systematic review and SMASH suggest that low job satisfaction (general opinion about the job) is a risk factor for the occurrence of low back pain. Low social support also seems to be a risk factor for low back pain, but it is difficult to draw definite conclusions on the role of this psychosocial work characteristic. When adding the present study to the review, no change was found in the levels of evidence for any of the psychosocial work characteristics. Strong evidence remained for both low job satisfaction and low social support, and insufficient evidence remained for a high work pace, high qualitative demands, low job content and low job control.

Do psychological strain variables play an intermediate role in the relationship between psychosocial work characteristics and low back pain?

Results of the analyses of data from SMASH do not support the hypothesis that the psychological strain variables of job satisfaction, emotional exhaustion and sleeping difficulties play an intermediate role in the relationship between conflicting demands, supervisor and co-worker support and low back pain (Chapter 5). Only in the relationship between high quantitative job demands and low back pain, is it possible that general opinion about the job and emotional exhaustion are intermediates. The small magnitude of the observed effects for the psychosocial work characteristics, however, complicated the examination of the potential intermediate role of psychological strain variables. Therefore, and because this is the first study in which this hypothesis has been examined, it is not possible to draw strong conclusions on this subject.

What is the relative importance of work-related physical factors and psychosocial work characteristics as risk factors for low back pain?

The results of the systematic reviews described in Chapters 2 and 3 indicate that the body of evidence supporting the role of physical load factors as risk factors for back pain is somewhat more consistent, and thus stronger, than that for psychosocial factors. Comparison of the results of SMASH for the physical and psychosocial factors, respectively, in relation to self-reported low back pain (Chapters 4 and 5) shows that the magnitude of the observed associations is similar. For both the physical and the psychosocial factors that are related to low back pain, moderate associations (relative risks of approximately 1.5) were observed. However, in particular for the psychosocial work characteristics, the associations were of borderline statistical significance. This implies that there is a substantial chance of a false-positive finding. The results of the GEE analyses described in Chapter 7, in which repeated measurements of the work-related risk factors were related to the repeated measurements of low back pain, also suggest that there is less evidence for a relationship between psychosocial work characteristics and low back pain than for a relationship between work-related physical factors and low back pain. From Chapter 6 it can be concluded that high physical load is more strongly related to increased sickness absence due to low back pain than high psychosocial load.

In conclusion, both the results of the systematic reviews and the results of SMASH show that there is more evidence for a relationship between work-related physical factors and low back pain than for a relationship between work-related psychosocial risk factors and low back pain.

Is there a difference in the relationship of work-related factors with sickness absence due to low back pain, on the one hand, and with self-reported low back pain on the other hand?

A comparison of the results presented in Chapter 4 with the results presented in Chapter 6 shows that high physical load seems to be more strongly related to sickness absence due to low back pain than to self-reported low back pain. Moreover, the risk of sickness absence started to increase at lower levels of exposure. With regard to the psychosocial work characteristics, there is not such a clear difference in the results. Low job satisfaction and low social support showed similar associations with self-reported low back pain (Chapter 5) and sickness absence due to low back pain (Chapter 6). For self-reported low back pain, some indications were also found for a relationship with high quantitative job demands and high conflicting demands, but these associations were not observed with sickness absence due to low back pain. These associations were also not found in Chapter 7, in which repeated measurements of the work-related factors were related to repeated measurements of self-reported low back pain.

In conclusion, in particular with regard to the work-related physical factors, there appears to be a difference in the relationship with sickness absence due to low back pain, on the one hand, and with self-reported low back pain on the other hand. Flexion and rotation of the trunk and lifting at work are more strongly related to sickness absence due to low back pain than to self-reported low back pain. This finding may indicate that high physical load at work, in particular, is a barrier in returning to work for workers with low back pain.

Systematic review methodology

In Chapters 2 and 3, a systematic approach was used to summarize the literature concerning the relationship between physical and psychosocial factors and low back pain. Predefined criteria were applied for the selection of studies, the methodological quality assessment and summarizing the evidence. The primary advantage of the use of explicit criteria is that the reader has insight into the way in which the review was performed. In that sense, everyone can make their own assessment of the results, given the criteria applied. Obviously, the choice of criteria can be the subject of discussion, especially since systematic reviews of observational studies are a relatively recent phenomenon.

As discussed in Chapters 2 and 3, it is still unclear which items are especially important in terms of bias, and should therefore be included in the methodological quality assessment. The list of criteria applied in the reviews presented in this thesis was specifically developed for this purpose, and was adapted from criteria lists applied in systematic reviews of randomised controlled trials on the efficacy of treatment[1] and criteria lists applied in other reviews of observational studies.[2,3] In a recently published review, performed by Davis and Heaney,[4] on the relationship between psychosocial work characteristics and low back pain, an assessment of methodological quality also was made. There is overlap in the criteria applied in the reviews presented in this thesis and the Davis and Heaney review.[4] There also appears to be a similarity in the evaluation based on the total score of most studies that were included in the review described in Chapter 3 and in the Davis and Heaney review.[4] However, there are also differences in the criteria applied, and in the exact operationalization and scoring of the criteria, resulting in relatively large differences in the scoring of some studies that may eventually influence the findings. In this case, the final conclusions of the review described in Chapter 3 and the Davis and Heaney review[4] were similar, although there were slight differences in the findings of the reviews. A comparison of the two reviews presented in this thesis with the Davis and Heaney review[4] also makes it clear that criteria lists should not only be evaluated in the context of the research question underlying the review in which they have been used, but also in combination with the inclusion criteria for that review. For example, in the reviews presented in this thesis (Chapters 2 and 3), cross-sectional studies were excluded, whereas the design of the study was one of the criteria for the methodological quality assessment in the Davis and Heaney review.[4] Furthermore, in the reviews presented in this thesis the presentation of quantitative measures of association was one of the criteria for the methodological quality assessment, whereas a review performed by Burdorf and Sorock[5] only included studies presenting quantitative measures of association. By evaluating the inclusion criteria and the methodological criteria applied in various reviews, consensus among experts might be reached on many issues. This is important, because it would then be possible to develop more or less standardized criteria for the inclusion of studies and methodological quality assessment in reviews on work-related risk factors for musculoskeletal symptoms.

The question then arises as to whether the above-mentioned process of developing standardized criteria should be based solely on common sense. One of the recommendations for future studies, resulting from the review presented in Chapter 2, was that these studies should report effect measures that reflect the risk of equivalent levels of contrast in exposure. This would make it possible to quantify the role of different risk factors in a meta-analysis. Although the estimate of an overall measure of effect may be the ultimate goal of a synthetic meta-analysis, meta-analysis can also be applied in a more deductive manner, which concentrates on explaining inconsistencies.[6] The latter approach can provide insight into the influence on the results of differences in study populations, the assessment of exposures and outcome, the statistical analysis performed and, consequently, the sources of bias.[7,8] Therefore, results of a deductive meta-analysis can also provide input for appropriate criteria lists for methodological quality assessment. This implies that in future, when sufficient quantitative and reasonably comparable data on the effect of work-related factors on the occurrence of low back pain are available, a meta-analysis can be performed. This meta-analysis should include a deductive component to assess the effect of differences in study design on the reported effect.

Although the reviews in this thesis were of a qualitative nature, they can also be classified as synthetic or analytic. The rating system used in the reviews is obviously more synthetic than analytic. A number of methodologists have expressed concerns about the use of a synthetic approach when performing a meta-analysis of non-experimental studies, because this can produce precise, but spurious results.[7,8] One disadvantage of the use of a rating system based on levels of evidence in a qualitative review is that it is somewhat mechanistic, and leaves very little possibility to interpret the findings. In the process of writing the systematic review, the use of a more deductive approach was also considered, but it was decided that the available literature was too limited for such an approach. In the Davis and Heaney review[4] and a review performed by Ferguson and Marras,[9] both of which were qualitative, an attempt was made to evaluate the literature with regard to the influence of individual methodological issues on inconsistencies in the results. However, these evaluations were somewhat rough, in the sense that the influence of methodological issues on the percentage of positive findings for the category of physical and/or psychosocial factors was studied, instead of the influence on the magnitude of the effect observed for specific physical and psychosocial factors.

In the review of psychosocial factors as risk factors for back pain described in Chapter 3, it was specifically emphasized that the review concentrated only on psychosocial factors at work and in private life, and did not include individual psychological factors such as personality traits or cognitive and behavioural variables. Unfortunately, in the literature the term psychosocial or psychological factors is often used without making this distinction. This may lead to considerable confusion about the role of these specific factors. This confusion becomes even greater when there is also no distinction made between the role of these factors in aetiology and prognosis, respectively.[10] This has led to the misconception that in etiological studies of psychosocial risk factors for low back pain, special attention should be paid to individual psychological factors, whereas existing evidence for the role of these variables has predominantly been derived from prognostic research.

Methodological issues concerning the prospective cohort study

Selection of the study population

In the prospective cohort study (SMASH), a number of criteria were applied for the selection of the study population. The choices that were made may have influenced the results in a number of ways.

Firstly, the choice was made to study a relatively heterogeneous cohort of workers to ensure adequate variation in the work-related physical factors to determine whether these factors influence the occurrence of low back pain and to explore the exposure-response relationship between these factors and low back pain. However, this method of selection may have affected the findings with regard to the relationship between psychosocial work characteristics and low back pain. It can be hypothesized that the effect of psychosocial work characteristics will be more pronounced in a population that is relatively homogeneous with regard to other potential determinants of low back pain.

Secondly, in order to reduce the possibility of loss to follow-up during the prospective cohort study, the choice was made to select a population that was expected to be stable. Therefore, it was decided to select companies with a relative low turnover rate and workers who had been employed in their current job for at least one year. The inclusion criterion for workers was based on the assumption that they would stay longer in their job because, among other things, after one year they probably had a fixed contract. However, this selection might have strengthened the healthy worker effect.[11] If high physical or high psychosocial load has a short-term effect on low back pain, workers may move to another job in less than one year. This would imply that the observed relative risks are an under-estimation of the true relative risk.

Thirdly, in all the analyses of the data from the prospective cohort study that focussed on self-reported low back pain, only workers with no low back pain in the previous 12 months at baseline were included. This selection was made in order to make sure that the focus of the study was on risk factors for new episodes of low back pain. The recurrent nature of back pain made this selection necessary. However, this selection might also have strengthened the healthy worker effect, which would again result in an under-estimation of the true effect of the work-related factors studied. Relatively more workers with low back pain in the previous 12 months at baseline were in the highest exposure category of all work-related physical and psychosocial factors under study. It is possible that the workers who had had no low back pain in the previous 12 months at baseline, and who were in the highest exposure category, were relatively insensitive to the effect of the exposures of interest. A similar effect may have occurred in the analyses of sickness absence, in which only workers with no sickness absences due to low back pain in the previous 3 months were included.

Exposure measurements

Assessment of exposure to physical load at work

To assess exposure to physical load at work, based on video-recordings and force measurements at the workplace, a grouping strategy was used, mainly for reasons of efficiency. The high costs of the measurements made it necessary to choose between a small study with intensive assessment of exposure at individual level and a large-scale study with an exposure-grouping strategy. The latter strategy implies that the average exposure of a sample of workers from a group is applied to all group members. One possible advantage of the use of a grouping strategy in the present study, is that the estimate of the average group exposure is based on multiple measurements on multiple days. It may therefore give a better estimate of the real exposure over time than individual exposure measured on one single day. A possible disadvantage is that misclassification of exposure for individual workers may have occurred, because of differences between workers within a group.

The consequences of the use of a grouping strategy to assess the exposure of individual workers depends on the relationship between the within and between person variance and the within and between group variance in the exposure. A recently developed theory describes how these variance components in the exposure measurements influence the validity and precision of the exposure-response relationship.[12] Theoretically, a grouping strategy is most optimal if each exposure category is as homogeneous as possible with regard to the exposure, if the greatest possible contrast exists between the categories, and if there are sufficient measurements per category to make a relatively precise estimate of the average exposure in that category. This will be achieved by minimizing the within group variance and maximizing the between group variance.[13]

It is possible to evaluate various different grouping strategies to determine which is the most optimal, but in the study presented in this thesis the grouping was based on pre-assessment of groups by subjectively estimating the comparability of the tasks and physical load of workers at the workplace. This took place during on-site inspections by the project assistants, when making the video-recordings. Further analyses of the data on the work-related physical factors are needed to assess the effect of other potential grouping strategies on the relationship of flexion and rotation of the trunk and lifting loads with low back pain. Analyses of data from a recent case-control study, which included a comparison of the exposure of job-matched pairs, showed that the level of agreement was good for the biomechanical factors, and especially good for the postural variables.[14] This indicates that there is good agreement for measures of work-related physical factors among pairs of workers doing exactly the same job.

One method of assessing exposure to physical load at individual level in a relatively efficient manner would be the conduct of a nested case-control study within the prospective cohort study. Because video-recordings were made of all workers at the workplace, it would have been possible to analyse the video-recordings at the end of the follow-up period for all workers who reported low back pain at one of the follow-up measurements and for a random selection of the workers who did not report low back pain at any of the follow-up measurements. The use of such a nested case-control design was considered, but decided against because of the amount of time that it would take to assess the video-recordings after completion of the follow-up measurements. In principle, however, this can still be done at a future date.

The method of assessment, based on observations of video-recordings and force measurements at the workplace, has not yet been fully validated. However, a number of pre-tests were performed to test the method. Video-recordings were made, instead of direct observations, because too many observers would have been needed to make real time observations at the workplace, due to the large number of variables that had to be observed. The validity and reliability of the method of assessment was tested for a number of simulated working conditions by comparing the video-recordings with opto-electronic measurements, after which the method was revised on some points. The results of this comparison showed that trunk rotation, in contrast to trunk flexion, could not be reliably assessed by continuous observation of the video-recordings. Therefore, it was decided to use multi-moment observations. Moreover, for trunk flexion the division into categories of the observed angles was adapted. The division into categories that was used, gave the most reliable results. Finally, a pilot study was performed to test the practical feasibility of the entire method, after which more revisions were made. Unfortunately, no further assessment of the accuracy and reliability of the method was made during the data-collection phase of the prospective cohort study.

Assessment of exposure to psychosocial work characteristics

In SMASH, the Job Content Questionnaire (JCQ) was used for the assessment of psychosocial work characteristics.[15] Questionnaire-based, self-reported methods have been used in most studies on psychosocial work characteristics and health. The main dimensions that are assessed with the JCQ are based on the Demand-Control-Support model developed by Karasek and colleagues,[16-18] which is one of the most widely used models in research on psychosocial work characteristics and health. This model was originally developed to evaluate psychosocial risk factors for cardiovascular diseases. The main hypothesis of the model is that the strongest adverse effects on health will occur when jobs are simultaneously high in job demands, low in decision latitude and low in social support.[19]

In the analyses, presented in Chapters 5 and 6, of the relationship of psychosocial work characteristics with self-reported low back pain and sickness absence due to low back pain, Karasek's model was used only as a framework for the factors that were included. No attempt was made to test the interactions as hypothesised by the Demand-Control-Support model. The main reason for not doing so was that only weak associations were found when testing the main effect of demands, control and support. However, additional analyses were subsequently performed to gain some insight into the assumed interaction between demands and control. In these analyses, the variables of quantitative job demands and decision latitude, a combined measure of decision authority and skill discretion, were combined into one variable referred to as job strain. Workers with a score in the highest tertile of quantitative job demands and in the lowest tertile of decision latitude were classified as workers with high job strain. In crude analyses, a borderline statistically significant and moderately increased relative risk (approximately 1.5) of both self-reported low back pain and sickness absence due to low back pain was found for workers with high job strain. No increased risk was found for workers with only high quantitative job demands, or only low decision latitude. However, in multivariable analyses the association with sickness absence due to low back pain completely disappeared, whereas the association with self-reported low back pain decreased slightly, and was no longer statistically significant. These results give some indication of the presence of an interaction effect in relation to self-reported low back pain. However, as in the study of the main effects, the magnitude of the association was low, and the association did not reach statistical significance. The observed association of high job strain with self-reported low back pain was similar to the observed association of high quantitative job demands with self-reported low back pain presented in Chapter 5.

One advantage of the JCQ is that it is probably the most widely accepted standardized questionnaire in research on work stress. Wider use of this questionnaire for the assessment of demands, control and support in studies on risk factors for low back pain would facilitate comparison of the results of different studies with regard to the role of these factors, and should therefore be encouraged. However, because much is still unknown about the role of psychosocial work characteristics, future studies should not be limited to the examination of the major dimensions of the Demands-Control-Support model alone. Other theoretical models have also been proposed to assess the adverse health effects of stress at work. Important examples of these are the effort-reward imbalance model and the Vitamin model.[20,21] It would seem reasonable to include additional components of these models in future studies to make it possible to examine different theoretical concepts of the effects of psychosocial work characteristics.

Assessment of back pain

The main outcome measure used in the present study was self-reported low back pain. Several authors have mentioned the lack of more objective outcome measures for low back pain.[22,23] However, because most cases of back pain are non-specific, it will not be possible to define cases of back pain solely by means of a physical examination based on objective medical criteria.[24] It is therefore suggested that efforts should be made to develop standardized classification criteria that are primarily based on differences in symptom-reporting.[25] Examination of the relationship of work-related factors with more specific and more homogeneous low back pain disease entities may result in the identification of stronger relationships between specific risk factors and certain groups of patients with low back pain. This may provide more clear indications for potentially effective measures in the prevention of low back pain, compared to the relatively weak findings of the present study in relation to low back pain in general.

Statistical analysis

Interrelationship between work-related physical and psychosocial factors
An important aspect of the statistical analysis performed in the prospective cohort study was the adjustment of potential determinants for each other in a multivariable analysis. In the analyses of the relationship of work-related physical factors with low back pain and sickness absence due to low back pain (Chapters 4 and 6), it was decided not to adjust the variables of flexion and rotation of the trunk and lifting for each other, because they appeared to have a very strong interrelationship (correlation coefficients in the region of 0.60 and greater) in the study population. Additional analyses on the relationship of work-related physical factors with self-reported low back pain and sickness absence due to low back pain, in which trunk flexion and lifting were adjusted for each other, showed that the results for trunk flexion were barely influenced, whereas the risk estimates for lifting clearly decreased. This suggests that the assessment of trunk flexion may have been more accurate than the assessment of lifting. However, it does not imply that lifting does not play a role, since these exposures are closely related.

Additional analyses, with a combined measure of trunk flexion and lifting, were also performed. In these analyses the workers were classified as follows:

1. workers who spent 5% or less of the working time with the trunk in a minimum of 30 degrees of flexion and did not lift any load
2. workers who spent more than 5% of the working time with the trunk in a minimum of 30 degrees of flexion, but did not lift any load
3. workers who lifted a load of any weight at least once during a working day, but who spent 5% or less of the working time with the trunk in a minimum of 30 degrees of flexion
4. workers who worked more than 5% of the working time with the trunk in a minimum of 30 degrees of flexion and lifted a load of any weight at least once during a working day.

The first category of workers on this list was used as the reference category in the analyses. The number of workers in the second category was too low, so no effect estimate could be made. In the other categories, no increased risk was found in relation to self-reported low back pain as was expected in view of the results of the study on the main effects of these exposures (Chapter 4). In relation to sickness absence due to low back pain, a clearly higher risk estimate was observed for the fourth category of workers (rate ratio of 2.8) than for the third category of workers (rate ratio of 1.8), which may imply that the effect of lifting is stronger when also working with the trunk in flexion.

In the analyses of the relationship of psychosocial work characteristics with low back pain and sickness absence due to low back pain (Chapters 5 and 6), all psychosocial work characteristics were also adjusted for each other, even though there was a relatively strong relationship between decision authority and skill discretion, and between supervisor support and co-worker support, respectively. These correlations were still below 0.50, and therefore not as high as the correlations between the work-related physical factors. It could be argued, however, that the adjustment of the psychosocial work characteristics for each other may have led to over-adjustment. Therefore, additional analyses were performed, in which the psychosocial work characteristics were adjusted for all variables that were included in the multivariable analyses described in the previous chapters, except for each other. These analyses showed only a difference in results for supervisor and co-worker support. Low supervisor support showed a borderline statistically significant relative risk of 1.6, compared with 1.3 in relation to self-reported low back pain when no adjustment was made for the other psychosocial work characteristics. The magnitude of the relative risk estimate for co-worker support remained at approximately 1.7, but the estimate became slightly more precise. The rate ratio for low supervisor support in relation to sickness absence due to low back pain also remained similar in magnitude and became more precise, whereas the rate ratio for low co-worker support increased from 1.5 to 1.7 and became borderline statistically significant when no adjustment was made for the other psychosocial work characteristics. In conclusion, the small differences in the results of the additional analyses did not provide clear indications of over-adjustment.

As discussed in Chapter 5, the assessment of the influence of adjustment for physical load at work on the effect estimates for the psychosocial work characteristics was complicated, due to the small size of the observed effects for the psychosocial work characteristics. In general, the effect of adjustment for physical load on the effect estimates for the psychosocial work characteristics seemed to be limited. However, in Chapter 5, adjustment for work-related physical factors slightly decreased the magnitude of the association between high quantitative job demands and self-reported low back pain in the subgroup of workers who had been employed in their current job for 5 years or less at baseline. This suggests that part of the crude association was due to an association between high physical load and high quantitative job demands in this subgroup. In Chapter 6, the disappearance of the association between skill discretion and sickness absence due to low back pain, after adjustment for all potential confounders, was also partly caused by the adjustment for work-related physical factors (data not shown). In conclusion, this study found limited evidence that the crude association between certain psychosocial work characteristics (i.e. quantitative job demands and skill discretion) and low back pain is partly based on confounding by physical factors at work (see also the conceptual model in Chapter 1).

In comparison with previous studies, one of the most important features of the prospective cohort study was that the effect of psychosocial work characteristics was adjusted for quantified physical load at work. Additional analyses of the total study population, in which the adjustment of psychosocial work characteristics for physical load at work was based on self-reported measures of physical work load instead of objectively assessed quantified measures, showed that there were hardly any differences in the results. Only the relationship between high quantitative job demands and self-reported low back pain appeared to have decreased more after adjustment for self-reported physical load than after adjustment for quantified physical load. In a recent case-control study, in which adjustment for self-reported physical load at work also appeared to have a relatively large impact on the observed association between job demands and low back pain, the suggestion was made that the demands scale of the JCQ was more a measure of the physical demands than of the psychosocial demands of work in the blue-collar population included in that study.[14] This implies that self-reported measures of physical load at work and psychosocial job demands would, to a certain extent, be the same. Future studies should further investigate the influence of adjustments for physical load at work on the effect of psychosocial work characteristics and the value of quantified and self-reported measures of physical load at work in making these adjustments.

Differences between the statistical analysis of self-reported low back pain and sickness absence due to low back pain

The study population that was used for the analyses of sickness absence due to low back pain (Chapter 6) was different from the population that was used for the analyses of self-reported low back pain (Chapters 4 and 5) in several respects. An important difference is that only those workers with sickness absences of 3 days or longer due to low back pain in the three months prior to the baseline survey were excluded. It was decided not to exclude all workers with self-reported low back pain in the 12 months prior to the baseline because workers with low back pain but with no sickness absence are at risk for sickness absence due to low back pain. However, this difference in the selection of the study population for the analyses of the two outcome measures might explain differences in the results. For that reason, additional analyses of sickness absence due to low back pain were performed in which workers with low back pain in the previous 12 months at baseline were also excluded. This did not change the results substantially. Therefore, it can be concluded that the difference in the findings for work-related physical factors in relation to sickness absence due to low back pain as compared to self-reported low back pain can not be explained by this difference in the selection of the study population.

The choice was made to consider the same set of variables in the analyses, with self-reported low back pain and sickness absence due to low back pain as outcome measures. However, it can be hypothesized that sickness absence due to low back pain is also influenced by other variables that may confound the relationship between work-related factors and sickness absence due to low back pain. This is also an important point to consider in the light of the finding in the present study that physical load at work was more strongly related to sickness absence due to low back pain, and especially to sickness absence with a relatively longer duration, than to self-reported low back pain. In the section of this chapter in which the findings of the study were summarized, the suggestion was already made that the relatively strong relationship between physical load at work and sickness absence due to low back pain might indicate that high physical load at work is a real barrier in returning to work. However, workers with a high physical load at work tend to have a relatively low socio-economic status. This group may also have other characteristics that might explain the increased sickness absence.

Supplementary analyses were performed to investigate the relationship between trunk flexion and lifting and sickness absence due to low back pain, with additional adjustment for level of education, as a rough measure of socio-economic status. One limitation of these analyses is that adjustment for socio-economic status probably introduces over-adjustment, because the type of job (occupational class) is one of the main indicators of socio-economic status.[26] However, it provides some insight into potential confounding by unmeasured characteristics that are also related to a low socio-economic status. The analyses showed lower effect estimates, especially for lifting. With regard to trunk flexion, a statistically significant increased relative risk remained, and it was higher than the risk found in relation to self-reported low back pain. With regard to lifting, the main decrease in the effect estimates was in the highest exposure categories, in which the relative risk reached the same level as the risk found in relation to self-reported low back pain.

Another potential explanation for the stronger relationship of physical load at work with sickness absence due to low back pain, could be that variables at the company level, such as return to work policies, play a role. In order to determine this, a multi-level analysis could be performed, in which different hierarchical levels in the sample (in the present study, company and individual level) can be taken into account and the influence of variables measured at different levels can be examined simultaneously.[27]

Statistical power

Of the original cohort of workers at baseline, only 861 workers were included in the analyses with self-reported low back pain as outcome measure (Chapters 4 and 5). Only 732 workers were included in the analyses with sickness absence due to low back pain as outcome measure (Chapter 6). Moreover, in most cases an increased risk of low back pain was only found at high levels of exposure to the work-related risk factors studied. For most work-related physical and psychosocial risk factors studied, less than 10% of the workers fell in the highest exposure category. As a result of the relatively small sample size and the small percentage of workers subjected to exposure, the statistical power of this study to detect weak associations (relative risk in the order of 1.5) was limited.

Choice of statistical methods

In the analysis of data on self-reported low back pain from the prospective cohort study, it was decided to apply Cox regression, with a constant risk period for all subjects, instead of logistic regression. This decision was made because it has been shown that the application of logistic regression for health outcomes with a relatively high incidence results in an over-estimation of the magnitude of the associations.[28-30] However, in Chapter 7, in which a comparison was made between conventional regression analysis and GEE analysis, logistic regression was applied. The fact that the adapted version of Cox regression cannot be applied within a GEE analysis could be used as an argument for this choice. However, the proc genmod procedure in the statistical package SAS does include the possibility to analyse a log-binomial model, which is an alternative method for the estimation of relative risks.[29,30] It also has an advantage over Cox regression, in that it produces correct estimates of the confidence intervals of the parameter estimates. Cox regression produces estimates of the confidence intervals which are too wide.[29,30] However, the use of this model resulted in some convergence problems that did not occur when logistic regression was applied. Similar problems with the use of the log-binomial model have been encountered by other investigators.[29]

In the analysis of the influence of work-related factors on sickness absence due to low back pain (Chapter 6), sickness absence was operationalized in terms of the frequency of sickness absences due to low back pain, and therefore Poisson regression was applied. The main reason for this choice was that the two most important previous studies on risk factors for company-registered sickness absence due to low back pain used the same approach.[31,32] Another possibility would have been to analyse the total number of days of sickness absence, or to use the time to the first episode of sickness absence due to low back pain as outcome measure. However, neither of these outcome measures take into account the recurrent nature of sickness absences due to low back pain. A disadvantage of using the total number of days of sickness absence as outcome measure is that there is no differentiation between workers with frequent short absences and workers with long absences. If the time to the first episode of sickness absence is studied, only part of the data on sickness absence that have been collected can be used.

Final conclusions

The final conclusions of this thesis are that:

- Flexion and rotation of the trunk and lifting at work are risk factors for low back pain.
- With regard to trunk flexion, a clear exposure-response relationship with low back pain was found.
- Low job satisfaction is a risk factor for the occurrence of low back pain. Low social support also seems to be a risk factor for low back pain, but it is not possible to draw definite conclusions on the role of this psychosocial work characteristic.
- No clear support was found for the hypothesis that the psychological strain variables of job satisfaction, emotional exhaustion and sleeping difficulties play an intermediate role in the relationship between the psychosocial work characteristics studied in this thesis and low back pain. However, it is not possible to draw strong conclusions on this subject.
- There is more evidence for a relationship between the work-related physical factors studied in this thesis and low back pain than for a relationship between the psychosocial work characteristics studied in this thesis and low back pain.
- Flexion and rotation of the trunk and lifting at work are more strongly related to sickness absence due to low back pain than to self-reported low back pain.

Implications for prevention

On the basis of the results of this thesis, the following recommendations can be made:

- Reduction of trunk flexion, trunk rotation and lifting at work should be an objective. In the prevention of low back pain in general, specific attention should be paid to high levels of exposure to physical load at work. In the prevention of sickness absence due to low back pain, lower levels of exposure are also important.
- Improvement of the psychosocial work environment, focused on an increase in social support may contribute to the prevention of low back pain and sickness absence due to low back pain.
- Improvement of job satisfaction may play a role in the prevention of low back pain. However, further studies are needed to obtain more insight into the factors that influence job satisfaction. Changes in these factors may lead to improvement of job satisfaction, and consequently help to prevent low back pain.

Efforts should be made to stimulate the implementation of these recommendations. In this light, it is important to make links with two developments that are currently taking place in the field of occupational health. Firstly, the development of guidelines for the management of workers with low back pain is receiving increasingly more attention. Dutch guidelines for the management of workers with low back pain by occupational physicians have already been issued.[33] However, the development of Dutch guidelines that also include recommendations for the prevention of back pain, similar to the recently issued British occupational health guidelines for the management of low back pain at work, should also be considered.[34] Secondly, in the Netherlands more and more agreements between the government and representatives of social bodies (employer and employee organizations) are being made in so-called covenants on health and safety at work. The objective of these covenants is to set common quantified targets for the improvement of working conditions and occupational health at sector level.[35] In Great Britain similar developments are taking place.[36]

Recommendations for future research

With regard to recommendations for future research, a distinction can be made between recommendations for additional research based on data from SMASH and recommendations for future studies in general. Since a large amount of data was collected within the framework of SMASH, it was not possible to include all these data in the analyses for this thesis. In additional research, the following topics deserve primary attention:

- Evaluation of the accuracy of the grouping strategy that was used in the present study for the assessment of work-related physical factors based on video-recordings, and investigation of possible alternative grouping strategies.
- Determination of the influence of cumulative physical load on the development of low back pain, based on analyses of the data on historical physical load collected at baseline.

- Investigation of the relationship of work-related factors with more specific low back pain disease entities that can be distinguished on the basis of the reported duration and frequency of episodes, reported presence of radiation, reported pain intensity, reported low back pain-related disability and the results of the physical examination that was a component of the third follow-up measurement.

The most important recommendations that can be made for future studies in general are the following:

- Efforts should be made to include standardized measures of work-related factors to make it possible to calculate effect measures that reflect the risk of equivalent levels of contrast in exposure. This will make it possible to conduct a meta-analysis that can also provide more insight into potential sources of bias.
- Additional efforts should be made to study the role of psychosocial work characteristics. In these studies, attention should be paid to different theoretic models of stress. Moreover, longitudinal studies involving repeated measurements with relatively short time-intervals should be performed to obtain more insight into the time-lag in the effect of psychosocial work characteristics.
- In order to clarify the finding that the relationship between high physical load at work and sickness absence due to low back pain is stronger than the relationship between high physical load at work and self-reported low back pain, it would be worthwhile to obtain more insight into the nature of the relationship between physical load at work and sickness absence due to low back pain. This also implies that, in addition to studying risk factors for low back pain, efforts should also be made to obtain more insight into prognostic factors for low back pain.

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Summary

This thesis investigates work-related risk factors for low back pain. Low back pain is one of the most common work-related health problems and, due to the considerable impact it has on sickness absence and work disability, it is also a heavy financial burden on society. Low back pain is assumed to be of multifactorial origin. Individual factors, as well as work-related and nonwork-related physical and psychosocial factors, may play a role in its development. Originally, the focus of most occupational research on low back pain was directed towards physical factors. Recently, however, the study of psychosocial work characteristics (such as demands, control, support) has also become an important aspect of epidemiological studies on low back pain in occupational settings.

In this thesis, attention is paid to the following research questions:

- Which work-related physical factors are risk factors for the occurrence of low back pain?
- Is there an exposure-response relationship between the work-related physical factors and low back pain?
- Which psychosocial work characteristics are risk factors for the occurrence of low back pain?
- Do psychological strain variables play an intermediate role in the relationship between psychosocial work characteristics and self-reported low back pain?
- What is the relative importance of work-related physical factors and psychosocial work characteristics as risk factors for low back pain?
- Is there a difference in the relationship of work-related factors with sickness absence due to low back pain, on the one hand, and with self-reported low back pain on the other hand?

In **Chapters 2 and 3** of this thesis the available literature concerning work-related risk factors for back pain is systematically reviewed. A computerized bibliographical search was made in several databases for studies with a cohort or case-control design. A rating system consisting of three levels of evidence was used to assess the strength of the evidence for various factors, based on the methodological quality of the included studies and the consistency of the findings. The methodological quality of the studies was assessed on the basis of a standardized set of criteria.

Chapter 2 describes the review concerning physical factors. Twenty-eight cohort and three case-control studies were included in this review. It was concluded that there is strong evidence that manual materials handling, bending and twisting, and whole-body vibration are risk factors for back pain. Moderate evidence was found that patient handling and heavy physical work are risk factors for low back pain. No evidence (labelled as insufficient evidence in Chapter 3) was found for an effect of standing or walking, because of contradictory findings, and no evidence was found for an effect of sitting, because there was

only one study available.

Chapter 3 describes the review concerning psychosocial factors. Eleven cohort and two case-control studies were included in this review. Strong evidence was found for low social support in the workplace and low job satisfaction as risk factors for back pain. Insufficient evidence was found for an effect of a high work pace and high qualitative jobs demands, because of contradictory findings, or for an effect of a low job content and low job control, because there was only one study available. However, since the results of the review appeared to be sensitive to slight changes in the methods used, the final conclusion was that there seems to be evidence for an effect of psychosocial work characteristics, but that evidence for specific factors has not yet been established.

The combined results of the systematic reviews described in Chapters 2 and 3 indicate that the body of evidence supporting the role of physical load factors as risk factors for back pain is somewhat more consistent, and thus stronger, than that for psychosocial factors.

Chapters 4 to 7 present results from analyses of data from the Study on Musculoskeletal disorders, Absenteeism, Stress, and Health (SMASH). The objective of this three-year prospective cohort study was to identify risk factors for musculoskeletal symptoms. The study population consisted of approximately 1,750 workers from 34 companies, which were located throughout the Netherlands. The companies were recruited in co-operation with Occupational Health Services. A prerequisite for participating companies was that no major reorganizations were planned for the next three years and that the annual turnover rate of the work-force was lower than 15%. Furthermore, the companies were asked to select workers who had been employed in their current job for at least one year and who were working for a minimum of 20 hours per week. Workers in blue-collar jobs, as well as workers in white-collar jobs and caring professions, were included in the study.

The baseline measurements of SMASH were conducted between March 1994 and March 1995, and consisted of three aspects: a self-administered questionnaire, assessment of physical load at the workplace by means of video-recordings and force measurements, and assessment of the functional capacity of the workers during a physical examination. The questionnaire included questions on individual factors, physical load during work and leisure time, psychosocial work characteristics, stress symptoms, and the occurrence of low back pain. Aspects of physical load at work were assessed by means of the Loquest questionnaire. Psychosocial work characteristics were measured by means of a Dutch version of Karasek's Job Content Questionnaire. The assessment of the occurrence of low back pain was based on an adaptation of the Nordic questionnaire. A case of low back pain was defined if a worker reported regular or prolonged low back pain in the previous 12 months.

For the quantitative assessment of physical load at the workplace, four video-recordings of all workers were made randomly during the course of one day. The duration of each video-recording was 10-14 minutes, depending on the variability of the worker's tasks. The project assistants who made the video-recordings classified all workers into groups with similar tasks and a similar physical load. Within each group, analyses of the posture, movement, and force exertion of one in four workers were made by means of observations from the video-recordings. The mean values for various physical load factors of the workers in each group for whom the video-recordings were analysed were assigned to all workers in the same group.

After the baseline survey of SMASH there was a follow-up period of three years. After each year of the follow-up period, the workers received a self-administered postal questionnaire, in which the majority of the questions from the baseline questionnaire were repeated. In addition, changes in the workplace were assessed in this questionnaire. From 1994 until the end of 1997, the companies provided data on sickness absences of participating workers.

Chapter 4 presents results of SMASH regarding the relationship between work-related physical factors at baseline and self-reported low back pain during the three-year follow-up period. The study population of the analyses consisted of 861 workers with no low back pain at baseline and complete data on the occurrence of low back pain during the three-year follow-up period. The analyses focused on quantified measures of flexion and rotation of the trunk and lifting at work. Trunk flexion led to an increased risk of low back pain when the trunk was in a minimum of 60 degrees of flexion for more than 5% of the working time (RR [relative risk] 1.5, 95% CI [confidence interval] 1.0-2.1). Lifting 25 kilograms or more increased the risk of low back pain when this occurred more than 15 times per working day (RR 1.6, 95% CI 1.1-2.3). In the initial analyses, the relationship of trunk rotation with low back pain was not so clear. However, in additional analyses, which included only those workers with no, or only minor changes in their work during the follow-up period, all relationships became somewhat stronger, and in the group of workers with the trunk in rotation for more than 10% of the working time, there was a definite increase in the risk of low back pain (RR 1.6, 95% CI 1.1-2.3). The main conclusion was that flexion and rotation of the trunk and lifting at work are moderate risk factors for low back pain, especially at higher levels of exposure. Extreme flexion and lifting loads of 25 kilograms or more seem to be especially important.

Chapter 5 deals with the relationship between psychosocial work characteristics at baseline and self-reported low back pain during the three-year follow-up period among those workers with no low back pain at the baseline measurement of the study. In addition, to obtain more insight into the pathway of the relationship between psychosocial work characteristics and low back pain, the potential intermediate role of psychological strain variables is also investigated in this chapter. After adjustment for individual factors and quantified physical load at work, nonsignificant relative risks ranging from 1.3 to 1.6 were observed for high quantitative job demands, high conflicting demands, low supervisor support and low co-worker support. No relationship was found between low decision authority or low skill discretion and self-reported low back pain. In the present study, only moderate, and not statistically significant associations were found between low supervisor and low co-worker support and the occurrence of low back pain. However, based on a comparison with the findings of previous studies, it was concluded that it seems likely that low social support is, indeed, a risk factor for the occurrence of low back pain. It was also concluded that there are some indications of a relationship between high quantitative job demands or high conflicting demands and low back pain, based on the results of the present study, but these relationships have not been consistently observed in other studies.

The results of analyses with additional adjustment for the psychological strain variables of job satisfaction, emotional exhaustion and sleeping difficulties did not support the hypothesis that these variables play an intermediate role in the relationship between conflicting demands, supervisor and co-worker support and low back pain. Only for the relationship between high quantitative job demands and low back pain, were indications found that the general opinion about the job and emotional exhaustion are intermediates. The small magnitude of the observed effects for the psychosocial work characteristics, however, complicated the examination of the potential intermediate role of psychological strain variables. As this is also the first study in which this hypothesis has been examined, it was not possible to draw strong conclusions on this subject. However, the psychological strain variables themselves were independent risk factors for the occurrence of low back pain.

Chapter 6 reports on the influence of work-related physical and psychosocial factors at baseline on company-registered sickness absence due to low back pain during the follow-up period. Twenty-one of the 34 participating companies provided adequate data on sickness absence. The study population of the analyses consisted of 732 workers from these companies with no sickness absence of 3 days or longer due to low back pain in the three months prior to the baseline survey and complete data on the reasons for absences during the follow-up period. The main measure of sickness absence used in the analyses was the rate of sickness absences of 3 days or longer due to low back pain. After adjustment of the work-related physical and psychosocial factors for each other and for other potential determinants, statistically significant rate ratios ranging from 2.0 to 3.2 were found for quantified measures of trunk flexion, trunk rotation and lifting and for low job satisfaction, operationalized in terms of general opinion about the job. An exposure-response relationship was found for trunk flexion, but not for trunk rotation or lifting. Statistically nonsignificant rate ratios of approximately 1.4 were observed for low supervisor support and low co-worker support. Quantitative job demands, conflicting demands, decision authority and skill discretion showed no relationship with sickness absence due to low back pain. On the basis of these results, it was concluded that flexion and rotation of the trunk, lifting and low job satisfaction are risk factors for sickness absence due to low back pain. Moreover, it was concluded that there are also some indications of a relationship between low social support, either from supervisor or co-worker, and sickness absence due to low back pain.

Comparison of the results of Chapter 6 with the results of Chapters 4 and 5 shows that, in particular with regard to the work-related physical factors, there appears to be a difference in the relationship with sickness absence due to low back pain, on the one hand, and with self-reported low back pain on the other hand. Flexion and rotation of the trunk and lifting at work are more strongly related to sickness absence due to low back pain than to self-reported low back pain. Moreover, the risk starts to increase at lower levels of exposure.

In **Chapter 7**, the results of two different analytic methods for the analysis of the data from SMASH are compared. The study population of these analyses consisted of 1,192 workers with no low back pain at baseline. In this chapter, self-reported measures of physical load at work were used instead of the quantified measures that were used in Chapters 4, 5 and 6, because only the measurement of self-reported physical load at work was repeated at the annual follow-up measurements. In a conventional logistic regression model, self-reported physical and psychosocial risk factors at baseline were related to the cumulative incidence of low back pain during the three-year follow-up period. In a generalized estimating equations (GEE) logistic model, self-reported repeated measurements of the physical and psychosocial risk factors were related to low back pain reported at one measurement point later. The results showed that there are differences between the two analytical methods in both the magnitude and the precision of the observed odds ratios. The conventional regression model showed a statistically significant effect of flexion and/or rotation of the upper part of the body (OR [odds ratio] 1.8, 95% CI 1.2-3.0), but not of moving heavy loads (OR 1.4, 95% CI 0.7-3.1). The GEE model showed a statistically significant effect of both flexion and/or rotation of the upper part of the body (OR 2.2, 95% CI 1.5-3.2) and moving heavy loads (OR 1.6, 95% CI 1.0-2.6). With both methods no statistically significant associations with low back pain were found for the psychosocial work characteristics, but the GEE model showed weaker odds ratios for these variables than the conventional regression model. The analysis with the GEE method of a model that only took into account the repeated measurements of low back pain provided insight into the causes of the differences between the two analytic methods. Taking into account the time-varying nature of both the outcome and the exposure appeared to have an influence.

Chapter 8 contains the general discussion, in which the findings are summarized in the context of the main research questions. Attention is also paid to some general methodological issues concerning the systematic reviews and the prospective cohort study. The discussion of the systematic review methodology deals mainly with the choice of criteria for the selection of studies, the methodological quality assessment and summarizing the evidence. Central issues in the discussion of the methodology of the prospective cohort study are the selection of the study population, the assessment of exposure to physical load at work and psychosocial work characteristics, the assessment of back pain, the interrelationship between work-related physical and psychosocial factors, the statistical power and the choice of statistical methods.

The final conclusions of this thesis are that:

- Flexion and rotation of the trunk and lifting at work are risk factors for low back pain. The systematic review also provided strong evidence that whole-body vibration is a risk factor for low back pain, and moderate evidence that patient handling and heavy physical work are risk factors for low back pain.

- With regard to trunk flexion, a clear exposure-response relationship with low back pain was found.
- Low job satisfaction is a risk factor for the occurrence of low back pain. Low social support also seems to be a risk factor for low back pain, but it is not possible to draw definite conclusions on the role of this psychosocial work characteristic.
- No clear support was found for the hypothesis that the psychological strain variables of job satisfaction, emotional exhaustion and sleeping difficulties play an intermediate role in the relationship between the psychosocial work characteristics studied in this thesis and low back pain. However, it is not possible to draw strong conclusions on this subject.
- There is more evidence for a relationship between the work-related physical factors studied in this thesis and low back pain than for a relationship between the psychosocial work characteristics studied in this thesis and low back pain.
- Flexion and rotation of the trunk and lifting at work are more strongly related to sickness absence due to low back pain than to self-reported low back pain.

At the end of Chapter 8, some implications for the prevention of low back pain, and recommendations for future research, based on the conclusions and the methodological discussion, are presented. Implications for the prevention of low back pain include the reduction of trunk flexion, trunk rotation and lifting at work and improvement of the psychosocial work environment, with a focus on an increase in social support and job satisfaction. An important recommendation for future studies on work-related factors and low back pain, in general, is that these studies should all include the same standardized measures of work-related factors. Moreover, in addition to studying work-related factors as risk factors for low back pain, the role of work-related factors in the prognosis of low back pain should be studied more extensively.

Samenvatting

Dit proefschrift gaat over werkgerelateerde risicofactoren voor lage rugklachten. Lage rugklachten zijn één van de meest voorkomende werkgerelateerde gezondheidsproblemen. Vanwege de impact van lage rugklachten op ziekteverzuim en arbeidsongeschiktheid, vormen lage rugklachten ook een aanzienlijke financiële belasting voor de maatschappij. Verondersteld wordt dat lage rugklachten veroorzaakt worden door een combinatie van verschillende factoren. Zowel individuele factoren als werkgerelateerde en niet werkgerelateerde fysieke en psychosociale factoren kunnen een rol spelen in de ontwikkeling van lage rugklachten. Aanvankelijk was het meeste onderzoek naar werkgerelateerde risicofactoren voor lage rugklachten gericht op lichamelijke belasting op het werk. Recent is er echter ook meer aandacht gekomen voor het bestuderen van de rol van psychosociale werkkenmerken (zoals taakeisen, autonomie en sociale steun).

In dit proefschrift staan de volgende onderzoeksvragen centraal:

- Welke werkgerelateerde fysieke factoren zijn risicofactoren voor het optreden van lage rugklachten?
- Is er een blootstellings-responsrelatie tussen de werkgerelateerde fysieke factoren en lage rugklachten?
- Welke psychosociale werkkenmerken zijn risicofactoren voor het optreden van lage rugklachten?
- Spelen arbeidstevredenheid, emotionele uitputting en slaapstoornissen een intermediaire rol in de relatie tussen psychosociale werkkenmerken en zelfgerapporteerde lage rugklachten?
- Wat is het relatieve belang van werkgerelateerde fysieke factoren en psychosociale werkkenmerken als risicofactoren voor lage rugklachten?
- Is er een verschil in de relatie van werkgerelateerde factoren met ziekteverzuim vanwege lage rugklachten aan de ene kant en met zelfgerapporteerde lage rugklachten aan de andere kant?

In de **hoofdstukken 2 en 3** van dit proefschrift wordt de beschikbare literatuur over werkgerelateerde risicofactoren voor rugklachten systematisch samengevat. Door middel van het doorzoeken van verschillende bibliografische databases werden de beschikbare studies geïdentificeerd. Alleen cohort en patiëntcontrole onderzoeken werden geselecteerd. De sterkte van het bewijs voor een relatie tussen verschillende fysieke en psychosociale factoren en rugklachten werd vastgesteld aan de hand van vooraf opgestelde beslisregels die gebaseerd waren op de methodologische kwaliteit van de beschikbare studies en de consistentie van de bevindingen. De methodologische kwaliteit van de studies werd bepaald aan de hand van een gestandaardiseerde criterialijst.

Hoofdstuk 2 beschrijft de systematische review over lichamelijke belasting.

Achtentwintig cohort en drie patiëntcontrole onderzoeken werden opgenomen in deze review. Er werd sterk bewijs gevonden dat het tillen en dragen van lasten, het buigen en draaien van de rug en blootstelling aan lichaamstrillingen risicofactoren zijn voor het optreden van rugklachten. Matig bewijs werd gevonden voor het tillen en verplaatsen van patiënten en zwaar lichamelijk werk als risicofactor voor het optreden van rugklachten. Er werd geen bewijs (gedefinieerd als onvoldoende bewijs in hoofdstuk 3) gevonden voor langdurig staan en lopen, omdat de bevindingen tegenstrijdig waren en er werd geen bewijs gevonden voor langdurig zitten, omdat er slechts één studie beschikbaar was.

Hoofdstuk 3 beschrijft de systematische review over psychosociale factoren. Elf cohort en twee patiëntcontrole onderzoeken werden in deze review opgenomen. Er werd sterk bewijs gevonden dat weinig sociale steun in het werk en een lage arbeidstevredenheid risicofactoren zijn voor het optreden van lage rugklachten. Er werd onvoldoende bewijs gevonden voor een hoog werktempo en hoge kwalitatieve taakeisen, omdat de bevindingen tegenstrijdig waren. Voor weinig vaardigheidsmogelijkheden (mogelijkheden om vaardigheden te ontwikkelen en toe te passen) en weinig autonomie in het werk werd ook onvoldoende bewijs gevonden, omdat er slechts één studie beschikbaar was. Echter, omdat de resultaten van de review gevoelig bleken te zijn voor kleine veranderingen in de gebruikte methoden was de uiteindelijke conclusie dat er wel bewijs lijkt te zijn dat psychosociale werkkenmerken een rol spelen bij het optreden van lage rugklachten, maar dat het bewijs voor specifieke factoren nog niet sluitend is.

De gecombineerde resultaten van de systematische reviews in de hoofdstukken 2 en 3 laten zien dat het beschikbare bewijs voor de rol van fysieke factoren als risicofactoren voor rugklachten consistenter en dus sterker is dan dat voor psychosociale factoren.

In de **hoofdstukken 4 tot en met 7** worden resultaten gepresenteerd van analyses van de gegevens van de 'Study on Musculoskeletal disorders, Absenteeism, Stress, and Health (SMASH)'. Het doel van dit driejarige prospectieve cohort onderzoek was het identificeren van risicofactoren voor klachten aan het bewegingsapparaat. De onderzoekspopulatie bestond uit ongeveer 1750 werknemers uit 34 bedrijven in Nederland. De bedrijven werden gerekruteerd in samenwerking met Arbo-diensten. Voorwaarde voor deelname van bedrijven was dat er geen belangrijke reorganisaties gepland waren in de nabije toekomst (3 jaar) en dat het jaarlijkse personeelsverloop lager was dan 15 procent. Daarnaast werd de bedrijven gevraagd om werknemers te selecteren die minimaal een jaar in hun huidige baan werkzaam waren en die minimaal 20 uur per week werkten. De onderzoekspopulatie bestond uit fabrieksarbeiders, kantoorpersoneel en werknemers in verzorgende beroepen.

De beginmeting van SMASH werd uitgevoerd tussen maart 1994 en maart 1995 en bestond uit drie onderdelen: een vragenlijst, bepaling van de lichamelijke belasting op het werk door middel van video-opnames en krachtmetingen, en bepaling van de lichamelijke belastbaarheid van werknemers tijdens een lichamelijk onderzoek. De vragenlijst bevatte vragen over individuele factoren, lichamelijke belasting op het werk en in de vrije tijd, psychosociale werkkenmerken, het voorkomen van stress symptomen en het optreden van lage rugklachten. De lichamelijke belasting op het werk werd nagevraagd met behulp van de Loquest vragenlijst. Psychosociale werkkenmerken werden gemeten met een Nederlandse versie van de 'Job Content Questionnaire' van Karasek. Voor het vaststellen van het optreden van lage rugklachten werd een aangepaste versie van de 'Nordic questionnaire' gebruikt. Een geval van lage rugklachten werd gedefinieerd als een werknemer die regelmatige of langdurige lage rugklachten rapporteerde in de afgelopen 12 maanden.

Voor de kwantitatieve bepaling van de lichamelijke belasting op het werk werden van iedere werknemer willekeurig verdeeld over een werkdag vier video-opnames gemaakt. De duur van iedere video-opname was 10 tot 14 minuten, afhankelijk van de variatie in de taken van de werknemer. De projectmedewerkers die de video-opnames maakten, deelden alle werknemers in in groepen met vergelijkbare taken een vergelijkbare lichamelijke belasting. Binnen ieder groep werden aan de hand van de video-opnames observaties gemaakt van de houding, beweging en krachtsuitoefening van één op de vier werknemers. De gemiddelde waarden voor verschillende fysieke factoren van de werknemers in een groep waarvan de video-opnames werden geanalyseerd, werden toegekend aan alle werknemers in deze groep.

Na de beginmeting werden de werknemers drie jaar gevolgd. Jaarlijks ontvingen de werknemers via de post een vragenlijst waarin het merendeel van de vragen uit de vragenlijst van de beginmeting herhaald werd. Daarnaast werden ook veranderingen op de werkplek nagevraagd. Van 1994 tot en met 1997 verstrekten de bedrijven gegevens over het ziekteverzuim van de deelnemende werknemers.

In **hoofdstuk 4** worden de resultaten van SMASH gepresenteerd die betrekking hebben op de relatie tussen lichamelijke belasting op het werk gemeten bij de beginmeting en zelfgerapporteerde lage rugklachten gedurende de driejarige follow-up periode. De onderzoekspopulatie voor deze analyses bestond uit 861 werknemers die klachtenvrij waren bij de beginmeting en volledige gegevens hadden over het optreden van rugklachten gedurende de follow-up periode. De analyses waren gericht op kwantitatieve maten van buigen en draaien van de rug en tillen op het werk. Buigen van de rug leidde tot een verhoogde kans op lage rugklachten wanneer de rug meer dan 5 procent van de werktijd minimaal 60 graden gebogen was (RR [relatief risico] 1,5, 95% BI [betrouwbaarheidsinterval] 1,0-2,1). Het tillen van 25 kilo of meer leidde tot een verhoogde kans op lage rugklachten wanneer dit meer dan 15 keer per dag gebeurde (RR 1,6, 95% BI 1,1-2,3). In de eerste analyses was de relatie tussen het draaien van de rug en lage rugklachten niet zo duidelijk, maar in aanvullende analyses waarin alleen werknemers werden meegenomen waarbij gedurende de follow-up geen of slechts kleine veranderingen in het werk waren opgetreden, werden alle relaties iets sterker en was er sprake van een duidelijk verhoogde kans op lage rugklachten in de groep werknemers die meer dan 10 procent van de werktijd met een gedraaide rug werkten (RR 1,6, 95% BI 1,1-2,3). De belangrijkste conclusie was dat buigen en draaien van de rug en tillen op het werk gematigde risicofactoren zijn voor lage rugklachten, met name bij hoge niveaus van blootstelling. Sterk buigen van de rug en het tillen van lasten van 25 kilo of meer lijken met name van belang te zijn.

Hoofdstuk 5 gaat over de relatie tussen psychosociale werkkenmerken gemeten bij de beginmeting en zelfgerapporteerde lage rugklachten gedurende de driejarige follow-up periode onder de werknemers die klachtenvrij waren bij de beginmeting. Om inzicht te krijgen in het mechanisme van de relatie tussen psychosociale werkkenmerken en lage rugklachten wordt in dit hoofdstuk ook gekeken naar de mogelijke intermediaire rol van arbeidstevredenheid, emotionele uitputting en slaapstoornissen. Na correctie voor individuele factoren en de gemeten lichamelijk belasting op het werk, werden niet-significante relatieve risico's variërend van 1,3 tot 1,6 gevonden voor hoge kwantitatieve taakeisen, tegenstrijdige taakeisen, weinig ondersteuning van de leidinggevende en weinig ondersteuning van collega's op het werk. De mate van autonomie en de vaardigheidsmogelijkheden in het werk lieten geen relatie zien met het optreden van lage rugklachten. Hoewel slechts zwakke en niet statistisch significante verbanden werden gevonden tussen weinig ondersteuning van leidinggevende en collega's en het optreden van lage rugklachten, werd op basis van een vergelijking met bevindingen van eerdere studies geconcludeerd dat het waarschijnlijk is dat weinig sociale steun inderdaad een risicofactor is voor het optreden van lage rugklachten. Er werd ook geconcludeerd dat er aanwijzingen zijn voor een relatie tussen hoge kwantitatieve taakeisen en tegenstrijdige taakeisen en het optreden van lage rugklachten. Deze relaties werden echter niet consistent gevonden in andere studies.

De resultaten van analyses met aanvullende correctie voor arbeidstevredenheid, emotionele uitputting en slaapstoornissen suggereren dat deze variabelen geen intermediaire rol spelen in de relatie van tegenstrijdige taakeisen, ondersteuning van leidinggevende en ondersteuning van collega's met lage rugklachten. Alleen voor de relatie tussen hoge kwantitatieve taakeisen en lage rugklachten werden aanwijzingen gevonden dat de algemene opinie over het werk en emotionele uitputting intermediaire variabelen zijn. Het feit dat slechts zwakke verbanden werden gevonden tussen de psychosociale werkkenmerken en lage rugklachten compliceerde het beoordelen van de mogelijk intermediaire rol van de genoemde variabelen. Mede doordat dit de eerste studie is waarin deze hypothese onderzocht is, was het niet mogelijk om sterke conclusies te trekken ten aanzien van dit onderwerp. Echter, de variabelen arbeidstevredenheid, emotionele uitputting en slaapstoornissen zelf zijn onafhankelijke risicofactoren gebleken voor het optreden van lage rugklachten.

Hoofdstuk 6 gaat over de invloed van werkgerelateerde fysieke en psychosociale factoren gemeten bij de beginmeting op geregistreerd ziekteverzuim vanwege lage rugklachten gedurende de follow-up periode. Eenentwintig van de 34 deelnemende bedrijven verstrekten bruikbare gegevens over het ziekteverzuim. De onderzoekspopulatie voor de analyses bestond uit 732 werknemers zonder ziekteverzuim van drie of meer dagen vanwege lage rugklachten in de drie maanden voorafgaand aan de beginmeting en met volledige gegevens over de redenen van verzuim voor de follow-up periode. De belangrijkste maat voor ziekteverzuim die gebruikt werd in de analyses was de frequentie van ziekteverzuim van drie of meer dagen vanwege lage rugklachten gedurende de follow-up periode. Na correctie van de werkgerelateerde fysieke en psychosociale factoren voor elkaar en voor andere mogelijke determinanten werden statistisch significante rate ratio's variërend van 2,0 tot 3,2 gevonden voor kwantitatieve maten van buigen en draaien van de rug en tillen op het werk en voor een lage arbeidstevredenheid (algemene opinie over het werk). Een blootstellings-responsrelatie werd gevonden voor buigen van de rug, maar niet voor draaien van de rug en voor tillen. Niet statistisch significantie rate ratio's van ongeveer 1,4 werden gevonden voor weinig ondersteuning van de leidinggevende en voor weinig ondersteuning van collega's. Kwantitatieve taakeisen, tegenstrijdige taakeisen, autonomie en vaardigheidsmogelijkheden lieten geen relatie zien met ziekteverzuim vanwege lage rugklachten. Op basis van deze resultaten werd geconcludeerd dat buigen en draaien van de rug, tillen en een lage arbeidstevredenheid risicofactoren zijn voor ziekteverzuim vanwege lage rugklachten. Daarnaast werd geconcludeerd dat er ook aanwijzigen zijn voor een relatie tussen weinig ondersteuning, van leidinggevende en collega's, en ziekteverzuim vanwege lage rugklachten.

Vergelijking van de resultaten in hoofdstuk 6 met de resultaten in de hoofdstukken 4 en 5 laat zien dat er met name voor lichamelijke belasting op het werk een verschil lijkt te zijn in de relatie met ziekteverzuim vanwege lage rugklachten aan de ene kant en met zelfgerapporteerde lage rugklachten aan de andere kant. Buigen en draaien van de rug en tillen zijn sterker gerelateerd aan ziekteverzuim vanwege lage rugklachten dan aan zelfgerapporteerde lage rugklachten. Bovendien begint de kans op ziekteverzuim vanwege lage rugklachten al toe te nemen bij lagere niveaus van blootstelling.

In **hoofdstuk 7** worden de resultaten van twee verschillende methoden voor de analyse van de gegevens van SMASH vergeleken. De onderzoekspopulatie voor deze analyses bestond uit 1192 werknemers die klachtenvrij waren bij de beginmeting. In dit hoofdstuk werden zelfgerapporteerde maten van lichamelijke belasting op het werk gebruikt in plaats van de gemeten belasting die gebruikt werd in de hoofdstukken 4, 5 en 6, omdat alleen de zelfgerapporteerde lichamelijke belasting ook bepaald werd bij de jaarlijkse vervolgmetingen. In een conventioneel logistisch regressiemodel werden gegevens over werkgerelateerde fysieke en psychosociale factoren van de beginmeting gerelateerd aan de cumulatieve incidentie van lage rugklachten gedurende de follow-up periode van drie jaar. In een generalized estimating equations (GEE) logistisch regressiemodel werden herhaalde metingen van de werkgerelateerde fysieke en psychosociale factoren gerelateerd aan lage rugklachten die bij de meting één jaar daarna gerapporteerd werden. De resultaten lieten zien dat er verschillen zijn tussen de twee analytische methoden in zowel de hoogte als de precisie van de gevonden odds ratio's. Het conventionele regressiemodel liet een statistisch significant effect zien voor buigen en/of draaien van het bovenlichaam (OR [odds ratio] 1,8, 95% BI 1,2-3,0), maar niet voor het verplaatsen van zware lasten (OR 1,4, 95% BI 0,7-3,1). Het GEE model liet een iets groter en statistisch significant effect zien voor zowel buigen en/of draaien van het bovenlichaam (OR 2,2, 95% BI 1,5-3,2) als het verplaatsen van zware lasten (OR 1,6, 95% BI 1,0-2,6). Met beide methoden werden geen statistisch significante verbanden gevonden tussen de psychosociale werkkenmerken en het optreden van lage rugklachten, maar het GEE model liet lagere odds ratio's zien voor de psychosociale werkkenmerken dan het conventionele model. De analyse met de GEE methode van een model dat alleen gebruik maakte van de herhaalde metingen van lage rugklachten gaf inzicht in de oorzaken van de verschillen tussen de twee analyse methoden. Zowel het rekening houden met de tijdsafhankelijkheid van de expositie als het rekening houden met de tijdsafhankelijkheid van de uitkomstmaat bleek invloed te hebben op de uitkomsten.

Hoofdstuk 8 bevat de algemene discussie. De bevindingen worden samengevat in de context van de belangrijkste onderzoeksvragen. Er wordt ook aandacht besteed aan enkele algemene methodologische kwesties met betrekking tot de systematische review en de prospectieve cohort studie. De discussie van de methodologie van de systematische review handelt met name over de keuze van criteria voor de selectie van studies, voor het vaststellen van de methodologische kwaliteit van studies en voor het bepalen van het beschikbare bewijs. Centrale kwesties in de discussie van de methodologie van de prospectieve cohort studie zijn de selectie van de onderzoekspopulatie, het bepalen van de blootstelling aan lichamelijke belasting op het werk en de psychosociale werkkenmerken, het bepalen van rugklachten, de onderlinge relatie tussen werkgerelateerde fysieke en psychosociale factoren, de statistische power en de keuze van de modellen voor de statistische analyses.

De uiteindelijke conclusies van dit proefschrift zijn als volgt:

- Buigen en draaien van de rug en tillen op het werk zijn risicofactoren voor lage rugklachten. In de systematische review werd ook sterk bewijs gevonden dat blootstelling aan lichaamstrillingen een risicofactor is voor lage rugklachten, en matig bewijs dat het tillen en verplaatsen van patiënten en zwaar lichamelijk werk risicofactoren zijn voor lage rugklachten.
- Voor buigen van de rug werd een duidelijke blootstellings-responsrelatie gevonden met lage rugklachten.
- Lage arbeidstevredenheid is een risicofactor voor het optreden van lage rugklachten. Weinig ondersteuning van de leidinggevende en collega's lijkt ook een risicofactor te zijn voor lage rugklachten, maar het is niet mogelijk een definitieve conclusie te trekken over de rol van deze werkgerelateerde psychosociale factor.
- Er werd geen duidelijke ondersteuning gevonden voor de hypothese dat de variabelen arbeidstevredenheid, emotionele uitputting en slaapstoornissen een intermediaire rol spelen in de relatie tussen de psychosociale werkkenmerken die bestudeerd zijn in dit proefschrift en lage rugklachten. Het is echter niet mogelijk sterke conclusies te trekken met betrekking tot dit onderwerp.
- Er is meer bewijs voor een relatie tussen de werkgerelateerde fysieke factoren die bestudeerd zijn in dit proefschrift en lage rugklachten dan voor een relatie tussen de bestudeerde psychosociale werkkenmerken en lage rugklachten.
- Buigen en draaien van de rug en tillen op het werk zijn sterker gerelateerd aan ziekteverzuim vanwege lage rugklachten dan aan zelfgerapporteerde lage rugklachten.

Aan het eind van hoofdstuk 8 worden implicaties voor preventie en aanbevelingen voor toekomstig onderzoek die volgen uit de conclusies en de methodologische discussie gepresenteerd. Aanbevelingen voor de preventie van lage rugklachten zijn het reduceren van buigen van de rug, draaien van de rug en tillen op de werkplek en het verbeteren van de psychosociale werkomgeving met de nadruk op het verbeteren van sociale ondersteuning en arbeidstevredenheid. Een belangrijke aanbeveling voor in de toekomst op te zetten studies naar de relatie tussen werkgerelateerde factoren en lage rugklachten is dat geprobeerd moet worden zoveel mogelijk dezelfde gestandaardiseerde maten mee te nemen voor werkgerelateerde factoren. Daarnaast moet niet alleen gekeken worden naar werkgerelateerde factoren als risicofactoren voor het optreden van lage rugklachten, maar moet ook de rol van rol van deze factoren in de prognose van lage rugklachten beter bestudeerd worden.

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About the author

Lisette Hoogendoorn was born on September 3rd, 1972 in De Hoef, Mijdrecht, and spent her childhood in Andel. After obtaining her secondary school diploma in 1990 at the 'Oude Hoven' in Gorinchem, she started to study Biomedical Health Sciences at the University of Nijmegen. In 1995 she graduated with a major in toxicology and epidemiology. From August 1995 to December 1996 she worked a researcher at the Work and Health Division of TNO Prevention and Health in Leiden. From January 1997 to December 2000 she worked as a PhD student at the Institute for Research in Extramural Medicine (EMGO Institute) of the Vrije Universiteit in Amsterdam and at TNO Work and Employment in Hoofddorp. During this period, she carried out the research on work-related risk factors for low back pain described in this thesis. She also attended statistical and methodological courses organized by the EMGO Institute, the Netherlands School of Primary Care, the Netherlands Institute for Health Sciences, the Environmental and Occupational Health Group of Wageningen University, and the New England Epidemiology Institute in Boston, USA. She is currently registered as an Epidemiologist with the Netherlands Epidemiology Society. In April 2001, she started working as a researcher at the Department of Medical Decision Making of the Leiden University Medical Centre.

This thesis investigates work-related risk factors for low back pain. Attention is paid to physical and psychosocial load at work. Systematic reviews of the literature on physical and psychosocial risk factors for back pain are presented. In addition, the results of a three-year prospective cohort study among a working population are reported. The most important conclusion with regard to physical load at work is that flexion and rotation of the trunk and lifting at work are risk factors for low back pain. The systematic review also provides strong evidence that whole-body vibration is a risk factor for low back pain, and moderate evidence that patient handling and heavy physical work are risk factors for low back pain. The most important conclusion with regard to psychosocial load at work is that low job satisfaction increases the risk of low back pain. Low social support also seems to be a risk factor for low back pain, but it is not possible to draw definite conclusions on the role of this psychosocial work characteristic.