The impact of physical load on the course of low back pain

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Content

Chapter 1
Introduction

Back disorders are a major health problem. In 1998, a study among the Dutch population of 25 years and older reported an annual prevalence of about 41% among men and about 46% among women (1). Low back pain (LBP) is associated with high costs due to disability and sick leave (2). In the Netherlands, musculoskeletal disorders are responsible for about 35% of all sickness absence. In 2002 more than 150.000 workers with back disorders received a disability pension (3). In various countries the total cost of LBP has been estimated to amount up to 2% of the gross national product. About 90% of these costs are indirect costs due to disability, sickness absence, and productivity loss (4).

Physical loads at work, such as manual materials handling, frequent bending and twisting, and forceful movements, have been identified as risk factors for LBP. The attributable fraction of physical work factors on the occurrence of LBP in various occupational populations was estimated between 11-58% (5). Several studies have suggested that also high psychosocial work demands in combination with a low job control and decision latitude affect the risk of LBP. Many of the studies on LBP, however, did not include measures of both physical and psychosocial work factors and, therefore, the combined effect of these factors remains unclear.

LBP is characterized by a full spectrum of conditions, ranging from minor episodes of short duration to severe and disabling episodes that persist for long periods (6-8). The course of LBP can be described as an interplay among three different health states commonly used in epidemiological research: 1) No LBP; 2) Presence of LBP without disability; and 3) disability due to LBP. It is assumed that a worker will move through different health states over time. The change from health state 1 to health state 2 is defined as onset of an episode of LBP of which recovery can be expected within weeks (a change from state 2 to 1). Aggravation of LBP to disabling conditions including sickness absence from work is described by the change from health state 2 to 3. Partial recovery from LBP is described by the change from state 3 to 2. The dynamic course of LBP can be characterized by a high annual incidence of LBP of up to 28% (9), a high recovery from a LBP episode with the vast majority of subjects with LBP to be recovered within about six weeks (10), and also a high annual recurrence rate of 60% or over (9). Although a growing body of evidence suggests that the occurrence of LBP is influenced by work-related factors, there is little information on the impact of these work-related factors on the course of LBP following the onset, i.e. aggravation, recovery, and recurrence.

Despite the evidence associating LBP with a variety of work-related factors, much remained to be learned about quantitative dose-response relations. The lack of quantitative data on the relations between physical work factors and LBP may be explained to a large extent by poor exposure characterization (11). In most studies assessment of physical load is based on qualitative self-reports or on an expert's opinion on presence or absence of generic work factors such as awkward postures, static load, and heavy labor. In order to study dose-response relations between physical load at work and LBP, attention needs to be directed at quantitative characterization of physical load describing exposure patterns. Physical load at the workplace can be described in terms of intensity, duration, and frequency. In the past two decades several methods have become available that facilitate a more quantitative approach to assess these important dimensions of physical load, such as direct measurement techniques and observation techniques. Direct measurements are focused on specific components of physical load and their major advantages are their precision, accuracy, and informational content. Observation techniques have the advantage of being easily applicable in many work situations combining sufficient detail of the important dimensions (12,13).

Since the burden of work-related LBP is high, prevention of LBP is important; especially prevention of chronic and disabling conditions (14-16). From the above mentioned issues we can conclude that in order to institute effective interventions for work-related LBP a quantitative description is needed of the impact of work-related factors on both the onset and the aggravation of LBP.

Objective

The overall objective of the current thesis is to study the course of LBP in several occupations, with a specific focus on the onset and aggravation of LBP in relation to quantitative exposure to physical and psychosocial factors at work.

The specific aims of this thesis are:

1. To evaluate methods to quantify physical load at the workplace.
2. To describe dose-response relations of occupational exposure to physical and psychosocial factors with the onset and aggravation of LBP.
3. To describe the dynamic pattern in the long-term course of LBP and associated disability in occupational populations.

In order to answer these research questions a longitudinal study with two follow-up measurements was conducted. The study population consisted of workers with different jobs in 7 nursing homes and homes for the elderly in the Netherlands. Workers employed for more than 10 hours per week were eligible to participate in the study. Baseline measurements were performed between March 1998 and March 1999, and included the assessment of physical load for each occupation at the workplace and the application of self-administered questionnaires. Follow-up questionnaires were administered one year and two years after the baseline measurements. The questionnaires included questions on working conditions, LBP symptoms, and associated disability and sickness absence.

Outline of the thesis

This thesis is divided in three parts. Part 1 focuses on the methodology used to characterize physical work load as risk factor for LBP. In Part 2 dose-response relations of occupational exposure to physical and psychosocial factors and LBP are evaluated. In Part 3 the information on dose-response relations is used to simulate the dynamic course of LBP over time by continuing exposure to physical load.

In Chapter 2 of Part 1 we review the scientific literature on work-related back disorders in order to evaluate the strength of the associations between physical load and LBP among different studies, and, secondly, to analyze whether the strength of the associations can partly be explained by the study design and methods used to characterize physical work load. In Chapter 3 we propose a novel approach to evaluate simultaneously level, frequency, and duration of lumbar posture during work in order to determine the essential characteristics in postural load. In Chapter 4, the last Chapter of Part 1, two important features in modeling dose-response relations between physical work load and LBP are evaluated: the measurement strategy of the exposure and the nature of the dose-response relation that is assumed.

In Chapter 5 of Part 2 dose-response relations between occupational exposures to physical and psychosocial factors at baseline and the risk of incident LBP at follow-up are investigated. In Chapter 6 the effect of occupational exposure to physical and psychosocial factors on the aggravation of the course of low back pain is assessed. Here, three measures of aggravation of LBP are used: increase in duration, increase in frequency, and increase in pain intensity.

In Chapter 7 of Part 3 the transient nature of LBP and its consequences for the long-term course of LBP and associated morbidity are investigated. LBP is characterized by a dynamic pattern of episodes and recovery but little is known about the long-term course of back pain and its consequences due to lack of cohort studies with sufficiently long follow-up periods. Thus, a Markov model was developed to extrapolate the results of the 2 year observational study to a hypothetical cohort study with life-long follow-up.

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Part 1

Quantification of physical load at the workplace

Chapter 2

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

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Abstract

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

Introduction

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

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

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

The aim of the present paper is to review the scientific literature on work-related back problems of the past 20 years in order to evaluate the strength of the associations between physical load and back disorders in different studies. A second aim is to evaluate whether the strength is explained by the measurement technique used.

Material and methods

Selection procedure of references and method of analysis

An extensive search of available literature was made for epidemiology studies published from January 1980 to December 1999. Computerized searches were carried out on several databases including MEDLINE (National library of Medicine, United States of America), NIOSHTIC (National Institute for Occupational Safety and Health, United States of America), HSELINE (Health and Safety Executive, United Kingdom), CISDOC

(International Labour Organization, Switzerland) and Ergoweb (University of Utah homepage). Furthermore, various review articles were browsed for useful references. The search was restricted to articles in the English language. All possible articles were collected and scrutinized for the description of the occurrence of back problems in relation to specific groups or specific work loads. In total, 255 articles were eligible for initial conclusion and subsequently scrutinized for available information.

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

Thus, there remained 43 (17%) publications (7-49) that met the above selection criteria. These articles formed the basis for the evaluation of the effect of measurement techniques on the associations between physical load and the occurrence of back problems.

Data extraction and analysis

The analysis focused on associations expressed by risk estimates such as the odds ratio and the relative risk. Whenever possible the risk estimate was retrieved from the original article together with the variables that were adjusted for in the statistical analysis. In several publications this information was not presented, but for all studies that provided sufficient raw data for 2*2 tables, odds ratios, or relative risks were calculated with 95% confidence intervals.

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

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

$$E(r \mid \mathbf{M\,P\,C}) = \alpha + \mathbf{M}\underline{\beta} + \mathbf{P}\underline{\gamma} + \mathbf{C}\underline{\varphi} \qquad 1.$$

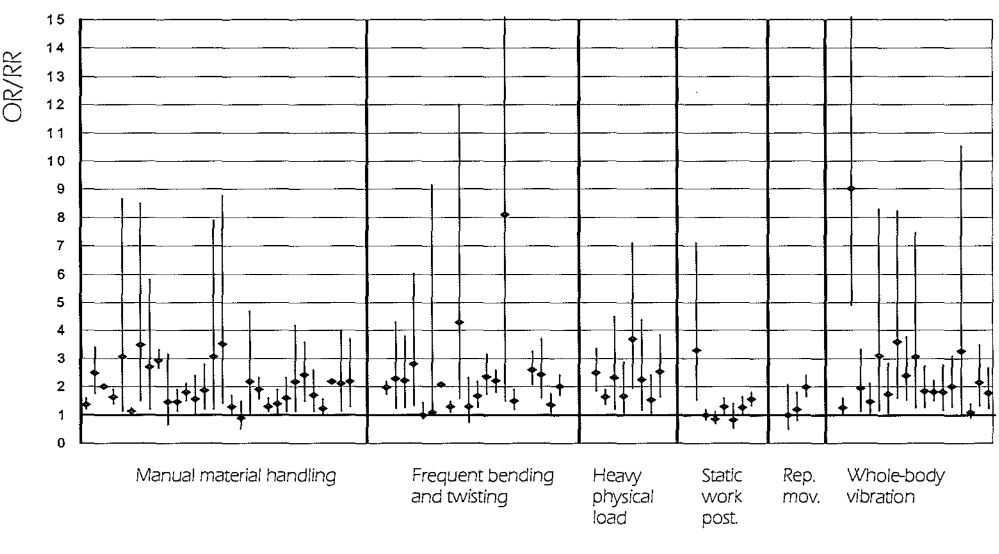
Where r is the risk estimate of the association between risk factors and the occurrence of back problems in the studies. Matrix **M** contains information on the measurement technique in the studies. The matrix **P** contain the random effects of the publications. Matrix **C** contains information on the covariates (the work related risk factor, study design, study size, and level of adjustments). α Is the intercept term; $\underline{\beta} = (\beta_1, \ldots, \beta_l)'$ is the column vector of risk-regression coefficients corresponding to the three measurement techniques (self-reports, observations, measurements). In this analysis self-reports were defined as the reference category, hence a β of 1 for observations, for example, means that studies measuring exposure with observations show on the average risk estimates of 1 unit higher than studies using self-reports. $\underline{\gamma}$ Are independent normal random variables with zero means. $\underline{\varphi}$ Is the vector of risk-regression coefficients corresponding to covariates (the work related risk factor, study design, study size, and level of adjustment in the multivariate analysis). The parameters of model 1 were estimated using the MIXED procedure available with SAS statistical software (SAS, inc., Cary, NC).

Results

Findings

Figure 2.1 summarizes the results of the 43 articles selected in this review stratified by work-related risk factor (7-49). (In annex 2.1 an extensive description of the basic characteristics of the studies is given. Three publications are not included in these tables since they did not present any significant association (21,28,38). The 43 publications comprise 44 epidemiologic studies since 1 publication was both cross-sectional and longitudinal (35). In 27 studies (61%) (7,8,18-20,23,26-28,30-36,39-48) that investigated the effects of manual material handling on back problems, risk estimates were found ranging from 0.90 up to 3.54. In the 18 studies (41%) (7,13-15,17,18,23,25,26,30,31,36-39,43,45,49) concerning frequent bending and twisting the risk estimates ranged from 1.08 up to 8.09. Seven studies (16%) (22,24,25,29,33,44,49) showed that the risk estimates of heavy physical load ranged from 1.54 up to 3.71, and in 6 studies (14%) (16,23,30,35,45,49) static work posture showed risk estimates from 0.80 up to 3.29. Furthermore, 3 studies (7%) (21,29,39) concerning repetitive movements showed that the estimates ranged from 0.98 up to 1.97, and in 15 studies (34%) (7,9-15,30-32,35,37,39,49) where whole body vibration was the aim of investigation risk estimates from 1.10 up to 9.00 were found.

Figure 2.1 Risk estimates (odds ratio and relative risk) and 95% confidence intervals for different work related risk factors of studies in review



Study characteristics

In Table 2.1 the study characteristics of the included studies are presented. Division by measurement techniques showed that in 30 studies (68%) self-reports were used for data collection, 8 (18%) used observations at the workplace, and 5 studies (11%) used direct measurement techniques. Concerning study design, 24 studies (55%) had a cross-sectional design, 8 (18%) a case-control design, 4 (9%) had a longitudinal design, and 8 (18%) studies were community-based studies. Division by size showed that in most studies, 19 (43%), the study population consisted of 250 to 1000 subjects. In 7 studies (16%) the study population was smaller than 250 subjects, and in 18 studies (41%) the population was larger than 1000 subjects. On average 1.9 covariates were included in the multivariate analysis, with a range of 0 up to 8.

Table 2.1 Descriptive of epidemiologic studies in the publications

	Number of studies
Work related risk factors	
Manual material handling	27 (61%)
Frequent bending and twisting	18 (41%)
Heavy physical load	7 (16%)
Static work posture	6 (14%)
Repetitive Movements	3 (7%)
Whole body vibration	15 (34%)
Measurement technique	
Self-reports	30 (68%)
Observations	8 (18%)
Direct measurements	5 (11%)
Study design	
Cross-sectional	24 (55%)
Case control	8 (18%)
Longitudinal	4 (9%)
Community based	8 (18%)
Study size	
<250	7 (16%)
250-1000	19 (43%)
>1000	18 (41%)
Number of confounders adjusted for	*Mean (SD)*
	1.9 (2.1) *range* 0 - 8

The results of the meta-regression analysis are presented in Table 2.2. It is shown that, adjusted for work-related risk factors and study characteristics, studies using observations at the workplace reported on average a 1.13-fold higher risk estimate of the association between risk factor and occurrence of back problems (β = 1.13, 95% CI -0.06; 2.33) than studies using self-reports, although this difference was not statistically significant. Studies relying on direct measurement techniques reported significantly higher risk estimates than studies using self-reports (β = 1.18, 95% CI 0.30; 2.07). Between observations and direct measurement techniques no significant difference was found. Furthermore, longitudinal studies showed significantly higher risk estimates than cross-sectional studies and case-control studies. Study size, and number of confounders adjusted for did not have an impact on the strength of the associations between risk factors and back problems.

Table 2.2 Results of the meta-regression analysis. The effects of study aspects on associations between risk factors and back problems

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

Discussion

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

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

Longitudinal studies reported higher risk estimates than cross-sectional studies, case-control studies, and community studies. A reasonable explanation is that in cross-sectional, case-control, and community studies the occurrence of back problems is expressed as the prevalence of occurrence, whereas in longitudinal studies the occurrence of back problems is mostly expressed as the (cumulative) incidence. By nature, prevalence rates are larger than incidence rates and specifically for back problems background prevalences may be very high. Hence, dividing prevalence rates of exposed workers by prevalence rates of unexposed workers (as is the case in cross-sectional or case-control studies) will result in smaller ratios (risk estimates) than when incidence rates of exposed workers are divided by incidence rates of unexposed workers (as in the longitudinal studies).

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

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Annex 2.1

Table A2.1 Significant associations between work-related risk factors and the occurrence of back disorders, expressed as odds ratio, in cross-sectional epidemiologic studies among occupational populations

Author	*Study population*	*Back disorders*	*Work-related risk factor*	*Risk*	*95% CI*[a]	*M*[b]
Alcouffe 1999	7010 workers (M&F)	LBP in past 12 months (56%)	Lifting (every day > 10 kg Whole-body vibration (> 4 h/day versus never) Awkward postures (yes/no)	1.37 1.26 1.96	1.18-1.59 1.01-1.59 1.72-2.17	q q q
Arad 1986	831 nurses (F)	LBP in past month (42%)	Lifts per shift (>6 vs less)	2.47	1.78-3.42	q
Bongers 1990	133 helicopter pilots and m 228 non-flying officers (M)	Regularly experienced LBP (55% and 11%)	WBV ($a_z > 0.5$ m/s^2)	9.00	4.90-16.4	0
Boshuizen 1990	450 tractor drivers and 110 agriculture workers (M)	Regularly experienced LBP (31% and 19%)	WBV ($a_z > 0.3$ m/s^2)	1.93	1.12-3.35	m
Boshuizen 1992	242 drivers and 210 operators (M)	LBP in past 12 months (51% and 42%)	WBV ($a_z > 0.5$ m/s^2)	1.73	1.06-2.81	m
Bovenzi 1992	234 bus drivers and 125 maintenance workers (M)	LBP in past 12 months (83% and 66%)	WBV ($a_z > 0.6$ m/s^2) Awkward posture (frequent)	3.62 2.29	1.60-8.22 1.22-4.29	m q
Bovenzi 1994	1155 tractor drivers and 220 office workers (M)	LBP in past 12 months (67% and 35%)	WBV ($a_z > 0.5$ m/s^2) Awkward posture (hard)	2.39 2.21	1.52-3.76 1.27-3.82	m q
Burdorf 1991	114 concrete workers and 52 maintenance workers (M)	LBP in past 12 months (59% and 31%)	Bends & twists (37% vs 27%) WBV (yes/no)	2.80 3.06	1.31-6.01 1.26-7.45	o o
Burdorf 1993	94 crane operators and 86 office workers (M)	LBP in past 12 months (50% and 34%)	Static sedentary posture (yes/no)	3.29	1.52-7.12	o
Burdorf 1997	161 tank terminal workers	LBP in past 12 months (35%)	Lack of social support (yes/no)	3.80	1.58-9.14	o

Table A2.1 continued Significant associations between work-related risk factors and the occurrence of back disorders, expressed as odds ratio, in cross-sectional epidemiologic studies among occupational populations

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

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

Table A2.2 Significant associations between work-related risk factors and the occurrence of back disorders, expressed by odds ratio, in case-control epidemiologic studies among occupational populations

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

Table A2.3 Significant associations between work-related risk factors and the occurrence of back disorders, expressed by relative risk, in longitudinal epidemiologic studies among occupational populations

Authors	*Study population*	*Back disorders*	*Work-related risk factor*	*Risk*	*95% CI*	*M*
Boshuizen 1990	789 tractor drivers (M)	Sickness absence > 28 days				
		due to back disorders	WBV (az > 0.4 m/s2)	1.47	1.04-2.10	m
		due to intervertebral disc	WBV (az > 0.4 m/s2)	3.10	1.16-8.30	m
Gardner 1999	31,076 material handlers in retail merchandise stores	BP claim due to material handling (2.8%/year)	Material handling (lifting jobs versus light-lifting jobs)	1.62	1.38-1.91	o
Kraus 1997	31,000 employees (M&F) in retail stores	BP claim (± 3.4%/year)	Lifting (frequently lifting or carrying loads > 11.35 kg)	2.94	2.64-3.32	o
Pietri 1992	601 commercial travellers	LBP incidence (13%/year)	WBV (> 20 h vs < 10 h)	3.28	1.03-10.49	q
Smedley 1997	838 female nurses (no LBP in past month)	LBP incidence (47% cum incidence / 2 year)	Lifting (>= 1 patient vs 0)	1.4	1.00-1.90	q
			Transfer (>= 5 patients vs less)	1.6	1.10-2.30	q
Stobbe 1988	415 nurses (F)	BP claim (5.2%/year)	Lifting (> 5 patients vs < 2)	2.16	1.12-4.19	q
Venning 1987	4,306 nurses (M&F)	BP claim (2.8%/year)	Lifting (□ 1 patient vs 0)	2.19	na	q

Table A2.4 Significant associations between work-related risk factors and the occurrence of back disorders, expressed by odds ratio, in cross-sectional community-based epidemiologic studies

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

Chapter 3

A novel approach for evaluating level, frequency, and duration of lumbar posture simultaneously during work

Adapted from: Jansen JP, Burdorf A, Steyerberg E. A novel approach for evaluating level, frequency and duration of lumbar posture simultaneously during work. Scand J Work Environ Health. 2001;27:373-80.

Abstract

Objective. Electrogoniometers are used to collect continuous information on postural distributions among workers. Enormous quantities of data are generated that have to be reduced to meaningful parameters: angle, frequency, and duration. In this study we propose statistical models to determine these essential characteristics in postural load among nurses, housekeepers and office workers.

Methods. A direct registration of the lumbar posture was made over a working day with an inclinometer. Exposure variation analysis summarized information on angle of trunk flexion, time period of maintained postures, and percentage of work time in a data matrix. Hierarchical regression analysis was used to compare these characteristics among nurses (n=64), housekeepers (n=16), and office workers (n=27).

Results. The occupational groups did not differ for either frequency or duration of trunk flexion over 30 degrees since frequency and duration were inversely related. Nurses experienced longer work times than office workers for trunk flexion between 30 and 70 degrees maintained less than 5 seconds, whereas office workers experienced longer work times in smaller angles (<30 degrees) for longer periods. Comparable differences in the distributions of postural load were found between housekeepers and office workers.

Conclusion. This study describes the use of hierarchical models in analyzing exposure level, frequency, and duration of postural load simultaneously and offers an alternative to the conventional analysis in ergonomics where dynamics of exposure are often ignored. The distinction in postural load between nurses or housekeepers and office workers is best determined by the combination of trunk angle and time period.

Introduction

Low back pain (LBP) constitutes a major health problem in many occupational populations. Despite the evidence associating LBP with a variety of work activities and risk factors (1,2) dose-response relations between mechanical load at work and LBP are far from clear. The lack of quantitative data on these relations may be explained to a large extent by poor exposure characterization (3). In order to study dose-response relations between mechanical load and LBP and to institute effective ergonomic improvements, attention needs to be directed at quantitative characterization of mechanical load describing exposure patterns as well as factors affecting these exposure patterns. In contrast to the usual concept in occupational epidemiology whereby exposure refers to an agent external to the worker, in musculoskeletal epidemiology the workers' interaction with the workplace will play a crucial role in exposure characterization, i.e. physical load cannot be determined independently from the worker (4).

Observational methods and direct measurement techniques are increasingly being used in musculoskeletal epidemiology. Direct measurements are focused on specific components of physical load. A major advantage of direct measurement techniques in comparison with subjective judgments or observations is their precision and accuracy as well as their informational content. However, the enormous amount of data has to be reduced, in order to be interpretable in epidemiological studies. Mathiassen and Winkel (5) have proposed an exposure variation analysis (EVA) whereby the available data is reduced to a limited number of essential parameters by which the exposure pattern is still sufficiently captured. The essential information on level, frequency, and duration of the exposure parameter of interest is summarized in a data matrix. In spite of the usefulness of the quantitative presentation of exposure in essential parameters using EVA, there is a clear need for a statistical method by which the EVA data-matrixes can be analyzed, i.e. to formally analyze data-matrixes among different groups of people.

To formally analyze EVA data-matrixes it has to be noted that successive combinations of level, duration, and frequency in the matrix are correlated. A comparison can be made with small area studies. The assumption in small area studies is that the variation in standardized mortality rates among neighbor areas is smaller than among areas further apart. To improve and stabilize these rates a hierarchical regression approach can be used, by which a second-stage model pulls the estimates of neighbor areas towards each other (6,7). In this study, we propose an analogous approach to analyze exposure patterns that are presented in EVA-data matrixes. In particular, the estimates of the ordinary regression model -which describes exposure level, duration, and frequency simultaneously- are improved using a second-stage model. The second-stage model incorporates *a priori* information on similarities among different classes of exposure level and exposure time periods.

In the present study we determine the essential characteristics in postural load among nurses, housekeepers and office workers. This information can be of great value within the framework of epidemiologic studies on postural load and musculoskeletal disorders.

Material and Methods

Data collection

The subjects in the present study participate in a large epidemiological study among nursing home personnel. The original study population consisted mainly of nurses, assistant nurses, home care workers, and office workers. For the present study 64 nurses and assistant nurses, 16 housekeepers, and 27 office workers were included.

The exposure pattern of trunk flexion in the sagittal plane as a function of time at the workplace was measured by means of an electrogoniometer. This electrogoniometer was attached to the trunk at L2-L3 while the angular position of the trunk was recorded with a frequency of 16 Hz for 8 hours (8). An exposure variation analysis (EVA) (Table 3.1) was used to summarize this enormous amount of data (about 460.000 data points per subject) in a data matrix for each subject (1). The exposure level (trunk angle) was grouped into nine different classes of 0-10 degrees ranging from 0 degrees to greater than 80 degree of flexion. Time period of trunk posture (as a representation of frequency) in a particular angular class was grouped into five classes with cutoff values of 1, 2, 5, and 10 seconds. The matrix consisted of 45 combinations (cells) of exposure level and time period. The percentage of work time spent in each cell is presented. It should be noted that the three parameters exposure level, time period, and percentage work time are interrelated.

Table 3.1 Exposure variation analysis matrix (EVA) for a given subject with percentage of work time the number in each cell for different angles of trunk flexion and different periods of sustained trunk flexion

Time period	Trunk flexion 0-10°	10-20°	20-30°	30-40°	40-50°	50-60°	60-70°	70-80°	>80°
0-1s	31.45	23.32	5.85	2.50	1.27	0.77	0.71	0.47	0.27
1-2s	4.70	7.70	2.11	0.41	0.18	0.09	0.04	0.12	0.01
2-5s	0.61	1.30	0.21	0.08	0.03	0.01	0.01	0.01	0.00
5-10s	0.51	1.32	0.19	0.07	0.03	0.01	0.00	0.00	0.00
>10s	0.29	0.37	0.09	0.02	0.00	0.01	0.01	0.00	0.00

Data analysis

Exposure level, time period, and percentage work time were simultaneously described using a log-linear model (equation 1). The elements of observation were the cells within a data matrix, with the percentage work time as the outcome variable. (There were 45 cells in each matrix for every one of the 107 subjects, totaling 4815 observations.) To capture the complete exposure pattern described by combinations of the 9 levels of exposure and the 5 levels of time period, 45 dummy parameters were included in the model without any intercept. In this way, the expected percentage work time in each cell of the matrix is determined by the model. Furthermore, the interaction of occupation (nurse or housekeeper versus office worker) and parameters of the exposure pattern were entered in the model:

$$\text{Log}\,\mathbf{w} = \mathbf{E}\underline{\beta} + \mathbf{I}\underline{\varphi} \qquad 1.$$

Where column vector **w** contains the percentage of work time for the given combination of trunk angle and time period in cell c (c=1, ...,45) for subject j (j=1, ...,107). **w** consists of 4815 (=107*45) elements. Matrix **E** consists of 4815 rows and 45 columns. The columns of **E** are dummy variates d (d=1, ...,45) corresponding to the 45 cells describing the combinations of trunk angle and time period. The 4815 rows of **E** define the value of dummy variate d in cell c for subject j. Matrix **I** defines the interaction between a co-factor (occupation) and the exposure pattern of trunk flexion. **I** consists of 4815 rows and 45 columns, the elements of **I** for subject j are obtained by multiplying the elements of **E** for subject j with a value of 1 or 0 of a dichotomous variable depending on the occupation of subject j. $\underline{\beta} = (\beta_1, \ldots, \beta_{45})'$ is the column vector of log-linear regression coefficients corresponding to the 45 dummy variates, $\underline{\varphi} = (\varphi_1, \ldots, \varphi_{45})'$ is the column vector of log-linear regression coefficients corresponding to the 45 interactions between exposure pattern and occupation. Since the group effect of the occupation was not entered in the model, the interaction factor reflects the differences in percentage work time for a given combination of level and time period between the different occupations. To actually interpret the φ, these parameters were transformed to create relative work times (RWT = $\exp(\varphi)$). The RWT represents the ratio of percentage work time for given combination of trunk angle and time period among occupational groups. For example, a RWT of 2.00 for nurses means that the percentage work time for a certain angle and time period among nurses is 2 times higher than the percentage of work time among the office workers.

Fitting model 1 using conventional maximum-likelihood has some drawbacks. First, it does not take dependencies of the observations into account. Here, there are dependencies among cells in the matrix. When a subject has worked on a certain level for a while, she will inevitably change from there to one of the neighbor classes; it is not possible to skip some classes. Hence, a spatial correlation pattern can be assumed: the correlation between neighbor cells in the matrix is stronger than the correlation between cells further apart. A second disadvantage is that the large number of parameters in the model may limit the ability to obtain accurate coefficient estimates (9,10).

One way to overcome the first drawback, i.e. to take the dependencies of the cells into account, is to include a random effect that is a coefficient for the sets of repeated observations on single individuals. However, such a model will not overcome the second drawback of less accurate estimates.

To overcome the second drawback of model 1 a multilevel model can be used, as illustrated by several authors (10-15). Such a hierarchical approach will provide estimates of model 1 that are more stable and accurate as a result of a priori defined similarities among the coefficients. In the present study this approach is used since the limited number of observations in some combinations of exposure level and time period resulted in imprecise estimates with model 1.

Since the main interest are the interaction factors φ, which reflect the relative work times for the different categories of exposure level and time periods, it is only necessary to improve these coefficients φ with a second stage model (and not the coefficients β):

$$\text{Log}\,\mathbf{w} = \mathbf{E}\underline{\beta} + \mathbf{I}\,\underline{\varphi} \qquad \text{(first-stage model)}$$
$$\underline{\varphi} = \mathbf{Z}\,\underline{\pi} + \underline{\varepsilon} \qquad \text{(second-stage model)} \qquad 2.$$

Where, as in model 1, $\underline{\varphi}$ is the column vector of log-linear regression coefficients corresponding to the 45 interactions between exposure pattern and co-factor. Matrix **Z** consists of 45 rows and 15 columns. **Z** contains the second-stage covariates for the interaction between the exposure pattern and co-factor. The second-stage covariates are 15 dummy variables corresponding to 15 clusters of interdependent cells (see Figure 3 .3) where the dashed lines separate 15 clusters of cells). $\underline{\pi}$ Is a column vector of coefficients responding to the effects of second-stage covariates on the coefficients φ, and the elements of $\underline{\varepsilon}$ are independent normal random variables with zero means and variances τ^2. Since design matrix **Z** defines which cells are a priori comparable (the cells within a cluster) and because for each cell there is a coefficient φ (from model 1) the second-stage model defines which coefficients φ are a priori comparable (the coefficients of cells within a cluster). The justification for introducing these similarities among cells within a cluster is based on the fact that subjects can only move from one cell to a neighbor cell and not to any other cell in the matrix. Hence, with this multilevel model the estimates of φ from model 1 for cells close to each other in space (i.e. within a cluster) are shrunken towards each other and, consequently, this will result in smaller and more stable estimates (12,14,15). It has to be noted that this novel approach in model 2 does not take into account the issue of repeated observations on single individuals.

To actually perform the hierarchical regression a two step procedure is used as described extensively by Witte and Greenland (14,16). In the first step the parameters of model 1 were estimated using the GENMOD procedure available with SAS statistical software (SAS, inc., Cary, NC) (16). In the second step the hierarchical model was fitted with a modified program of Witte et al. written in the IML procedure using a weighted-least-squares method (16). The coefficients π are estimated using a weighted-least squares-method (10) with weights derived from the covariance matrix of φ from the maximum-likelihood estimation of the first-stage model and the variances of the RWTs in different cells, taking into account the cluster effect. The variances (τ^2) of the RWTs were constrained with a semi-Bayes approach in order to introduce more stable estimates. When the vector of variances equals 0, it implies equal RWTs among the combinations of exposure level and time period within one cluster of cells. Large pre-specified values of τ result in less shrinkage towards the prior RWTs, whereas small values of τ result in more shrinkage (12,14,15). We set the standard deviations τ to modest values: 0.32, which implies 95% a priori certainty that the differences in RWTs between cells within a cluster lie within a exp(3.92*0.32) = 3.5 fold range (for example 0.5 to 1.75).

Results

In Figure 3.1 the distribution of work time over trunk flexion categories is presented in a traditional way in the field of ergonomics. Distinct differences between nurses, housekeepers, and office workers were seen for trunk angles between 0-10 degrees. A major disadvantage of this traditional approach, for both presentation and analysis, is that the focus is on exposure level and duration and that exposure frequency is not taken into account; i.e. the percentage work time spent in each trunk angle is totaled over the different classes of exposure time period, whereby the dynamics of trunk flexion are ignored.

Figure 3.1 Traditional approach to exposure to trunk flexion for nurses, housekeepers, and office workers

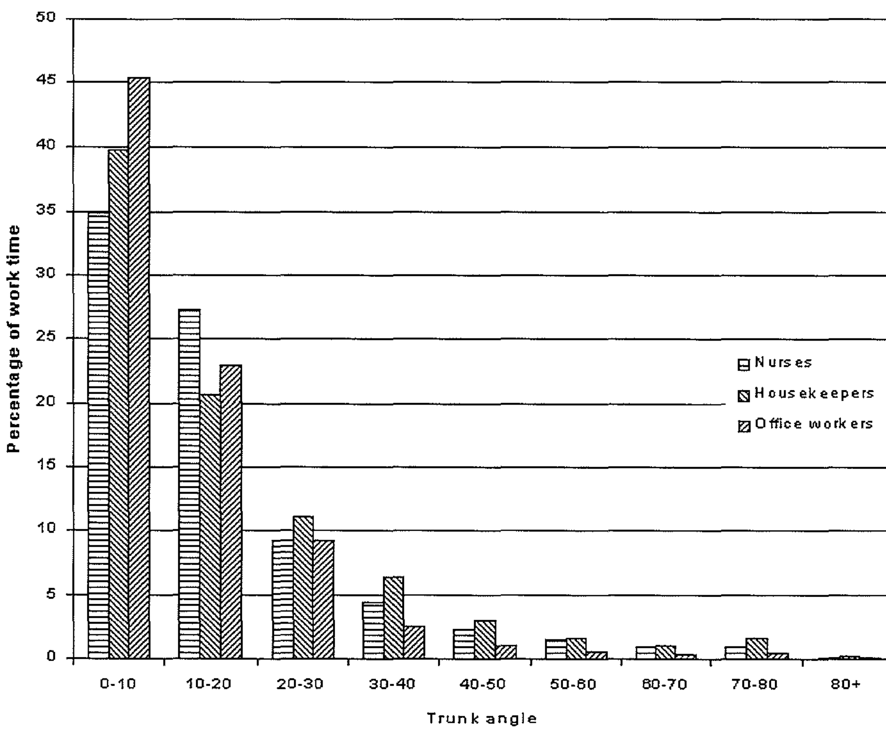
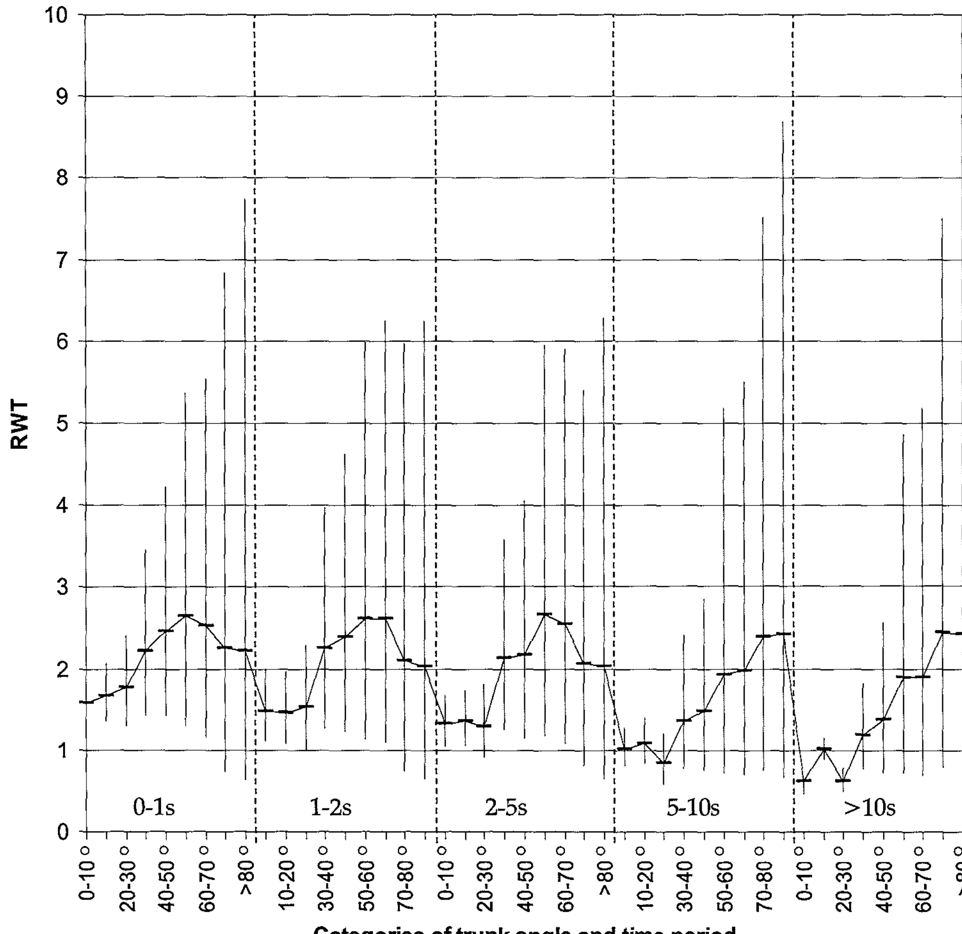


Figure 3.2a summarizes the results from fitting the hierarchical regression model by which ratios of percentage work time for classes of trunk angle and exposure time period for nurses and office workers (RWTs) are presented. It is shown that nurses experienced significant longer work times in trunk flexion between 0-70 degrees for periods less than 5 seconds. The largest relative work times were found between 30-70 degrees of flexion for 0-5 seconds: RWTs varied from 2.13 (95% CI 1.26-3.58, for 30-40 degrees and 2-5 seconds) to 2.66 (95% CI 1.19-5.94, for 50-60 degrees and 2-5 seconds). For an exposure time period of more than 5 seconds, office workers experienced longer work times in trunk angles up to 30 degrees.

Figure 3.2a Differences in percentage work time between nurses and office workers, expressed in relative work time (RWT) and 95% confidence intervals



When housekeepers and office workers are compared (Figure 3.2b), the RWTs indicated that housekeepers experienced significantly longer work times in trunk flexion between 0-80 degrees for periods up to 5 seconds. The largest relative work times were found between 30-80 degrees: RWTs varied from 4.25 (95% CI 1.28-14.17, for 70-80 degrees for less than 1 second), to 2.85 (95% CI 1.59-5.12, for 30-40 degrees and 2-5 seconds). Furthermore, the housekeepers experienced lower frequencies in trunk flexion between 0-30 degrees for periods of 5 seconds or more.

Figure 3.3 shows the dynamics of trunk flexion of the occupational groups. It can be seen that nurses and housekeepers showed longer work times in the upper–right half of the matrix, which reflects dynamic work. The lower-left half of matrix reflects more static work; office workers experienced the longer work times in that area.

Figure 3.2b Differences in percentage work time between housekeepers and office workers, expressed in relative work time (RWT) and 95% confidence intervals

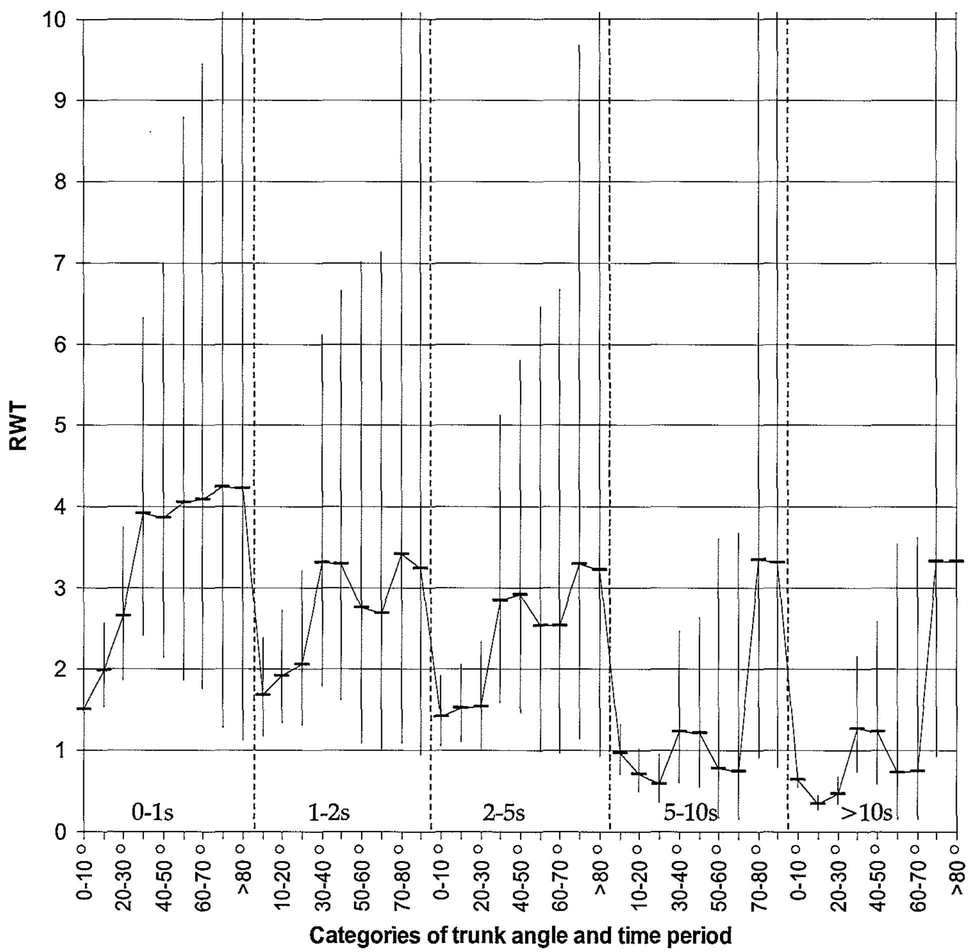
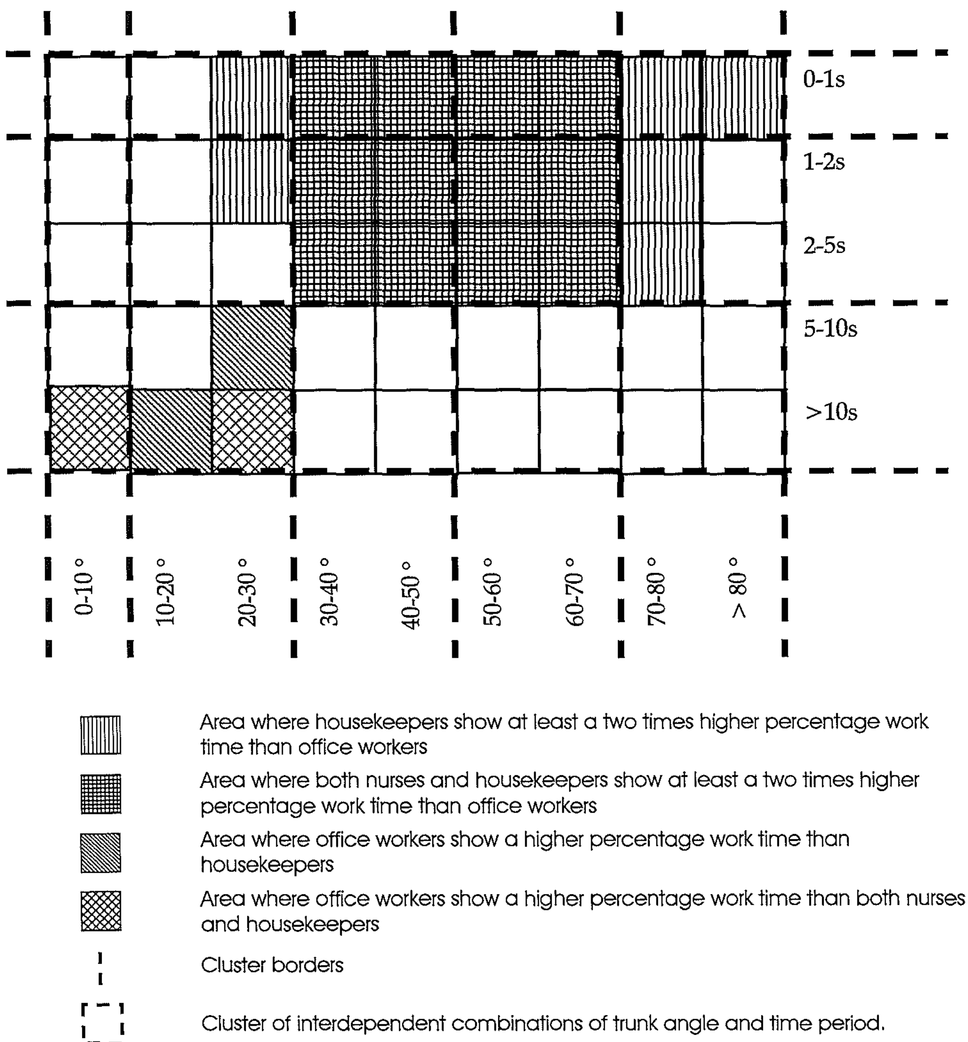


Figure 3.3 Graphic presentation of the dynamics of lumbar posture



Discussion

It is well known that the dynamic and static aspects of postural movements are important in explaining why physical load may cause musculoskeletal problems (3,4,5). Hence, exposure characterization of physical load should take into account the three essential parameters of any exposure parameter: level, frequency, and duration. Traditionally, emphasis is given to the level of exposure (see Figure 3.1). The frequency of exposure parameters, that is changes from one exposure level to another, is seldom presented (17). In principle, real-time registration of angular trunk position acquired through direct measurement techniques allows for quantitative description of all three essential parameters of exposure. The question that arises is how this amount of information can be used within the framework of epidemiologic studies on postural load and musculoskeletal problems. More specifically, the main interest is to reduce the data and subsequently identify the relevant aspects of the exposure pattern (in terms of level, frequency, and duration) to be applied in epidemiologic designs. The enormous amount of data acquired with direct measurement techniques can be reduced with the exposure variation analysis processing method by which the parameters level, frequency, and duration are still captured. Subsequently, to identify relevant aspects of the exposure pattern the obtained EVA data-matrix has to be evaluated within the existing body of epidemiological knowledge. In the present study, postural load data of three occupational groups were evaluated. The a priori epidemiologic knowledge concerning nurses and office workers is, first, that nurses experience higher proportions of back problems, and, second, postural load is a known risk factor for back problems. Hence, it is reasonable that exposure parameters as extracted by the EVA are risk-indicative. More specifically, with EVA matrixes the epidemiologic relevant aspects of postural load in terms of level, frequency, and duration can be identified. However, valid statistical techniques are a requisite.

In the present study we proposed models for analyzing exposure patterns whereby the three essential parameters exposure level, frequency, and duration are taken into account simultaneously. The analyses demonstrated that nurses and housekeepers spent a significant larger amount of their work time in larger trunk angles in combination with shorter time periods than office workers; the office workers spent a larger amount of their work time in smaller angles for longer time periods. In other words, nurses and housekeepers are exposed to more dynamic work with more trunk flexion, whereas office workers perform static work. The pattern of lumbar posture of nurses and housekeepers in reference to office workers differed most strongly for work time in trunk flexion between 30 en 80 degrees for periods less than 5 seconds. Furthermore, it was shown that nurses (and housekeepers) cannot be discriminated from office workers on the basis of work time with trunk flexion over 30 degrees because the (relative) work times for these angles are strongly dependent of the exposure time period (see Figure 3.2a and 3.2b); the differences in time period and percentage work time may offset each other, thereby presenting a seemingly similar level of physical load. This means that the often adopted measure of exposure -percentage of work time with a cutoff of 20 degrees flexion, which ignores frequency- does not discriminate between nurses (or housekeepers) and office workers. When observations at the workplace are chosen to characterize physical load, it is practically impossible to characterize both level (trunk angle) and time period (two observers are needed, one for level and one for time period). In the present study, an alternative would be to choose for observations with a cutoff of 30 degrees for the exposure level and ignore time period, since the RWT for a given angle were only moderately influenced by the time period of exposure. However, due to the fact that above 30 degrees of flexion a smaller percentage of work time is found, the number of observations carried out has to be increased dramatically in order to get valid estimates when the aim is to discriminate between nurses (or housekeepers) and office workers on the basis of percentage of work time in trunk flexion. This can also be concluded from Figure 3.2a and 3.2b: in angles over 30 degrees, the confidence intervals are very large which reflect large interindividual differences for those angles.

An important feature of the statistical models applied is that determinants of the exposure pattern factors are taken into account. These models in combination with EVA in the field of ergonomics and epidemiology are very powerful. They may be used to search for optimum cutoff points in exposure patterns among different working groups or among people with and without musculoskeletal problems. Furthermore, it offers possibilities to create job-exposure matrixes. Dependencies among exposure level, time period, and percentage work time are defined by the parameters of the model, and can be presented conditionally on job titles. Furthermore, the combination of angle, time period, and percentage work time allows a quantitative definition of the concepts static and dynamic work, and can be presented in a graphic way, such as Figure 3.3. This definition of static and dynamic work allows an even further reduction of the data, and provides possibilities to define the essential parameters concerning the dynamics of the work that can be included in epidemiologic designs.

As shown in the present study, the advantages of statistical models in combination with EVA are clear. As mentioned earlier, conventional regression analysis does not take the dependencies among neighbor classes of exposure level and time period into account. One way to adjust for this effect is to use a random effects model. The disadvantage of such a model is that it may result in inaccurate and instable estimates in the case of small numbers. The reason to use hierarchical regression models (model 2) is to acquire more stable estimates. Instead of estimating all the 90 coefficients of the first-stage model with maximum likelihood, the coefficients were modeled with far less parameters in the second-stage model: the a priori similarities among the combinations of exposure level and time period within a cluster. In a comparable way to disease mapping where mortality rates of small areas with few observations are shrunk towards the mortality rates of large surrounded areas (6,7), here, unstable estimates were shrunk towards more stable coefficients of neighbor classes of level and time period within the cluster. The elements of $\underline{\tau}$ were the shrinkage parameters (14,15). However, the hierarchical model does not take the correlations of neighbor observations into account. It is possible to create a hierarchical model which includes also a random subject effect to capture the dependencies. The major disadvantage is the complexity of the model, as well as the computation time necessary to estimate the coefficients. The expectation is that such a model would result in slightly larger standard errors of the estimates (assuming the same τ).

In conclusion, the present study describes the use of hierarchical regression models in analyzing exposure level, frequency, and duration of postural load simultaneously. The distinction in postural load between nurses or housekeepers and office workers is best determined by the combination of trunk angle (exposure level) and time period (frequency). The proposed statistical procedure is of use when the study groups of interest differ a priori in epidemiologically interesting aspects such as disease prevalence, or when exposure parameters as extracted by the EVA processing method could be risk-indicative. In these cases the statistical technique proposed offers great possibilities to pinpoint the relevant aspects of the exposure of interest, so that they can be used in epidemiologic designs.

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Chapter 4
Effects of measurement strategy and statistical analysis on dose-response relations between physical work load and low back pain

Adapted from: Jansen JP, Burdorf A. Effects of measurement strategy and statistical analysis on dose-response relations between physical work load and low back pain. Occup Environ Med 2003;60:942-7.

Abstract

Objective. In epidemiologic studies on physical work loads and back complaints, among the important features in modeling dose-response relations are the measurement strategy of the exposure and the nature of the dose-response relation that is assumed. The aim of the present study is to evaluate the effect of these two features on the strength of the dose-response relation between physical load and severe low back pain.

Methods. The study population consisted of 769 workers in nursing homes and homes for the elderly. Observations at the workplace were made of 212 subjects. These observations were analyzed to determine exposure to physical load according to two measurement strategies: the individual approach and the group approach. The nature of the dose-response relation was evaluated with nested logistic regression models.

Results. The group approach resulted in higher odds ratios for the associations between physical load and low back pain than the individual approach. Spline logistic regression models appeared to describe the dose-response relation between physical load and low back pain best. The corresponding curve showed small changes in risk for small changes in exposure, whereas the categorical model only showed sudden large changes in risk at predefined exposure values.

Conclusion. The choice for a particular measurement strategy of physical load influences the strength of the associations between physical load and severe low back pain. Spline models allow changes in risk over the whole exposure range and are therefore a promising approach to identify quantitative dose-response patterns between physical load and low back pain.

Introduction

Back disorders are a major health problem in many occupational populations. Among others physical load has been identified as a significantly contributing factor in the occurrence of low back pain (LBP) (1,2). Despite the evidence associating LBP with these variety of work factors quantitative dose-response relations are far from clear. In most studies assessment of physical load is based on qualitative self-reports or on an expert's opinion on presence or absence of generic risk factors such as awkward postures, static load, and heavy labor. In order to study dose-response relations between physical load and LBP, attention needs to be directed to quantitative characterization of physical load. In the past two decades several methods have become available that facilitate a more quantitative approach to assess physical load in the workplace, such as observation techniques. Observation techniques have the advantage of being easily applicable in many work situations combining sufficient detail of the important dimensions of physical load (3,4).

In general, to measure exposure levels of physical load with observation techniques two approaches can be used: 1) the individual approach, in which every worker is observed, and 2) the group approach, in which subjects are grouped into several a priori defined groups and samples of these groups are observed. It has been shown that the group approach may greatly reduce the measurement effort required, but at the expense of precision of the risk estimates (5,6). The individual approach is often associated with considerable random error and, hence, will lead to the attenuation of risk estimates. This is less likely using the group approach, given that enough subjects are observed with a sufficient number of repetitions. In contrast to the group approach, the effect of measurement error on the degree of attenuation is well described for the individual approach and several authors have suggested methods for the correction of risk estimates for measurement error (5,7-9). To our knowledge, the choice of the measurement approach on the measures of association between exposure and outcome in musculoskeletal epidemiology has never been evaluated.

The quantitative relation between physical work load and the occurrence of LBP is not monotonic increasing, with an increased intensity or duration of exposure resulting in an increased risk of disease. When describing dose-response relations for physical load, a u-curve probably better describes the nature of the associations (10,11). Modeling the dose-response relation between physical load and LBP with statistical models that follow a linear form may be unable to identify existing patterns of exposure and associated risks when applied over the whole exposure range. Modeling the dose-response relation by breaking the range of study exposure (physical load) in several categories and comparing the trend in category-specific risk estimates also has drawbacks. Among others, it assumes homogeneity of risk within categories of exposure and allows large changes in risk between these categories (12). An alternative to these approaches are spline analyses. Like categorical regression analysis the splines allow changes in risk at the boundaries of the categories. However, the advantage of the spline approach is that it also makes use of information within categories of exposure (as is not the case with the categorical analysis). Splines allow the risk to vary within and between categories of exposure (13).

The purpose of the present study is 1) to evaluate the effect of measurement strategy of physical work load on the relations between physical work load and LBP;

and 2) to compare dose-response relations of physical work load and LBP acquired with different statistical techniques.

Material and methods

Population

The subjects in the present study (n=769) participated in a large epidemiologic study among nursing home personnel. The study population consisted of 9 different occupational groups: 129 nurses, 264 care givers, 58 kitchen workers, 49 housekeepers, 14 transportation and technical workers, 9 laundry workers, 38 (physical) therapists, 146 office workers, and 62 miscellaneous workers. All subjects worked for more than 10 hours a week.

Data collection

Questionnaire survey

Information on back problems during a period of 12 months was gathered with self-administered questionnaires. The questions were derived from the Nordic questionnaire for the analysis of musculoskeletal symptoms (14). Severe LBP was defined as an episode of low back problems in the past 12 month with severe pain, defined as those subjects whose back problems exceeded the pain intensity score of 50 according to the Von Korff-scheme for gradation severity of chronic pain (15). 153 Of the 769 subjects (19.8%) experienced an episode severe LBP in the past 12 months.

The Karasek job-control, skill-discretion, job-demands dimensions were used to collect information on psychosocial work demands (16). These dimensions were combined in a dichotomous measure reflecting "low job decision latitude with high job demands" versus "other".

Quantitative assessment of physical load

Among a random sample of 212 workers, observations at the workplace were performed to collect information on physical load during work among the 9 *a priori* defined occupational groups. In this study an observational multimoment method was used to describe three measures of physical load: trunk flexion over 20 degrees, trunk flexion over 45 degrees and lifting or carrying loads over 10 kg, all expressed in percentage of work time. On each of the workers every 20 seconds observations were made during 4 periods of 30 minutes stratified over one whole working day, thus collecting 360 observations per worker.

Individual approach. For each of the 212 observed workers, the subset of the population, the individual exposure to the different physical work loads was estimated by the average percentage of work time over the 4 measurement periods on that subject

Group approach. For each occupational group the average exposure to the physical work loads of that group was calculated as the average of the individual exposure of the observed workers (as determined by the individual approach) in that group. This group arithmetic mean was used as a proxy for exposure of all subjects, both observed and unobserved, in a given occupational group.

Besides the subject's average exposure expressed in *percentage work time* a cumulative exposure to physical load per work week was calculated by multiplying the average exposure with the number of work hours per week per individual. With the individual approach this cumulative exposure is expressed in *work hours per week* for the subset of 212 workers and with the group approach this cumulative exposure is expressed for both the subset as well as each worker in the study (n=769).

Data analysis

Physical load

To estimate the ratio of the between-subject variance of the physical work loads and the within-subject variance of the physical work loads a one-way analysis of variance was performed. A random effect model was used, since the observed workers were regarded as random 'samples' from the total study population, and the four repeated measurements on each worker were assumed to be drawn at random from the total exposure distribution from each worker. Since the underlying distributions of exposure were assumed to be best described by normal distributions, the variance components were estimated by S^2_{bs} (between-subject variance) and S^2_{ws} (within-subject variance), using proc NESTED in SAS statistical software (17). To estimate the partitioning of the total variance in the variance components occupational groups, subjects, and within subjects a nested two way analysis of variance was performed.

Measurement approach, physical load and low back pain

To evaluate the effect of the two measurement approaches (the individual approach and the group approach) on the associations between physical load and severe LBP logistic regression analyses were performed on three sets of data: 1) data set WSG consisted of the Whole Study population and exposure to physical load was determined by the Group approach; 2) data set SSI consisted of the SubSet of 212 observed workers and exposure to physical load was determined by the Individual approach; 3) Data set SSG consisted of the SubSet of 212 observed workers and exposure to physical load was determined by the Group approach. Finally the estimates with the individual approach were corrected for measurement error according to Lui et al. (9).

Nature of the dose-response relations of physical load and low back pain

To analyze dose-response relations for the physical load factors (expressed in work hours per week) and severe LBP, a sequence of nested logistic regression models (13) were compared using data set WSG. The models assessing the dose-response relations were 1) the linear logistic regression model, 2) the quadratic logistic regression model (a quadratic term for the exposure added to the linear model), 3) the quadratic spline logistic regression model, and 4) the restricted quadratic spline logistic regression model. In contrast to the linear (and quadratic) model, the spline model allows for flexibility in modeling the dose-response curve. Specifically if the exposure measure is divided into a number of intervals, then a linear spline would model the response as a series of line segments connecting these points. To smooth out the connections between the line segments a further improvement is the quadratic spline, which allows for a parabolic curve to connect the points. Because of the possibility of instability in the tails of the exposure measure, a restricted spline model allows for the curve at either end to be replaces by a line segment. Performance of the 4 logistic regression models in terms of goodness of fit was judged by the use of likelihood ratio statistics. The model that described the dose-response relations best was compared with the classical categorical models.

For the categorical analysis and the splines the continuous physical load variables were divided into four categories based on the distributions of these variables with cutoffs at 25th, 50th, and 75th percentiles of exposure. Next to the physical work loads, potential confounders psychosocial work demands and age were entered in the model as co-factors. The models were fitted on data of the whole study population (data set WSG) and parameters were estimated with proc Logistic in SAS statistical software (17). With proc IML available in SAS odds ratios (OR) and 95% confidence intervals (95% CI) were calculated in reference to exposure at the midpoint of the lowest exposure category (12.5th percentile of the distribution).

Results

Physical load

Results of the analysis of variance of the observations of physical load (measured with the individual approach) are presented in Table 4.1. The overall percentage of working time in trunk flexion over 20 degrees was 20.4%, for trunk flexion over 45 degrees was 4.4%, and for lifting and carrying over 10 kg 0.9%. Considerable differences existed between workers' exposure levels (the between subject variance). Furthermore, the largest variance ratio of within-and between subject variance was found for lifting and carrying loads over 10 kg.

Table 4.1 Overall mean and variability of trunk flexion over 20 degrees, trunk flexion over 45 degrees, and lifting and carrying loads over 10 kg expressed in percentage work time

(n=212)	*Mean (SD[a])*	S^2_{bs} [b]	S^2_{ws} [c]	λ [d]
Trunk flexion over 20 degrees	20.4 (11.4)	96.8 (41.3%)	137.0 (58.7%)	1.4
Trunk flexion over 45 degrees	4.4 (4.5)	14.2 (35.9%)	25.5 (64.1%)	1.8
Lifting and carrying loads over 10 kg	0.9 (1.6)	1.2 (16.5%)	6.2 (83.5%)	5.2

[a] SD = Standard deviation
[b] S^2_{bs} = between-subject variance
[c] S^2_{ws} = within-subject variance
[d] λ = variance ratio S^2_{ws} / S^2_{bs}

In Table 4.2 the distribution of the variance over the groups, workers, and within-workers is presented. Assigning the workers to occupational groups reduced the between-subject variance, with the between-group variance not capturing more than

10% of the total variance. The within-subject variance captured 58.6% to 82.2% of the total variance.

Table 4.2 Variance components of trunk flexion over 20 degrees, over 45 degrees, and lifting and carrying loads over 10 kg expressed in percentage work time for the group approach

(n=212)	S^2_{bg} [a]	S^2_{bs} [b]	S^2_{ws} [c]
Trunk flexion over 20 degrees	3.2 (1.3%)	94.1 (40.1%)	137.8 (58.6%)
Trunk flexion over 45 degrees	2.8 (6.8%)	12.0 (29.8%)	25.5 (63.4%)
Lifting and carrying loads over 10 kg.	0.7 (9.4%)	0.6 (8.4%)	6.2 (82.2%)

[a] S^2_{bg} = between-group variance
[b] S^2_{bs} = between-subject variance
[c] S^2_{bs} = within-subject variance

Table 4.3 Corrected and uncorrected logistic regression estimates for the associations of trunk flexion over 20 and 45 degrees and lifting and carrying over 10 kg with the risk of low back pain using the individual approach and group approach of observations

	OR [a] *(95% CI)* [b]			
	Individual approach, corrected for measurement error [c] *(SSI, n=212)*	*Individual approach (SSI, n=212)*	*Group approach (SSG, n=212)*	*Group approach (WSG, n=769)*
Trunk flexion over 20 degrees				
% work time (unit is 5%)	0.91	0.93 (0.79-1.10)	1.00 (0.52-1.93)	0.94 (0.64-1.40)
Work hours per wk	0.91	0.93 (0.84-1.04)	0.93 (0.75-1.14)	0.95 (0.87-1.04)
Trunk flexion over 45 degrees				
% work time (unit is 5%)	1.36	1.23 (0.86-1.78)	2.06 (0.73-5.86)	1.85 (1.07-3.20)
Work hours per wk	1.06	1.04 (0.79-1.36)	1.18 (0.62-2.26)	1.22 (0.89-1.67)
Lifting and carrying loads over 10 kg.				
% work time (unit is 5%)	1.18	1.08 (0.34-3.40)	1.26 (0.14-11.77)	4.09 (1.41-11.90)
Work hours per wk	0.65	0.84 (0.37-1.90)	1.00 (0.24-4.10)	1.62 (0.84-3.12)

[a] OR =odds ratio
[b] 95% CI = 95% confidence interval
[c] Correction method based on Lui et al. (9)

Physical load and low back pain, the effect of measurement approach

In Table 4.3 the effect of the measurement approach on the observed associations between physical load and severe LBP is presented. In reference to the measurement-error-corrected estimates the individual approach (SSI) showed that measurement error had an effect on the point estimates for trunk flexion over 45 degrees and lifting and carrying loads over 10 kg; the uncorrected estimates were closer to unity. The attenuation (defined as the relative difference between corrected and uncorrected estimates) of exposure to physical load expressed in percentage of work time was comparable with the attenuation of exposure expressed in work hours per week.

The group approach resulted in higher odds ratios than the individual approach at the expense of larger confidence intervals. Data set WSG showed significant associations for the effect of trunk flexion over 45 degrees and lifting and carrying loads over 10 kg expressed in percentage work time. These associations were not present when exposure was expressed in work hours per week.

Physical load and low back pain, nature of the dose-response relations

The traditional way to analyze the dose-response relation between lifting and carrying over 10 kg and severe LBP with the categorical model is presented in Figure 4.1. For lifting and carrying between 0 and 7.5 minutes the OR was set at 1.00 (the reference category). Between 7.5 and 15 minutes an OR of 2.13 (95% CI 1.10-4.14) was found, and between 15 and 30 minutes of exposure an OR of 1.38 (95% CI 0.84-2.29), and more than 30 minutes of lifting and carrying resulted in an OR of 1.33 (95% CI 0.84-2.11).

Nested models (linear, quadratic, quadratic restricted spline, and quadratic spline) were compared to each other with the likelihood ratio test (see Table 4.4). The restricted quadratic spline model described the dose-response relation between lifting and carrying loads over 10 kg and severe LBP significantly better than the linear and quadratic model, and appeared the satisfactory model to reflect the dose-response patterns among the data. The quadratic spline with no restrictions appeared to be no improvement over the restricted spline. In Figure 4.1 this restricted spline is presented and the ORs are in reference to exposure measured at the median of the lowest exposure category (12.5th percentile) and corresponds to about 3.6 minutes of exposure to lifting and carrying. For 7.5 minutes of lifting and carrying loads per week an OR of 1.58 (95% CI 1.32-2.00) was found, for 15 minutes an OR of 1.71 (95% CI 1.17-2.49) was found, for 30 minutes of exposure an OR of 1.04 (95% CI 0.63-1.70), and for 40 minutes of lifting and carrying loads an OR of 1.06 (95% CI 0.67-1.67) was found. With the spline the ORs up to 15 minutes changed in a much more regular way than with the categorical model; the differences between the two models were most striking at 7.5 and 15 minutes of exposure, the borders of the lowest two exposure categories.

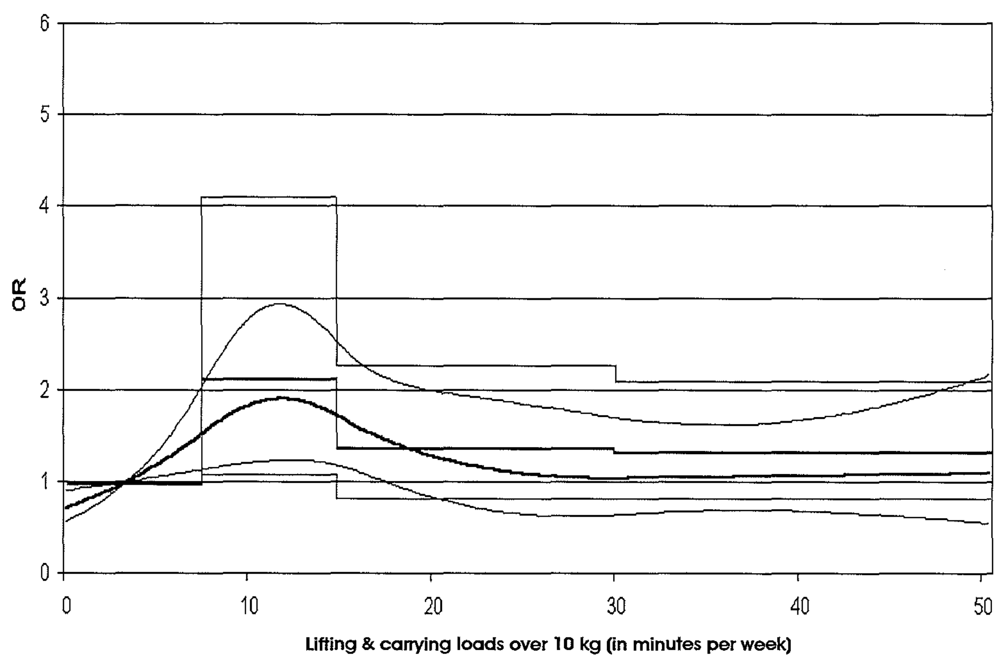
For trunk flexion over 20 degrees and trunk flexion over 45 degrees comparable results were found, the quadratic spline model (with restrictions) appeared to be the most satisfactory model to reflect variations among the data. (Likelihood ratio test results not presented.) The associations appeared to be described by an upward arc-shaped curve; increasing exposure resulted in increasing risk of back problems followed by a decreasing risk. However the ORs for severe LBP over the range of exposure were not statistically significant.

Table 4.4 Comparison of the nested logistic models for the relation between physical work loads (Lifting and carrying loads over 10 kg) and low back pain (Method by Witte and Greenland (13))

Model	*-2 log likelihood*	*Likelihood ratio* [a]	*Degrees of freedom*	*P-value*
Lifting and carrying loads over 10 kg (work hours per week)				
Intercept only	721.5			
Linear	711.1	10.4[b]	1	0.02
Quadratic	707.0	4.1[c]	1	0.04
Quadratic spline restricted both tails	703.3	3.7[d]	1	0.05
Quadratic spline	700.5	2.8[e]	2	0.25

[a] Likelihood ratio statistic (χ^2) comparing the nested models
[b] compared to the intercept only model
[c] compared to the linear model
[d] compared to the quadratic model
[e] compared to the quadratic spline restricted both tails

Figure 4.1 Restricted quadratic spline and categorical model for the relation between lifting and carrying loads over 10 kg and low back pain adjusted for age and psychosocial work demands: Odds ratios and 95% confidence intervals are in reference to the 12.5% percentile (3.6 minutes of exposure)



Discussion

To identify quantitative dose-response relations between physical work load and severe LBP, quantitative characterization of physical load and determination of the nature of the relation between physical load and severe LBP are essential. In the present study we evaluated the effects of measurement strategy and the choice of statistical models on the dose-response relations between physical work loads and severe LBP.

Measurement approach

When establishing dose-response relations for back disorders, assessment of physical load should be able to result in valid estimates of workers. Direct observation techniques may meet this requirement when a sufficient number of exposure assessments are performed. In general, two measurement approaches can be identified: the individual approach and the group approach.

It appeared that for all physical load factors the within-subject variance captured a much larger part of the total variance than the between-subject variance, especially for lifting and carrying loads over 10 kg. This implies that many measurements are necessary to arrive at valid estimates of exposure to these physical factors for a given subject. For example a variance ratio of 1.4 for trunk flexion over 20 degrees implies that 12 repeated measurements are necessary to obtain an estimate with a reliability of 90% (3). Assigning workers to pre-defined groups with the group approach resulted in a small reduction of the between-subject variance since less than 10% of the total variation in exposure was captured by the between group-variance. This variance analysis strongly suggested that the pre-defined occupational groups (by job title) did not reflect distinguishable exposure profiles of physical work loads.

The individual approach and attenuation

With the individual approach the differences in variance ratios among the physical load factors are reflected by the degree in attenuation of the dose-response relations of these factors. When the corrected estimates of the dose-response relations were used as a reference, the point estimates for the effect of lifting and carrying loads over 10 kg were mostly affected by attenuation, followed by trunk flexion over 45 degrees. Trunk flexion over 20 degrees was not notable affected by attenuation. With the introduction of the individual work hours per week to create the cumulative measure of exposure the variance ratios were not changed significantly (data not shown) and, hence, the degree of attenuation was comparable for exposure expressed in percentage work time and work hours per week.

The group approach versus the individual approach

In the present study, the group approach (SSG) resulted in stronger associations for trunk flexion over 45 degrees and lifting and carrying loads over 10 kg expressed in percentage work time than the individual approach (SSI). In general, attenuation resulting from the group approach is a fraction of the attenuation resulting from the individual approach (5). However, since in the present study the groups explained less than 10% of the total variance of physical load the stronger associations of the group approach can hardly be explained by less attenuation. In reference to the estimates corrected for measurement error, it seems that the associations for trunk flexion over 45 degrees and lifting and carrying loads over 10 kg with the SSG group approach were even overestimated. Simulation studies (18,19) have shown that Berkson measurement error (as is the case with the group approach) may result in bias in logistic and log-linear models with dichotomous outcomes. The bias is away from the null in estimating dose-response relations when, among others, the groups' variance of exposure increases with the groups' mean of the exposure. The correlation coefficient between the mean and the standard deviation of the percentage of work time in trunk flexion over 45 degrees among the different occupational groups was 0.90 and for lifting and carrying loads over 10 kg 0.97. Besides the estimates for exposure to physical load expressed in percentage of work time bias may also have affected the estimates for the cumulative exposure expressed in work hours per week. Simulation studies have shown that when cumulative measures of exposure are used that are a combination of data at a group level and individual level, estimates may be biased away or towards unity (19).

The group approach. The whole study population versus observed subset

In contrast to the group approach applied on the subset of observed individuals (SSG) the group approach applied on the whole study population (WSG) showed statistically significant associations that are the result of the larger study population that allowed more precise estimates of the associations. The largest differences in odds ratios between SSG and WSG were observed for lifting and carrying. From a theoretical point of view, the exposure parameter with the lowest occurrence will have the highest misclassification since levels close to zero will be (too) difficult to assess accurately.

Trunk flexion over 45 degrees and lifting and carrying loads showed significant associations expressed in percentage of work time, whereas these factors were not significant when expressed in work hours per week. Besides the possibility of bias due to the cumulative measure of exposure (as mentioned above), the disappearance of significant associations can also be explained by the fact that subjects who worked 40 or more hours per week experienced less severe LBP (OR= 0.30, 95% CI 0.09-1.03 in reference to subjects working less than 20 hours per week). In particular a negative association between work hours and severe LBP was found in the group of workers with the highest exposure to physical load (expressed in percentage work time). Hence, in the present cross-sectional study the results are indicative of a healthy worker effect where subjects without severe LBP experience longer work weeks than subjects with severe LBP.

Nature of dose-response relations

A hierarchy of nested logistic regression models (13) was used to determine a model rich enough to capture patterns of exposure and associated risk among the data. In comparison with the linear and quadratic models, the restricted quadratic spline models fitted the dose response relations between the three physical load factors and severe LBP among the data best. The associations between trunk flexion over 20 and 45 degrees and severe LBP were described by an upward-arc shaped curve. However, the associations were not statistically significant. For lifting and carrying loads over 10 kg the upward-arc shaped curve representing significant associations up to eighteen minutes of exposure was followed by associations close to unity. In contrast to these upward-arc shaped curves, some authors have stated that absence of any physical load as well excessive physical load is considered a risk for back problems, as described by a U-curve

(10,11). As shown above, subjects without severe LBP worked more hours per week than subjects with severe LBP, especially among groups that are exposed to high physical load for a large percentage of their work time. This healthy worker effect resulted in the negative trend of the dose-response curve for the cumulative calculated exposure to physical load expressed in work hours per week.

The quadratic spline was compared with the more traditional approach of dose-response analysis, the categorical model. The categorical model results in dose-response associations that follow a step-wise pattern with abrupt changes in risk at the transition of one exposure category to the other. The most dramatic change in risk caused by a small change in exposure was found for exposure to lifting and carrying up to 15 minutes per week. In contrast with the categorical model, the quadratic spline model is able to pick up variation among the data within categories and the shape of the dose-response curve is therefore less sensitive to the choice of cutoff points for the categories as additional analysis showed (results not presented). In the present study, the resulting dose-response curve was a more realistic representation where a small change in exposure resulted in a small change in the risk of severe LBP. Such a smooth curve allows identifying thresholds of exposure where exposure to physical load really becomes an issue in the occurrence of severe LBP. However, the cross-sectional nature of the present study limits the interpretation.

When only a few exposure categories can be defined due to a limited number of subjects in the study, splines may have an advantage over the categorical approach. The categorical analysis may not capture the pattern of the dose-response relations since large changes in risk may occur within the same broad exposure category. Therefore, spline models will probably have an advantage when dose-response relations are estimated with the individual approach because the number of subjects is often not very large, simply due to the fact that all subjects in the study have to be measured repeatedly. Since the individual approach was not the best approach to estimate individual exposure to physical load in the present study, we did not perform dose-response analysis on exposure data based on this approach.

When the group approach is used to assess exposure to physical load, spline models are only of use when these group estimates of physical load are multiplied by individual information, such as work hours per week, in order to reach for a continuous exposure scale. (With the group approach only as many different exposure values exist as there are occupational groups.) However, in the present cross-sectional analysis this cumulative exposure duration was affected by bias due to a healthy worker effect.

Conclusions

In the present study two features of dose-response modeling were scrutinized: the measurement strategy of the exposure and the nature of the dose-response relation defined by statistical models. One has to realize that choices in study design, sample size, and handling of bias and confounding are important when dose-response relations are determined. Although there are limitations to draw conclusion from one data set, the present study showed that the choice for a particular measurement strategy of physical load influenced the strength of the associations between physical load and severe LBP. Furthermore, statistical models that anticipate a linear relation between physical load and severe LBP may be unable to identify patterns of exposure and associate risks among the data when applied over the whole exposure range. Categorical models have also drawbacks, since broad categories of exposure may not reflect relevant effects of physical load on severe LBP. It has to be noted that it is of major importance to obtain valid estimates of exposure to physical load before the nature of the dose-response relations is investigated; without valid estimates this is of no use. However, when indeed valid estimates of physical work load are obtained, this enormous measurement effort asks for statistical techniques that make full use of the informational content. Hence, spline models are a promising approach to identify quantitative dose-response patterns between physical load and LBP.

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Part 2

Dose-response relations of occupational exposures to physical and psychosocial factors and the onset and aggravation of low back pain

Chapter 5

Dose-response relations between occupational exposures to physical and psychosocial factors and the risk of low back pain

Adapted from: Jansen JP, Morgenstern H, Burdorf A. Dose-response relations between occupational exposures to physical and psychosocial factors and the risk of low back pain. Occup Environ Med 2004; in press

Abstract

Objective. To assess dose-response relations between occupational exposures to physical and psychosocial factors and the risk of low back pain.

Methods. A cohort of 523 subjects, working in nursing homes and homes for the elderly, was followed prospectively for one year. Physical load for different occupations was assessed by quantitative observations at the work place. Information on low back pain and other factors was gathered with questionnaires administered at baseline and at one year. Two outcome measures of low-back-pain incidence were used: any new episode of pain lasting for at least a few hours during follow-up (LBP); and any new episode of disabling pain that interfered with daily activities during follow-up (LBP/D). Hierarchical regression analysis with a spline function was used to estimate dose-response relations.

Results. The risk of LBP was not associated with physical factors, controlling for confounders; but this outcome was inversely associated with age and weakly, though imprecisely, associated with two psychosocial factors--low decision authority and high work demands. In contrast, the risk of LBP/D was positively associated with age and unassociated with the psychosocial factors. Trunk flexion over 45 degrees was monotonically associated with the risk of LBP/D; the estimated relative risk was 3.18 (95% confidence interval 1.13-9.00) for 1 hour and 45 minutes of bending per week (90th percentile), relative to 30 minutes per week. The hierarchical estimates of effect were more stable than were the maximum likelihood estimates.

Conclusion. Occupational exposure to trunk flexion over 45 degrees appears to be a risk factor for low back pain with disability among persons employed in nursing homes and homes for the elderly in the Netherlands.

Introduction

Back disorders are a major health problem in many occupations. Physical loads at work, such as manual materials handling, frequent bending and twisting, lifting, and forceful movements, have been identified as possible risk factors for low back pain (LBP). Furthermore, psychosocial work factors may have a contribution as well;. the results of several studies suggest that Karasek's model, i.e. high work demands in combination with low job control and decision latitude, affect the risk of LBP (1-3). Many of those studies, however, did not include measures of both physical and psychosocial work factors as well as other potential confounders. Although we know very little about dose-response associations between occupational exposures and LBP risk, some authors have suggested that the relation between physical work load and LBP is U-shaped rather than monotonic (4,5). Apart from the need to assess quantitatively the broad array of occupational exposures, we must also consider the full spectrum of LBP, including minor episodes of short duration as well as severe and disabling episodes that persist for long periods (6-8).

In order to estimate dose-response relations with sufficient detail, quantitative information on exposures to possible risk factors is necessary. In the past two decades, observational methods have been developed to facilitate a quantitative assessment of physical load at the workplace (9-13). The large measurement efforts involved with these methods require statistical techniques that make complete use of all data. Furthermore, these statistical techniques should allow for possible non-linearities between exposure and risk, for example, using spline analysis (14,15).

In many occupations, exposure to physical load is not limited to one physical factor but encompasses many factors such as trunk flexion, rotation, lifting, and carrying. Often these physical factors are strongly inter-correlated. In epidemiologic studies, conventional approaches for analyzing such correlated exposures (e.g., deleting certain variables from the model or adjusting the alpha level) may invoke problems of multiple comparisons (16). Several authors have shown that hierarchical regression models provide an alternative to these conventional approaches and can have important advantages in the adjustment for covariates that are strongly interrelated (16-19).

In the study reported here, dose-response relations of physical load at work, psychosocial work factors, and other factors with the incidence of LBP and LBP with disability (LBP/D) are investigated simultaneously.

Material and methods

The study population consisted of workers from 7 nursing homes and homes for the elderly in the Netherlands. Workers employed for more than 10 hours per week were eligible to participate in the study. Baseline measurements performed between March 1998 and March 1999, included the assessment of physical load for each occupation at the workplace and a self-administered questionnaire. Follow-up measurements were performed one year after the baseline measurements.

Of the 1,208 subjects invited to participate in the study, 769 (64%) agreed to participate. After one year, 523 (68%) of the 769 subjects were observed again. These subjects worked in 9 professions: 85 nurses, 197 care givers, 26 kitchen workers, 23 housekeepers, 9 transportation and maintenance workers, 8 laundry workers, 24 physical therapists, 108 office workers, and 43 miscellaneous workers. For the analyses reported in this paper, we selected those workers who reported at baseline no LBP in the previous 12 months.

Data collection

Quantitative assessment of physical load

In a group of 212 workers randomly sampled at baseline, observations were made at the workplace on physical load during work for each of the 9 occupations. The proportion of observed subjects per group ranged from 16% for the nurses to 64% for the transportation and maintenance workers, thereby oversampling those occupations with fewer subjects. The primary aim was to have at least 10 workers in each occupation in order to arrive at a reasonable estimate of the average exposure of each group (9). In the 3 largest occupational groups at least 10 workers were sampled in 4 different nursing homes in order to increase generalisibility across homes. An observational multimoment method was used to describe three measures of physical load: trunk flexion between 20 degrees and 45 degrees, trunk flexion over 45 degrees, and lifting or carrying loads over 10 kg, all expressed in percentages of work time. Observations were made on selected workers every 20 seconds during 4 periods of 30 minutes each in one working day; thus, we collected 360 observations per worker. For each occupation, the average exposure to each type of physical load was calculated as the mean percentage of time devoted to that activity. An underlying assumption of this strategy is that the average physical load of the observed workers is equal to the average physical load of the total occupational group. Thus, the arithmetic mean for the group was used as a proxy for exposure in all subjects, both observed and unobserved, in that occupation (9,11-13). To estimate an individual's cumulative exposure to physical load, the occupation-specific exposure expressed in percentage of work time was multiplied by self reports of the number of hours worked per week.

Questionnaire survey

A questionnaire was used to collect personal data on age, job history, including the number of years employed at that facility, and LBP in the past 12 months.

Information was collected on three psychosocial work factors included in Karasek's model (20): decision authority, skill discretion, and work demands. The 11 questions on decision authority reflected aspects such as influence on the planning of tasks, influence on the pace at work, brief pauses when needed, and decisions on time spent on given tasks (Cronbach's alpha 0.90); the 6 questions on skill discretion reflected required skills, task variety, learning new things, and amount of repetitive work (Cronbach's alpha 0.80); and the 11 questions on work demands reflected working fast, working hard, excessive work, insufficient time to complete the work, and conflicting demands (Cronbach's alpha 0.88). The response to each question was scored on a 4-point ordinal scale. The total score for each factor was computed by summing the item scores for all questions related to that factor and expressing the sum on a 0-100 scale. A score of 100 was defined as least desirable for that factor— i.e. low decision authority, low skill discretion, and high work demands (8,21).

Information on the occurrence and nature of LBP was measured at baseline and at follow-up with questions derived from the Nordic questionnaire for the analysis of musculoskeletal symptoms (22). This questionnaire has been shown to be valid for collecting information on the nature, duration, and frequency of symptoms. In this study, LBP was defined as any episode of pain that lasted for at least a few hours in the previous 12 months. An incident case of LBP was defined as the report of LBP at follow-up among subjects who reported no LBP at baseline. LBP/D in the previous 12 months was defined as a report of LBP for which the Von Korff et al. disability score was greater than 50, indicating "high disability" (23). This second outcome event is a subset of the first. An incident case of LBP/D was defined as the report of LBP/D at follow-up among subjects who did not report LBP/D at baseline (but who might have reported any LBP at baseline).

Data analysis

Log-linear models with quadratic splines were used to assess dose-response relations for 8 possible predictors of LBP and LBP/D incidence: trunk flexion between 20 and 45 degrees, trunk flexion over 45 degrees, lifting and carrying loads over 10 kg, decision authority, skill discretion, psychosocial work demands, years of employment in the facility, and age at baseline. The choice for these predictors and their particular cutoff values were based on a literature review and a cross-sectional analysis (1,13) These variables were entered in the multivariate model simultaneously. In order to capture non-linearities all continuous variables were categorized into tertiles of the observed distributions to allow for a quadratic spline function (14,15). On the basis of likelihood ratio statistics, it appeared that a full quadratic spline (for all categories) did not fit the data better than did a restricted quadratic spline in which a linear spline was used for the lowest category. Since this restricted spline has one linear and two quadratic terms per factor, the 8 predictors resulted in $3 \times 8 = 24$ parameters and an intercept that had to be estimated. The model was fitted using Proc Genmod (with a log link-function) available with SAS statistical software (24).

This conventional (one-stage) method may result in large standard errors when the number of parameters in the model is large or these parameters are highly correlated, due to instability of the maximum-likelihood estimates (16). As shown by Greenland and colleagues (16-18), the maximum-likelihood estimates can be improved by fitting a second-stage linear model in which *a priori* similarities among certain parameters are taken into consideration. The variances of the physical factors as well as the psychosocial factors were constrained and assumed to have a similar magnitude, thereby introducing more stable and accurate estimates. In this hierarchical regression approach, estimated parameters from the first stage are treated as outcomes in the second stage. For these analyses, the 8 predictors were grouped into three relatively homogeneous domains: the three physical factors, the three psychosocial factors, and the two time-related factors (age and years of employment). In the second stage, we assumed that the effect estimates for the factors within a domain are similar. One second-stage covariate per domain is not sufficient to describe similarities among the predictors because we have both linear and quadratic terms for each predictor and because we cannot assume that these two terms are similar. Therefore, two second-stage covariates per domain were used, which yielded 6 second-stage covariates in the model. The actual values of the second-stage covariates (design matrix with elements z_{pc}, with $p = 1,..., 24$ and $c = 1,..., 6$) were calculated as follows: $z_{pc} = 1/w$ for the linear parameters and $z_{pc} = 1/w^2$ for the quadratic parameters, where w is the length (in units of exposure) of the category corresponding to the particular parameter. With these values assigned to the covariates, the second-stage model described the prior curve of the spline for each of the 8 predictors with the relative risk at a given percentile of exposure equal for all factors in a domain.

A two-step procedure, described Greenland and Witte (16,18,25), was used to do the hierarchical regression analyses. The second-stage variances $\underline{\tau}^2$ could be estimated from the data with empirical Bayes methods; however, the large number of parameters relative to the sample size let us to pre-specify the $\underline{\tau}^2$ to upper and lower bounds for the parameters of the splines (i.e., a semi-Bayes approach) (16-18). We set τ_p^2 to 0.5, which corresponds to a prior certainty of 95% that the relative risk (RR) per unit exposure lies in a 16-fold range, that the RR per unit exposure, reflecting departure from linearity comparing the first and second categories, lies in a 16-fold range, and that the difference in the quadratic term between the second and third categories also lies in a 16-fold range.

For both the conventional spline models and the hierarchical spline models, estimated relative risks and corresponding 95% confidence intervals (CI) are presented at the 25th, 50th, 75th, and 90th percentiles of the exposure distribution, relative to the 10th percentile. Effect estimates are presented for both the conventional and hierarchical models to compare the point estimates, precision, and stability of the estimates.

Results

The estimated prevalence of LBP at baseline among workers in each elderly facility was not related to the response rate in that facility. Of the 769 subjects observed at baseline, 246 (32%) were not available to provide outcome information at follow-up. Of those lost to follow-up, 39 subjects changed jobs to employers not participating in the study. The estimated prevalences of LBP and LBP/D at baseline among subjects lost to follow-up were similar to the prevalences among subjects available for follow-up. Among those subjects free of LBP at baseline, no differences in the physical factors were found between workers available for follow-up and those lost to follow-up. Those lost to follow-up, however, were younger and had fewer years of employment at the facility. In addition, among those subjects free of LBP/D at baseline, those who were lost to follow-up reported less exposure to lifting and carrying loads over10 kg and less skill discretion than did those not lost to follow-up. No differences were found for decision authority and work demands between these groups.

Descriptive findings

In the baseline cohort of 523 workers, the estimated prevalence of LBP was 57.9%, and the estimated prevalence of LBP/D was 8.4%. The prevalence of LBP one year later was 54.5%, and the prevalence of LBP/D was 11.6%. The estimated one-year cumulative incidence (risk) of LBP was 58/220 = 26.4%, and the estimated one-year cumulative incidence of LBP/D was 42/479 = 8.8%. The estimated cumulative incidences of LBP and LBP/D for each occupation are presented in Table 5.1. Although the estimated cumulative incidence of LBP and LBP/D did not vary appreciably across occupations (at least for those occupations with more than 10 subjects at risk), the incidence of LBP was relatively low for nurses, and the incidence of LBP/D was relatively low for office workers.

Table 5.1 Cumulative incidence of LBP and LBP/D among different occupational groups

	LBP		LBP/D	
	n	*Cumulative incidence*	*n*	*Cumulative incidence*
Total	220	58 (26.4%)	479	42 (8.8%)
Nurses	34	5 (14.7%)	76	8 (10.5%)
Caregivers	74	25 (33.8%)	180	21 (11.7%)
Kitchen workers	12	4 (33.3%)	23	2 (8.7%)
Housekeepers	7	1 (14.3%)	19	2 (10.5%)
Transportation & maintenance workers	7	2 (28.6%)	9	1 (11.1%)
Laundry workers	6	0 (0%)	8	0 (0%)
Therapists	9	4 (44.4%)	23	2 (8.7%)
Miscellaneous	16	4 (25.0%)	37	4 (10.8%)
Office workers	55	13 (23.6%)	104	2 (1.9%)

The means and standard deviations of the 8 exposures at baseline are presented in Table 5.2 for all 523 workers. These results were similar for those subsets of workers free of LBP at baseline (n = 220) and free of LBP/D at baseline (n = 479). The greatest exposure to trunk flexion between 20 and 45 degrees was found among the therapists (5.7 hrs/wk), followed by the nurses (5.3 hrs/wk) and office workers (4.7 hrs/wk). Nurses experienced greater exposure to trunk flexion between 20 and 45 degrees than did caregivers (4.2 hrs/wk). The greatest exposure to trunk flexion over 45 degrees was found among transportation and maintenance workers (2.6 hrs/wk), followed by housekeepers (1.7 hrs/wk) and caregivers (1.3 hrs/wk). Caregivers experienced greater exposure to this type of trunk flexion than did nurses (1.0 hr/wk). Furthermore, the greatest exposure to lifting and carrying loads was found among nurses (38 min/wk). No other appreciable differences among occupations were observed for the other exposures.

Table 5.2 Descriptive information of the physical, psychosocial, and time related factors at baseline (n=523)

	Mean (SD[a])
Physical factors	
Trunk flexion between 20 and 45 degrees (hours per week)	4.5 (1.6)
Trunk flexion over 45 degrees (hours per week)	1.1 (0.6)
Lifting and carrying loads over 10 kg (minutes per week)	18.8 (16.1)
Psychosocial factors	
Decision authority[b]	40.5 (19.9)
Skill discretion[b]	41.8 (19.2)
Work demands[b]	46.9 (16.2)
Time related factors	
Age (years)	40.7 (9.7)
Years in service	9.3 (6.9)

[a] SD = Standard Deviation
[b] Range of score = 0 –100, the higher the score, the lower the experience on that factor.

Dose-response findings

Adjusted dose-response associations are presented in Table 5.3 for the estimated effects of 8 exposures on the one-year risk of LBP. The relative risks (and 95% CIs), comparing selected values of each exposure, were estimated using a conventional (one-stage) model and a hierarchical (two-stage) model. Similar results are presented in Table 5.4 for LBP/D. Note that, in general, the 95% confidence intervals are narrower with hierarchical regression than with conventional modeling.

Table 5.3 Results of the conventional and hierarchical analyses for the effect of the physical, psychosocial, and time related factors on incident LBP. RRs (and 95% CI) are presented for the 25th, 50th, 75th, and 90th percentile of the distribution in reference to the 10th percentile

		Conventional model RR (95% CI)[a]	*Hierarchical model RR (95% CI)*
Physical factors			
Trunk flexion between 20 and 45 degrees	2 hours pw[b]	1 reference	1 reference
	3 hours pw	1.25 (0.66-2.37)	1.12 (0.71-1.77)
	4 hours pw	1.55 (0.44-5.37)	1.25 (0.51-3.07)
	5 hours pw	1.55 (0.42-5.66)	1.21 (0.45-3.30)
	6 hours pw	1.13 (0.30-4.22)	0.91 (0.34-2.47)
Trunk flexion over 45 degrees	30 minutes pw	1 reference	1 reference
	45 minutes pw	0.99 (0.66-1.49)	1.08 (0.90-1.30)
	1 hour pw	0.98 (0.43-2.23)	1.16 (0.80-1.68)
	1 hour 30 min pw	1.31 (0.42-4.11)	1.34 (0.66-2.74)
	1 hour 45 min pw	2.02 (0.60-6.83)	1.40 (0.61-3.22)
Lifting and carrying loads over 10 kg.	1 minute pw	1 reference	1 reference
	5 minutes pw	1.01 (0.77-1.32)	0.93 (0.85-1.02)
	15 minutes pw	1.03 (0.38-2.77)	0.77 (0.54-1.08)
	30 minutes pw	0.54 (0.18-1.63)	0.56 (0.28-1.11)
	45 minutes pw	0.33 (0.08-1.40)	0.37 (0.13-1.09)
Psychosocial factors			
Decision authority	10 pct[c] (13.3)[d]	1 reference	1 reference
	25 pct (27.7)	1.27 (0.80-2.03)	1.25 (0.80-1.97)
	50 pct (41.2)	1.60 (0.65-3.95)	1.54 (0.64-3.71)
	75 pct (54.5)	2.14 (0.84-5.40)	2.03 (0.83-5.00)
	90 pct (66.7)	2.10 (0.74-6.00)	1.91 (0.71-5.18)
Skill discretion	10 pct (16.0)	1 reference	1 reference
	25 pct (27.8)	0.82 (0.53-1.28)	0.81 (0.52-1.26)
	50 pct (40.0)	0.70 (0.31-1.56)	0.69 (0.31-1.52)
	75 pct (55.6)	0.78 (0.36-1.67)	0.77 (0.36-1.64)
	90 pct (66.7)	0.65 (0.26-1.62)	0.67 (0.27-1.66)
Work demands	10 pct (27.0)	1 reference	1 reference
	25 pct (33.3)	1.01 (0.76-1.36)	1.03 (0.78-1.38)
	50 pct (45.5)	1.09 (0.53-2.23)	1.14 (0.56-2.31)
	75 pct (57.6)	1.47 (0.71-3.05)	1.47 (0.71-3.04)
	90 pct (66.7)	1.82 (0.76-4.39)	1.78 (0.75-4.27)
Time related factors			
Age	25 years	1 reference	1 reference
	30 years	0.78 (0.57-1.05)	0.80 (0.59-1.07)
	40 years	0.47 (0.19-1.16)	0.51 (0.21-1.22)
	50 years	0.37 (0.14-0.95)	0.38 (0.15-0.98)
	55 years	0.30 (0.11-0.82)	0.33 (0.12-0.88)
Years in service	1 year	1 reference	1 reference
	5 years	0.77 (0.41-1.45)	0.78 (0.43-1.40)
	10 years	0.81 (0.36-1.80)	0.79 (0.38-1.65)
	15 years	0.90 (0.35-2.32)	0.85 (0.34-2.10)
	20 years	0.82 (0.30-2.23)	0.79 (0.30-2.09)

[a] RR =Relative Risk & 95% CI =95% Confidence Interval; [b] pw =per week; [c] pct =percentile of distribution; [d] ( )=actual value

Table 5.4 Results of the conventional and hierarchical analyses for the effect of the physical, psychosocial, and time related factors on incident LBP/D. RRs (and 95% CI) are presented for the 25th, 50th, 75th, and 90th percentile of the distribution in reference to the 10th percentile

		Conventional model *RR (95% CI)*[a]	*Hierarchical model* *RR (95% CI)*
Physical factors			
Trunk flexion between 20 and 45 degrees	2 hours pw[b]	1 reference	1 reference
	3 hours pw	0.83 (0.33-2.09	0.95 (0.53-1.72)
	4 hours pw	0.70 (0.12-4.20)	0.90 (0.28-2.87)
	5 hours pw	0.60 (0.08-4.57)	0.83 (0.22-3.18)
	6 hours pw	0.50 (0.07-3.72)	0.80 (0.19-3.32)
Trunk flexion over 45 degrees	30 minutes pw	1 reference	1 reference
	45 minutes pw	1.56 (0.91-2.68)	1.31 (1.03-1.65)
	1 hour pw	2.44 (0.83-7.16)	1.71 (1.08-2.72)
	1 hour 30 min pw	6.49 (1.28-32.98)	2.82 (1.16-6.86)
	1 hour 45 min pw	9.82 (2.05-47.10)	3.18 (1.13-9.00)
Lifting and carrying loads over 10 kg.	1 minute pw	1 reference	1 reference
	5 minutes pw	1.02 (0.77-1.35)	1.05 (0.94-1.17)
	15 minutes pw	1.08 (0.39-2.99)	1.18 (0.79-1.77)
	30 minutes pw	0.71 (0.23-2.28)	1.33 (0.60-2.95)
	45 minutes pw	1.03 (0.25-4.25)	1.26 (0.38-4.20)
Psychosocial factors			
Decision authority	10 pct[c] (13.3)[d]	1 reference	1 reference
	25 pct (27.7)	1.10 (0.66-1.86)	1.07 (0.64-1.78)
	50 pct (41.2)	1.22 (0.45-3.32)	1.13 (0.42-3.04)
	75 pct (54.5)	1.55 (0.56-4.34)	1.50 (0.55-4.14)
	90 pct (66.7)	0.77 (0.21-2.82)	0.76 (0.21-2.72)
Skill discretion	10 pct (16.0)	1 reference	1 reference
	25 pct (27.8)	1.08 (0.62-1.88)	1.10 (0.63-1.89)
	50 pct (40.0)	1.19 (0.44-3.26	1.22 (0.45-3.31)
	75 pct (55.6)	1.41 (0.51-3.90)	1.44 (0.53-3.91)
	90 pct (66.7)	1.05 (0.36-3.09)	1.09 (0.38-3.16)
Work demands	10 pct (27.0)	1 reference	1 reference
	25 pct (33.3)	0.84 (0.60-1.19)	0.86 (0.61-1.21)
	50 pct (45.5)	0.72 (0.32-1.67)	0.75 (0.33-1.73)
	75 pct (57.6)	1.48 (0.65-3.36)	1.41 (0.63-3.18)
	90 pct (66.7)	1.59 (0.65-3.90)	1.45 (0.60-3.53)
Time related factors			
Age	25 years	1 reference	1 reference
	30 years	1.03 (0.74-1.43)	1.01 (0.73-1.40)
	40 years	1.09 (0.40-2.93)	1.03 (0.39-2.74)
	50 years	1.66 (0.56-4.93)	1.49 (0.52-4.25)
	55 years	1.81 (0..59-5.53	1.68 (0.57-4.90)
Years in service	1 year	1 reference	1 reference
	5 years	0.69 (0.33-1.45)	0.70 (0.35-1.41)
	10 years	0.47 (0.19-1.17)	0.45 (0.19-1.09)
	15 years	0.37 (0.12-1.09)	0.34 (0.12-1.01)
	20 years	0.33 (0.11-1.03)	0.32 (0.11-1.00)

[a] RR =Relative Risk & 95% CI =95% Confidence Interval; [b] pw =per week; [c] pct =percentile of distribution; [d] ( )=actual value

Physical work load

Although the estimated risk of LBP is monotonically associated with trunk flexion over 45 degrees, using hierarchical regression, the association is weak and the relative risks for high exposures are imprecisely estimated. The association with this exposure is much stronger, however, for LBP/D. The relative risk estimated from the hierarchical model was 3.18 (95% CI 1.13-9.00) for 1 hour and 45 minutes of bending per week (90th percentile) relative to 30 minutes per week. There was little association between trunk flexion between 20 and 45 degrees and either outcome. For lifting and carrying loads over 10 kg, there was little association with LBP/D using either method, but there was an unexpected inverse association with LBP.

The 95% confidence intervals were narrower for effect estimates derived from hierarchical models than for those effect estimates derived from the conventional models. This difference was largest for the estimated effect of trunk flexion over 45 degrees on the incidence of LBP/D. For the effects of trunk flexion between 20 and 45 degrees on LBP and LBP/D and for the effect of trunk flexion over 45 degrees on LBP/D, the point estimates were closer to unity with the hierarchical model. The shape of the dose-response curve was not altered appreciably and remained linear for the hierarchical model. In contrast, for the effect of trunk flexion over 45 degrees on LBP and for the effect of lifting and carrying loads on LBP and LBP/D, the estimated dose-response relations changed from non-monotonic or inconsistent with the conventional model to more linear with the hierarchical model.

Psychosocial work factors

We observed adjusted associations between LBP incidence and low decision authority and high work demands, but little association with skill discretion. In all cases, however, the confidence intervals were wide. No consistent dose-response associations were observed between any of these psychosocial variables and LBP/D. For both outcomes, effect estimates were similar with conventional and hierarchical models.

Time-related factors

We observed an inverse monotonic association between age and the incidence of LBP; the estimated relative risk derived from the hierarchical model, comparing 55-year-olds with 25–year-olds was 0.33 (95% CI 0.12-0.88). In contrast, a weak but positive association was observed between age and LBP/D; the corresponding estimate of the relative risk was 1.68 (95% CI 0.57-4.90). Years of employment in the facility was inversely associated with LBP/D but relatively unassociated with LBP. Similar findings were obtained for these variables with conventional and hierarchical models.

Discussion

Few differences in the incidence of any LBP were found between occupational groups. Although a few of the work-related factors were consistently associated with the incidence of LBP, these associations were not precisely estimated and may have been chance findings. Younger workers were at higher risk of any LBP than were older workers. Findings differed somewhat for the other outcome--LBP/D. In particular, younger workers were at lower risk than were older workers, and trunk flexion over 45 degrees was strongly and consistently associated with LBP/D. It appears therefore, that trunk flexion at work affects the risk of more severe or disabling low back pain but not the risk of less severe or transient low back pain. Since the objective of this study was to investigate the incidence of low back pain among workers who had reported at baseline no low back pain during the previous year, the results cannot be generalized to predicting the recurrence of low back pain among chronic cases.

Methodologic issues

The participation rate among the 9 professions and 7 nursing homes varied considerably, but was not related to the prevalence or severity of LBP at baseline. Hence, selective participation does not seem to pose a problem in this study, although the lack of information on individual characteristics of non-participants prohibits a further underpinning of this important assumption. Subjects lost to follow-up were younger, had fewer years of employment, reported less exposure to lifting and carrying loads, and reported less skill discretion than did subjects not lost to follow-up. Thus, the presence of bias due to selective loss to follow-up cannot be ruled out. Loss to follow-up is determined by non-response and job change (to an employer other than those participating in the study) during follow-up. Of those lost to follow-up, 39 subjects changed jobs. Furthermore, we know that there is a high turnover rate in the source population during the first years of employment and that changing jobs was associated with age and years of employment among our subjects. These factors might explain the difference in age and years of employment between subjects lost and not lost to follow-up.

An observational method was used to measure physical load at the workplace. The advantage of this approach is the ability to collect detailed quantitative information. In earlier analyses of these data, we found that this approach was subject to a certain degree of random measurement error, especially for lifting and carrying loads, where the within-subject variance captured up to 80% of the total variance. In general, random or nondifferential measurement error results in underestimation of effect (26). In our study, the direct measurement of physical load was not made at the individual level but at the occupational-group level. To measure an individual worker's cumulative exposure to physical load, the average percentage of work time devoted to that activity in the worker's occupation was multiplied by that individual's self-reported number of hours worked per week. It is difficult to predict whether, and to what extent, this approach resulted in biased estimates of physical-load effects in our study and in what direction the bias is likely to have occurred (27).

In many previous epidemiologic studies of LBP, the study population has been limited to an occupational group with a more or less fixed ratio of high levels of exposure to different physical factors and a reference group with low levels of exposure. Furthermore, when estimating the effects of physical factors that were strongly interrelated, those researchers typically did not fully adjust each effect estimate for all other factors. Those results, therefore, might have been confounded. In this study, correlation coefficients among physical factors ranged from 0.29 to 0.59. We estimated the effect of each occupational exposure by controlling for all other exposures--first, by including several occupational groups with different physical-exposure distributions; and second, by using a hierarchical regression approach that enhanced effect estimation for multiple interrelated exposures (16-19).

Issues in the hierarchical modeling of the dose-response splines

When results from the conventional and hierarchical models were compared, clear differences were found only for the physical factors, especially for the effect of trunk flexion over 45 degrees on LBP/D. Estimated confidence intervals tended to be narrower with hierarchical modeling than with conventional modeling. These findings are in accordance with the results of earlier research on log-linear hierarchical models (16-18). In general, with hierarchical regression, large and unstable effect estimates are pulled (regressed) towards a common mean. With a linear model, the common mean or prior distribution describes a monotonic linear function; in practice, this often means that extremely unstable effect estimates are reduced towards unity. In contrast, with a spline model, the prior function is nonmonotonic (when the values of the second-stage design matrix are not zero). Essentially, this prior function is the mean of all dose-response curves found with the conventional model in one covariate domain. Unstable effect estimates are regressed towards this mean spline. The implication, in contrast to linear models, is that hierarchical regression affects not only the point estimates of effect, but also the shape of the dose-response relations.

In order to minimize bias in the estimates caused by regression to an inappropriate common mean or prior function, we must assume that parameters are exchangeable, and quantitative exposures must be scaled so that regression estimates for one unit of exposure can be compared (16). Therefore, in this study, we grouped the variables into three domains (physical factors, psychosocial factors, and time-related factors), and we identified exchangeable linear and quadratic parameters as described by positive second-stage covariates. A comparison of regression estimates was possible since the same unit of exposure was used for all variables within a domain.

When $\underline{\tau}^2$ was preset to 0.25 (instead of 0.5), which implies larger regression towards the prior curve (16-18) results were different only for estimates of less stable physical factors. Estimated relative risks for the effects of trunk flexion over 45 degrees were about 20% smaller and 95% confidence intervals were narrower when $\underline{\tau}^2$ was set to 0.25, whereas estimated relative risks for the effects of lifting and carrying loads were somewhat larger. When $\underline{\tau}^2$ was set to 1, estimated relative risks obtained from the hierarchical model were closer to the maximum likelihood estimates and the 95% confidence intervals were wider than when $\underline{\tau}^2$ was set to 0.5.

Comparison with other studies and evaluation of results

Several reviewers have presented clear evidence that physical work load contributes to the occurrence of LBP (1,2). Since our study population included many nurses and caregivers, it is informative to compare our results with the results of other LBP studies of nurses. Nursing work is physically strenuous due to patient handling, and a major part of the work involves trunk flexion and lifting. The results of our study do not confirm the association between lifting and LBP that has been reported in other studies (28,29). One explanation for our negative finding might be random error in measuring this exposure (as indicated above). Another explanation might be selection factors operating before baseline, e.g., if workers previously exposed to lifting and carrying heavy loads and at high risk of LBP were more likely to leave their jobs or reduce their strenuous activities at work.

Other epidemiologic studies of LBP that incorporated observational techniques to measure physical load at work were conducted by Punnett et al. (30) and

Hoogendoorn et al. (31). Punnet et al. used the same cutoff points for trunk flexion that we used in our study: 20-45 degrees, and over 45 degrees. They also found a positive association between trunk flexion and the risk of LBP, but their effect estimates were larger than ours. In their prospective cohort study of low back pain, Hoogendoorn et al. found similar estimates for the effect of trunk flexion that we report in this paper. They also found a positive association between lifting loads of at least 25 kg more than 15 times per work day and the risk of LBP, but the association was weaker and inverse for lighter loads and lower frequencies of lifting. This latter finding is similar to the results of our study.

Although there is evidence that psychosocial factors at work affect the risk of LBP, the specific factors responsible for such effects are not well understood (3,28). Many studies of psychosocial factors were cross-sectional or did not involve adequate adjustment for physical factors and other potential confounders. In both the case-control study of nursing personnel by Josephson et al. (32) and the cohort study of different worker groups by Hoogendoorn et al. (21), the investigators found weak associations between psychosocial work factors and low back pain, controlling for physical factors and other potential confounders. The evidence from our study does little to refute or confirm the results of those studies.

Results from several previous studies suggest that the occurrence of LBP increases with age (1,33). We also found a positive association with LBP/D but an inverse association with LBP. In contrast, we found an inverse association between years of employment and LBP/D but no association between years of employment and LBP. These seemingly contradictory findings might be due to selection factors that operated before the start of follow-up. It is possible that the observed risk of LBP was lower in older workers because many workers of that age had developed LBP before follow-up and thus were excluded from this incidence study. Indeed, the estimated prevalence of LBP at baseline in the original worker population was about 70% in nurses and caregivers. It is also possible that the observed risk of LBP/D was lower in workers with more years of employment because workers with more years of employment and free of LBP/D at baseline represent a healthy (low-risk) group of "survivors" who had not developed LBP/D before follow-up.

There is a growing body of evidence suggesting that different types of back pain are affected by different factors (6-8). In this study, we found that while LBP/D was more strongly associated with exposure to physical factors at work, LBP was more strongly associated with psychosocial factors. Although these associations may reflect true differences in effect, another possible explanation is differential reporting (i.e., misclassification) of low back pain. It is possible, for example, that workers with less decision authority and more work demands might be more likely than workers without these stressors to report minor episodes of low back pain. Another possible explanation might be the difference in study populations for predicting our two outcomes: The prediction of LBP was restricted to only those 220 workers who were free of LBP at baseline, while the prediction of LBP/D was conducted in 479 workers who were free of LBP/D at baseline (56% of whom had LBP). Thus, the effect of occupational exposures to physical factors on LBP/D might be greater for workers with existing (nondisabling) LBP than in workers without any LBP. Unfortunately, we could not test that hypothesis in our study because there were too few incident cases of LBP/D among workers without LBP at baseline.

This study has several methodologic strengths including the prospective cohort design, the detailed quantitative measures of occupational exposures, the use of hierarchical regression to adjust for confounders, and the use of spline techniques to assess dose-response relations. We conclude that occupational exposure to trunk flexion over 45 degrees appears to be a risk factor for low back pain with disability among persons employed in nursing homes or homes for the elderly in the Netherlands.

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Chapter 6

The impact of physical and psychosocial work factors on the aggravation of low back pain

Jansen JP, Burdorf A. The impact of physical and psychosocial work factors on the aggravation of low back pain. *Submitted*

Abstract

Objective. To assess the effect of occupational exposures to physical and psychosocial factors on the aggravation of the course of low back pain.

Methods. A cohort of 319 subjects with low back pain, working in nursing homes and homes for the elderly, was followed prospectively for two years. Physical load for different occupations was assessed by quantitative observations at the workplace. Information on low back pain and other factors was gathered with questionnaires administered at baseline, at one, and at two years. Three measures of aggravation of low back pain were used: increase in duration, increase in frequency, and increase in pain severity of low back pain reported at follow-up in reference to low back pain reported at baseline. Log-linear regression analysis with a spline function was used to estimate dose-response relations.

Results. The recurrence of low back pain was about 70% in a two-year-period. The proportion of low back pain characterized by a total duration of more than 4 weeks per year remained constant over time with about 45%. Low back pain with more than 5 recurrent episodes in one year increased slightly over time to about 40%. The severity of low back pain was constant as well. About 25% of the subjects reported aggravation of low back pain. The risk of aggravation of low back pain in terms of severity was positively associated with age and was unassociated with the psychosocial factors. Lifting and carrying over 10 kg was monotonically associated with the risk of LBP episodes characterized by aggravation in terms of severity; the estimated relative risk was 3.01 (95% CI 1.42-6.38) for 45 minutes per week of exposure (90th percentile) in reference to 1 minute per week.

Conclusion. Individuals experience changes in the duration, frequency, and severity of their LBP episodes over time, with a relative constant prevalence of more serious LBP in terms of duration, frequency, and severity. Occupational exposure to lifting and carrying loads over 10 kg appears to be a risk factor for aggravation of low back pain among persons employed in nursing homes or homes for the elderly.

Introduction

Back problems constitute a significant health problem in industrialized countries. Physical load at work, like manual materials handling, frequent bending and twisting, and forceful movements, has been identified as a significant contributing factor in the occurrence of low back pain (LBP). Furthermore, several studies showed that psychosocial work factors and individual factors may also be important in the occurrence of LBP (1-3).

The future course of LBP has primarily been studied in prognostic studies (4-20) with a focus on recovery from LBP. The majority of patients recover within 4 to 8 weeks. (21). Information on the future course of LBP among patients that do not recover within those 4 weeks, i.e. patients that experience aggravation, is limited though.

Aggravation of LBP cannot be captured in terms of acute versus chronic LBP (22). Hence, measures of aggravation need to be defined. Aggravation of LBP can be characterized by an increase in the level of pain experienced. However, when a patient experiences recurrent episodes of LBP, aggravation can also be defined as an increase in the duration of the LBP episodes over time. In addition, an increase in the frequency of recurrent LBP episodes over time may also be defined as aggravation of the course of LBP.

Although etiological studies on chronic LBP exist, information on factors contributing to the aggravation of LBP over time is hardly available. It cannot be assumed that well known etiologic factors for LBP, such as work-related factors, have a comparable impact in the aggravation of LBP (4,5). In order to evaluate the impact of work-related factors on LBP many studies have used qualitative self-reports or an expert's opinion on presence or absence of the work-related factors to characterize exposure. However, self-reported exposure to risk factor may depend on the presence of LBP. This is especially an issue in a study when the outcome of interest is aggravation of the LBP already present at the time of the exposure assessment. Hence, objective assessment of risk factors is needed in order to avoid recall bias with assessment of work-related factors directed to quantitative characterization.

The aims of the present study were 1) to describe the natural course of LBP over a prolonged period of 2 years with focus on aggravation of LBP; and 2) to evaluate the impact of work-related factors on aggravation of LBP.

Material and Methods

The study population consisted of workers from 7 nursing homes and homes for the elderly in the Netherlands. Workers employed for more than 10 hours per week were eligible to participate in the study. Baseline measurements performed between March 1998 and March 1999, included the assessment of physical load for each occupation at the workplace and a self-administered questionnaire. Follow-up questionnaires were administered one year and two years after the baseline measurements.

Of the 1,208 subjects invited to participate in the study, 769 (64%) agreed to participate at baseline. After one year, 523 (68%) of the 769 subjects were observed again. After two years, 368 (48%) of the 769 subjects were observed again. In total, 550 subjects of the 769 subjects were observed on at least one follow-up measurement (after one and/or two years). Three hundred nineteen (319; 58%) of these 550 subjects reported

LBP at baseline, and were selected for the analysis. These subjects worked in 7 professions: 57 nurses, 126 care givers, 17 kitchen workers, 16 housekeepers, 16 physical therapists, 56 office workers, and 31 miscellaneous workers.

Back pain

At baseline and follow-up, information on LBP was measured with questions derived from the Nordic questionnaire for the analysis of musculoskeletal symptoms (23). This questionnaire has been shown to be a valid instrument to collect information on the nature, duration, and frequency of symptoms. In the present study LBP was defined as any episode of pain that lasted for at least a few hours in the previous 12 months. Total duration of the episodes of LBP in the previous 12 months was stratified in 5 categories: 1 to 7 days, between 1 and 4 weeks, between 4 and 7 weeks, between 7 weeks and 3 months, and between 3 months and 12 months. This last category was defined as chronic LBP. The frequency of the episodes during the 12 months was stratified in 3 categories: 1 episode, between 2 and 5 episodes, and more than 5 episodes. Aggravation of LBP in terms of duration or frequency was defined as a change to a longer duration category and a higher frequency category respectively at the last available follow-up measurement in reference to baseline. The severity of LBP in the past 12 months was measured according to the Von Korff-scheme for grading severity of chronic pain (24) and rated on a 100 point scale. Aggravation of LBP in terms of severity was defined as an increase in the Von Korff score of at least 10 points at the last available follow-up measurement in reference to baseline.

Other LBP and health related measures assessed were the type of onset of LBP (sudden or gradual), and self-perceived health.

Quantitative assessment of physical load

In a group of 212 workers randomly sampled at baseline, observations were made at the workplace on physical load during work for each of the 7 occupations. The proportion of observed subjects per group ranged from 16% to 64%, thereby oversampling those occupations with fewer subjects. An observational multimoment method was used to describe three measures of physical load: trunk flexion between 20 degrees and 45 degrees, trunk flexion over 45 degrees, and lifting or carrying loads over 10 kg, all expressed in percentages of work time (25). Observations were made on each worker every 20 seconds during 4 periods of 30 minutes each in one working day; thus, we collected 360 observations per worker. For each occupation, the average exposure to each type of physical load was calculated as the mean percentage of time devoted to that activity. An underlying assumption of this strategy is that the average physical load of the observed workers is equal to the average physical load of the total occupational group. Thus, the arithmetic mean for the group was used as a proxy for exposure in all subjects, both observed and unobserved, in that occupation. To estimate an individual's cumulative exposure to physical load, the occupation-specific exposure expressed in percentage of work time was multiplied by self reports of the number of hours worked per week.

Psychosocial work factors

A questionnaire was used to collect information on three psychosocial work factors included in Karasek's model (26): decision authority, skill discretion, and work demands.

The 11 questions on decision authority reflected aspects such as influence on the planning of tasks, influence on the pace at work, brief pauses when needed, and decisions on time spent on given tasks. The 6 questions on skill discretion reflected required skills, task variety, learning new things, and amount of repetitive work. The 11 questions on work demands reflected working fast, working hard, excessive work, insufficient time to complete the work, and conflicting demands. The response to each question was scored on a 4-point ordinal scale. The total score for each factor was computed by summing the item scores for all questions related to that factor and expressing the sum on a 0-100 scale. A score of 100 was defined as least desirable for that factor— i.e. low decision authority, low skill discretion, and high work demands.

Data analysis

Nine log-linear regression models with a quadratic spline function were used to assess dose-response relations for each of the following 9 possible continuous predictors of aggravation of LBP at the last available follow-up measurement in reference to baseline LBP: trunk flexion between 20 and 45 degrees, trunk flexion over 45 degrees, lifting and carrying loads over 10 kg, decision authority, skill discretion, psychosocial work demands, self-perceived health, age, and number of years at that facility at baseline. All continuous variables were categorized into quartiles of the observed distributions. On the basis of likelihood ratio statistics, it appeared that a full quadratic spline (for all categories) did not fit the data better than a restricted quadratic spline did in which a linear spline was used for the lower and upper category (27,28). In each of the 9 models adjustment was made for the other covariates including type of onset of LBP. These adjustments were modeled by a linear function with 1 parameter for each factor. The model was fitted using Proc Genmod (with a log link-function) available with SAS statistical software (29).

Relative risks (RR) and corresponding 95% confidence intervals (CI) are presented for the 25th, 50th, 75th, and 90th percentiles of the exposure distribution of the physical and psychosocial factors, relative to the 10th percentile.

Results

Selectiveness

The estimated prevalence of LBP at baseline in each elderly facility was not related to the response rate in that facility. Of the 446 subjects with LBP observed at baseline, 303 (68%) were able to provide information at one year follow-up (t2), and 216 subjects (48%) were able to provide information at two years follow-up (t3). Hence, 127 subjects (29%) were not available to provide outcome information at follow-up. The distribution of the duration, frequency, and severity of LBP at baseline among these 127 subjects lost to follow-up were similar to the duration, frequency, and severity among subjects available for follow-up (n=319). At baseline, no differences in the physical factors were found between subjects available for follow-up and those lost to follow-up. Those lost to follow-up, however, reported less skill discretion, had fewer years of employment, and received more medical treatment for LBP.

Duration, frequency, and severity of LBP

In Table 6.1 the prevalence of LBP at baseline and follow-up is presented, as well as the distribution of the duration, frequency, and severity of the episodes. At one year follow-up (t2) the prevalence of LBP was 227/303=74.9%. At two years follow-up (t3) the prevalence of LBP was 147/216=68.1%. In total, 225 of the 319 subjects available reported LBP at their last available follow-up measurement (t2 or t3), a prevalence of 70.5%.

Both at baseline and follow-up more than 20% of the subjects reported LBP with a total duration of more than 3 months during a 12 month period. The proportion of subjects with LBP with a total duration of more than 4 weeks remained relatively constant as well. The proportion of subjects with more than 5 LBP episodes during a 12 month period increased slightly from 35% at baseline to about 40% at follow-up. The proportion of subjects with less than 5 episodes in a 12 month period decreased to about 30%. The decrease in the LBP prevalence over time was primarily due to a drop in the proportion of LBP characterized by less than 5 episodes with a combined duration of less than 4 weeks in a 12 month period. Regarding the severity of LBP, patients reported a mean pain score of 41.9 (0-100 range) at baseline and a mean pain score of about 47 at follow-up.

Table 6.1 Descriptive of low back pain outcome measures at baseline and follow-up

	Baseline (t1) n=319	Follow-up 1 (t2) n=303	Follow-up 2 (t3) n=216	Follow-up[a] (t2& t3 combined) n=319
LBP	*319 (100%)*	*227 (74.9%)*	*147 (68.1%)*	*225 (70.5%)*
Total duration of episodes[b]				
1 -7 days	65 (22.2%)	32 (11.0%)	23 (10.9%)	33 (10.6%)
1 – 4 weeks	88 (30.0%)	49 (16.9%)	33 (15.6%)	47 (15.1%)
4 - 7 weeks	35 (12.0%)	39 (13.5%)	18 (8.5%)	32 (10.3%)
7 weeks – 3 months	44 (15.0%)	31 (10.7%)	24 (11.3%)	37 (11.9%)
3 months – 12 months	61 (20.8%)	63 (21.7%)	45 (21.2%)	69 (22.1%)
Frequency of episodes[c]				
1 episode	49 (17.1%)	23 (7.9%)	7 (3.3%)	13 (4.1%)
2 - 5 episodes	136 (47.4%)	70 (24.0%)	52 (24.8%)	77 (24.5%)
>5 episodes	102 (35.5%)	123 (42.1%)	82 (39.1%)	130 (41.4%)
Severity of the episodes (score on a range from 0-100)[d]				
Subjects with LBP	41.9 (21.1)[e]	45.6 (21.7)[e]	47.2 (22.4)[e]	46.8 (22.7)[e]

[a] Follow-up measurement at t3 when information for subject was available at t3, else information at t2 when information for the subjects was available at t2.
[b] At baseline information was missing for 26 subjects, at t2 for 13 subjects, at t3 for 4 subjects, and at follow-up combined information was missing for 7 subjects.
[c] At baseline information was missing for 32 subjects, at t2 for 11 subjects, at t3 for 6 subjects, and at follow-up combined information was missing for 5 subjects.
[d] At baseline information was missing for 19 subjects, at t2 for 5 subjects, at t3 for 1 subject, and at follow-up combined information was missing for 2 subjects.
[e] Standard devation

In Table 6.2 the development of LBP in terms of changes in duration, frequency, and severity of episodes is presented. In reference to baseline, more than 20% of the subjects reported an increase in the total duration of the LBP episodes at follow-up. About 50% reported a decrease in the total duration of LBP episodes or complete recovery at follow-up. In reference to baseline about 25% of the subjects reported an increase in LBP episodes (in a 12 month period) at follow-up. About 39% reported a decrease in the number of episodes. About 26% of the patients with LBP reported an increase in the severity of LBP at follow-up, and about 50% a decrease or complete disappearance of pain.

The association between the duration and severity of complaints was strong with correlation coefficients ranging from 0.62 at baseline to more than 0.80 at follow up. The association between frequency and severity was also strong (correlation coefficients ranging from 0.18 at baseline to about 0.80 at follow-up), as well as the association between frequency and duration (correlation coefficients ranging from 0.35 at baseline to more than 0.80 at follow-up).

Table 6.2 Change in low back pain outcome measures at follow-up in reference to baseline at the individual level

	Follow-up 1 (t2)	Follow-up 2 (t3)	Follow-up[a] (t2 & t3 combined)
Total duration of episodes[b]			
Increased total duration	58 (21.7%)	44 (22.6%)	67 (23.3%)
Equal total duration	82 (30.7%)	48 (24.6%)	74 (25.8%)
Decreased total duration	127 (47.6%)	103 (52.8%)	146 (50.9%)
Frequency of episodes[c]			
Increased frequency	63 (24.1%)	48 (25.5%)	70 (24.7%)
Equal frequency	97 (37.0%)	63 (33.5%)	102 (36.1%)
Decreased frequency	102 (38.9%)	77 (41.0%)	111 (39.2%)
Severity of the episodes[d]			
Increased severity	71 (25.5%)	53 (26.0%)	79 (26.5%)
Equal severity	85 (30.5%)	45 (22.1%)	71 (23.8%)
Decreased severity	123 (44.0%)	106 (52.0%)	148 (49.8%)

[a] Follow-up measurement at t3 when information for subject was available at t3, else information at t2 when information for the subjects was available at t2.
[b] At t2 information on change was available for 267 subjects, at t3 for 195 subjects, and at follow-up combined for 287 subjects.
[c] At t2 information on change was available for 262 subjects, at t3 for 188 subjects, and at follow-up combined for 283 subjects.
[d] At t2 information on change was available for 279 subjects, at t3 for 204 subjects, and at follow-up combined for 298 subjects..

Work-related factors and covariates

The means and standard deviations of the work-related exposures and covariates at baseline are presented in Table 6.3 for all 319 subjects. The mean exposure to trunk flexion between 20 and 45 degrees was 4.4 hours per week, to trunk flexion over 45 degrees 1 hour per week, to lifting and carrying loads about 20 minutes per week. Mean decision authority at work, skill discretions, and work demands was between 40 and 50 points. At baseline, the subjects with a mean age of 40 years worked on the average about 9 years at the facility. The majority of the subjects reported a gradual onset of LBP (62.7%) and self-perceived health was rated with an average score of 32.9.

Table 6.3 Descriptive information of the work-related factors, age, years of service, self-perceived health, and type of onset of LBP at baseline (n=319)

	Mean (SD[a]) *% (n)*
Physical factors	
Trunk flexion between 20 and 45 degrees (hours per week)	4.4 (1.6)
Trunk flexion over 45 degrees (hours per week)	1.0 (0.5)
Lifting and carrying loads over 10 kg (minutes per week)	19.2 (15.6)
Psychosocial factors	
Decision authority[b]	40.9 (18.7)
Skill discretion[b]	42.4 (19.0)
Work demands[b]	48.1 (16.3)
Age (years)	40.0 (9.7)
Years in current employment	8.9 (6.3)
Self-perceived health[b]	32.9 (23.2)
Onset of LBP[c]	
Sudden	37.3% (106)
Gradual	62.7% (178)

[a] SD = Standard Deviation
[b] Range of score = 0 -100, the higher the score, the lower the experience on that factor.
[c] Information missing for 35 subjects.
[d] Information missing for 22 subjects.

Dose-response findings

Physical and psychosocial work factors

In Table 6.4 adjusted dose-response relations are presented for the estimated effects of the 3 physical exposures and psychosocial work demands on the risk of aggravation of LBP in terms of duration and severity. Due to strong correlation between aggravation in terms of duration and frequency the results for aggravation in terms of frequency are not presented.

Although the estimated risk of aggravation of LBP in terms of frequency was monotonically associated with lifting and carrying loads over 10 kg, the association was weak. The association with this exposure was much stronger, however, for aggravation of LBP in terms of duration and severity. For aggravation in terms of duration and severity, the estimated relative risk was 2.04 (95% CI 0.99-4.18) and 3.01 (95% CI 1.42-6.38) respectively for 45 minutes of lifting and carrying over 10 kg per week (90^{th} percentile) (See Figure 6.1). There was little association between trunk flexion, both between 20 and 45 degrees and over 45 degrees, and aggravation of LBP.

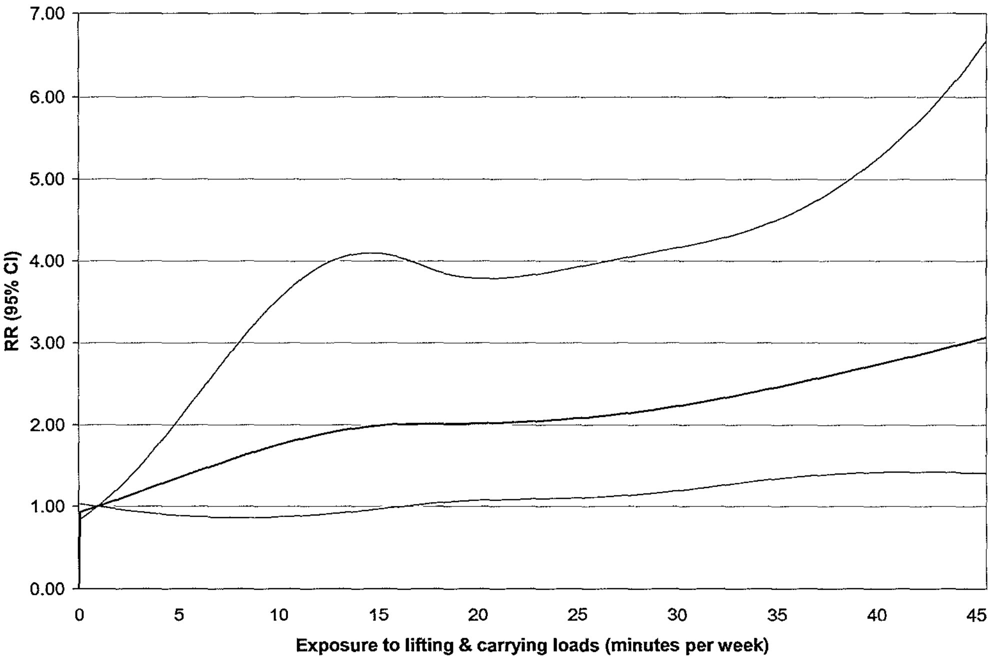
An inverse but weak association was found between work demands and aggravation of LBP in terms of severity. For aggravation of LBP in terms of duration and frequency there was little association. Decision authority and skill discretion showed little association with aggravation of LBP as well.

Table 6.4 The association between physical and psychosocial work-factors at baseline and aggravation of LBP at follow-up

		Aggravated LBP stratified by different characteristics	
		Increase in the total duration of the episodes of LBP	*Increase in the severity of LBP*
		RR[a] (95% CI)	RR (95% CI)
Trunk flexion 20- 45 degrees	2 hours pw[b]	1 reference	1 reference
	3 hours pw	0.94 (0.63-1.39)	0.97 (0.66-1.42)
	4 hours pw	0.92 (0.51-1.66)	0.92 (0.51-1.65)
	5 hours pw	0.97 (0.54-1.71)	0.87 (0.50-1.50)
	6 hours pw	0.72 (0.39-1.32)	1.07 (0.64-1.80)
Trunk flexion > 45 degrees	30 minutes pw	1 reference	1 reference
	45 minutes pw	0.84 (0.60-1.19)	1.26 (0.87-1.82)
	1 hour pw	1.01 (0.70-1.47)	1.40 (0.90-2.19)
	1 hour 30 min pw	1.23 (0.73-2.05)	1.42 (0.83-2.42)
	1 hour 45 min pw	0.85 (0.44-1.63)	1.43 (0.82-2.48)
Lifting and carrying loads over 10 kg.	1 minute pw	1 reference	1 reference
	5 minutes pw	0.92 (0.60-1.44)	1.35 (0.90-2.04)
	15 minutes pw	1.06 (0.51-2.20)	1.98 (0.96-4.10)
	30 minutes pw	1.79 (0.98-3.27)	2.21 (1.18-4.15)
	45 minutes pw	2.04 (0.99-4.18)	3.01 (1.42-6.38)
Decision authority	10 pct[c] (15.2)[d]	1 reference	1 reference
	25 pct (27.3)	1.04 (0.66-1.64)	0.84 (0.56-1.24)
	50 pct (42.4)	0.94 (0.52-1.71)	1.12 (0.68-1.85)
	75 pct (54.5)	1.05 (0.56-1.98)	1.32 (0.76-2.32)
	90 pct (63.6)	1.44 (0.75-2.75)	1.05 (0.57-1.91)
Skill discretion	10 pct (16.7)	1 reference	1 reference
	25 pct (27.7)	0.66 (0.43-1.02)	0.85 (0.54-1.32)
	50 pct (42.2)	0.88 (0.50-1.53)	0.88 (0.50-1.57)
	75 pct (55.6)	1.26 (0.69-2.30)	1.07 (0.57-1.99)
	90 pct (66.7)	0.98 (0.51-1.87)	1.17 (0.63-2.16)
Work demands	10 pct (27.3)	1 reference	1 reference
	25 pct (36.4)	1.05 (0.69-1.62)	0.97 (0.67-1.40)
	50 pct (45.5)	0.92 (0.53-1.57)	0.91 (0.57-1.46)
	75 pct (60.6)	0.74 (0.40-1.36)	0.78 (0.45-1.35)
	90 pct (69.7)	0.80 (0.42-1.50)	0.70 (0.38-1.29)

[a] RR = Relative Risk & 95% CI = 95% Confidence Interval; [b] pw = per week; [c] pct = percentile of distribution; [d] ( ) = actual value

Figure 6.1 Association between lifting & carrying loads over 10 kg and aggravation of LBP in terms of severity



Years of service, age, and self-perceived health

In Table 6.5 adjusted dose-response relations are presented for years of service, age, and self-perceived health. We observed an inverse but weak association between years of service and aggravation of LBP in terms of severity. No-consistent dose-response relations were found for LBP in terms of duration and frequency. The association between aggravation of LBP in terms of duration and frequency with age was weak. The association with age was much stronger, however, for aggravation of LBP in terms of severity. The monotonically association showed an estimated relative risk up to 2.09 (95% CI 0.97-4.47) for 55-year-olds (90^{th} percentile) compared with 25-year-olds (see Figure 6.2).

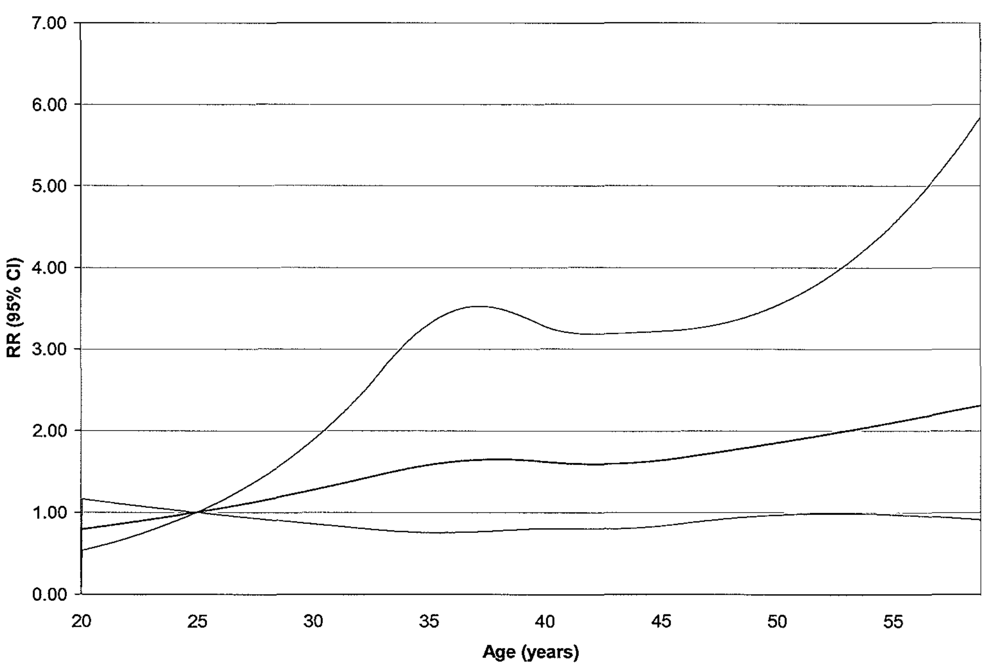
Little association was found between self-perceived health and aggravation of LBP in terms of duration, frequency, and severity.

Table 6.5 The association between years of service, age, and self-perceived health at baseline and aggravation of LBP at follow-up

		Aggravated LBP stratified by different characteristics	
		Increase in the total duration of the episodes of LBP	*Increase in the severity of LBP*
		RR[a] (95% CI)	RR (95% CI)
Years of service	1 year	1 reference	1 reference
	5 years	1.01 (0.54-1.88)	0.92 (0.55-1.54)
	10 years	1.37 (0.70-2.69)	0.68 (0.37-1.23)
	15 years	1.30 (0.67-2.55)	0.68 (0.39-1.19)
	20 years	1.16 (0.50-2.69)	0.71 (0.35-1.45)
Age	25 years	1 reference	1 reference
	30 years	1.46 (0.96-2.23)	1.27 (0.86-1.87)
	40 years	2.02 (0.93-4.41)	1.63 (0.80-3.30)
	50 years	1.41 (0.64-3.08)	1.84 (0.96-3.15)
	55 years	1.20 (0.45-3.24)	2.09 (0.97-4.47)
Self-perceived health	10 pct (7.7)	1 reference	1 reference
	25 pct (16.7)	0.88 (0.61-1.27)	0.91 (0.66-1.24)
	50 pct (30.8)	0.77 (0.48-1.23)	0.86 (0.56-1.33)
	75 pct (50.0)	0.73 (0.43-1.24)	0.92 (0.55-1.54)
	90 pct (66.7)	0.74 (0.41-1.33)	0.96 (0.56-1.64)

[a] RR = Relative Risk & 95% CI = 95% Confidence Interval.

Figure 6.2 Association between age and aggravation of LBP in terms of severity



Discussion

The recurrence of LBP among workers in elderly facilities was about 70% in a two-year-period. The prevalence of severe LBP, chronic LBP, and frequent LBP remained constant over time. The proportion of LBP characterized by a total duration of more than 4 weeks per year was about 45%, and LBP with duration for more than 3 months was about 20%. LBP characterized by more than 5 recurrent episodes in one year increased slightly over time to about 40%. However, individual patterns of LBP characteristics were larger than reflected by these numbers. The course of LBP of individuals moves up and down the different levels of duration, frequency, and severity over time, with a relative constant prevalence of more serious LBP in terms of duration, frequency, and severity at a group level as a result. About 25% of the individuals reported aggravation of their course of LBP.

The observed risk of aggravation of LBP characterized by increased levels of pain severity was higher for older workers than younger workers. Although a few of the work-related factors were weakly associated with aggravation of LBP, these associations may have been chance findings. However, lifting and carrying loads over 10 kg was consistently associated with aggravation of LBP in terms of severity. An increased risk for a longer duration of LBP episodes was found as well. It appears, therefore, that among LBP patients lifting and carrying loads over 10 kg affects the risk of aggravation of LBP characterized by increased levels of pain and a longer duration of the episodes.

Methodological issues

Since the participation rate for each facility was not related to the prevalence of LBP at baseline, selective participation does not seem to have been a problem in this study. Subjects lost to follow-up had fewer years of employment, reported less skill discretion, and were more likely to receive medical treatment than did subjects not lost to follow-up. Thus, the presence of bias due to selective loss to follow-up cannot be ruled out. No differences in the distribution of duration, frequency, and severity of LBP episodes were found between subjects available and lost to follow-up. Loss to follow-up is determined by non-response and job change (to an employer other than those participating in the study) during follow-up. Furthermore, we have observed that there is a high turnover rate in the source population during the first years of employment and that changing jobs was associated with years of employment among our subjects as well. This might explain the difference in years of employment between subjects lost and not lost to follow-up.

Unlike the continuous scales used to measure severity of LBP, duration and frequency were measured on an ordinal scale. The disadvantage was that not many categories were defined and the categories at the upper end of the scales were rather wide. This limited the sensitivity to detect changes in duration and frequency over time. Subjects with LBP in the upper categories of the duration scale (>3 months) and frequency scale (>5 episodes) are not able to report aggravation, due to the lack of a category reflecting a worse condition. This may have caused an underestimation of the rate of aggravation of LBP over time.

An observational method was used to measure physical load at the workplace. The advantage of this approach is the ability to collect detailed quantitative information. In earlier analyses of these data, we found that this approach was subject to a certain degree of random measurement error, especially for lifting and carrying loads, with the within-subject variance capturing up to 80% of the total variance. In general, nondifferential measurement error results in underestimation of effect (30). In our study, the direct measurement of physical load was not made at the individual level but at the occupational-group level. To measure an individual worker's cumulative exposure to physical load, the average percentage of work time devoted to that activity in the worker's occupation was multiplied by that individual's self-reported number of hours worked per week. It is difficult to predict whether, and to what extent, this combination of exposure at a group level combined with individual working hours resulted in biased estimates of the effect of physical-load, and in what direction the bias is likely to have occurred (31).

Comparison with other studies and evaluation of results

Previous studies showed that up to 45% of subjects with acute LBP still reported complaints after 3 months (4,5,7,11-13,32). In our study the transition rate of non-chronic LBP at baseline to LBP lasting for more than 3 months, chronic LBP, at follow-up was 9.7% over a 2-year period. It has to be remarked that in our study for every measurement a 12 month recall period was used in which several episodes of LBP may have occurred; the transition from non-chronic to chronic as measured in the present study may not involve one LBP episode stretched over 3 months. Anyhow, the rate of LBP aggravation over the 2-year period in our study was about 25%, which is higher than the transition rate of non-chronic LBP to chronic LBP. This indicates that the transition rate of LBP to chronic conditions may underestimate the rate of aggravation of LBP.

The recurrence of LBP is common in many patients (33-37). In the prospective study by Troup et al. (37) a drop in recurrence rates from 50% in the first year to 32% in the second year was observed. This confirms the results of our study which showed a drop in the proportion of LBP with a frequency of more than one episode per year as well (82.9% at baseline and 65.9% at follow-up).

Regarding LBP in terms of severity the results of our study confirm the results reported by Walhgren et al (38). In their study on the course of pain intensity and disability they found that about 50% of patient's symptoms had improved after 6 months and more than 60% after 12 months. Aggravation of LBP over a 12-month period was not found in their study, this in contrast to our study. An explanation for the difference is that in our study we did not focus on the development of one LBP episode over time, but on the course of LBP which may be characterized by several different episodes whereby subsequent LBP episodes get worse over time.

From clinical studies on LBP it is known that patients with higher perceived pain levels experience longer LBP episodes (4). In light of the strong correlation between the different endpoints reflecting aggravation, it was expected to find comparable risk estimates. However, strong risk factors were identified for aggravation of LBP in terms of severity and duration but not for frequency. An explanation is the limited discriminative power of the 3 level scale used to measure frequency of LBP episodes.

Results from previous studies on physical load at work and the development of LBP are limited. The majority of studies concern the risk of no return to work after sick leave due to LBP. Fransen et al. (11) found a strong association between the unavailability of light duties at return to work and the risk of not returning to work due to disability of LBP. Lifting at work appeared to be a risk factor as well. In several other studies, though, little association was found between physical load and return to work

(5,7-10,18). The endpoint 'no return to work' implies no improvement in LBP, or at least not sufficient improvement in LBP that a patient believes he or she is able to work again. No improvement of LBP implies that the severity of LBP is constant over time, or that aggravation may occur. Hence, the endpoint 'no return to work' cannot be assumed to reflect aggravation of LBP, and hence, results of our study are difficult to compare with the studies on 'no return to work.' Re-analysis with no-improvement as endpoint (=aggravation or stability of the severity of LBP) did not alter our results of our study though. Lifting and carrying loads over 10 kg was the only physical risk factor for the development of the course of LBP over time in the present study.

A few studies have suggested that psychosocial work factors are associated with a slower return to work or with the development of chronicity and disability, most notably poor job satisfaction, and high work demands (6,9,10,15). This result is in contrast with our study where little association was found between work demands and aggravation of LBP. The lack of an association between skill discretion and the development of LBP as reported in the previous studies (9,10) was confirmed by our study.

Results from several previous studies suggest that the development of LBP over time is associated with age (4,10,18,40). We found that the observed risk of aggravation of LBP characterized by increased levels of pain severity was higher for older workers than younger workers. In contrast, we found a weak but inverse association between years in current employment and aggravation of LBP in terms of severity. These seemingly contradictory findings might be due to selection factors that operated before the start and during follow-up. With a mean age of 40 years and with average employment duration in the current job of 8.9 years (Table 6.3) this implies that, on the average, subjects with LBP at baseline started working at the facilities participating in this study at the age of 31. Since a career of nurses or caregivers usually starts in their early twenties, this indicates that many subjects with LBP used to work somewhere else previously. An explanation for the contrasting results of age and years in current employment is that the majority of older workers that experienced aggravation LBP did not work their whole career in the current employment or facility and changed jobs in the past due to the seriousness of their LBP, whereas a minority of older worker that have a long working history in the current employment or facility are a selection of relatively healthy workers that do not feel they have to change jobs due to LBP and have less risk of aggravation of their LBP.

We conclude that individuals experience changes in the duration, frequency and severity of their LBP episodes over time, whereas at group level there seems a relatively constant prevalence of more serious LBP in terms of duration, frequency, and severity. Occupational exposure to lifting and carrying loads over 10 kg appears to be a risk factor for aggravation of LBP among persons employed in nursing homes or homes for the elderly.

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Part 3

The dynamic pattern in the long-term course of low back pain and associated disability in occupational populations

Chapter 7

The transient nature of low back pain and its consequences for the long-term course of low back pain and associated disability

Chapter 7

The transient nature of low back pain and its consequences for the long-term course of low back pain and associated disability

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Abstract

Background. Low back pain is characterized by a dynamic pattern of episodes and recovery, but little is known about the long-term course of back pain and its consequences due to lack of cohort studies with sufficiently long follow-up periods.

Methods. A cohort of 523 workers in nursing homes and homes for the elderly was followed prospectively for two years. Physical load for different occupations was measured by observations at the workplace. Psychosocial factors at work, individual characteristics, and low back pain were determined by questionnaire once a year. The effect of work load on the occurrence of low back pain and the transition of low back pain into sickness absence due to low back pain was calculated with logistic regression analysis. A Markov model was used to evaluate the long-term consequences in a hypothetical cohort of workers. A follow-up of more than 40 years was constructed (40 cycles of 1 year) with transition probabilities between no complaints, low back pain, and sickness due to low back pain. Permanent disability was used as end state of health.

Results. Depending on the physical load experienced in the job, the transition probability from no complaints to low back pain varied between $p=0.25$ and $p=0.29$, from low back pain to sickness absence due to low back pain between $p=0.09$ and $p=0.25$, and the probability of recurrence of sickness absence varied between $p=0.27$ and $p=0.50$. During a 40 year career, total sickness absence due to low back pain was approximately 140 weeks (6.6%) among workers with high exposure to physical load and about 30 weeks (1.4%) among those with low exposure to physical load.

Conclusion. The Markov modeling approach illustrated the profound impact of physical load on (permanent) disability due to low back pain among workers with exposure to physical load. These consequences will not become apparent in cohort studies with follow-up periods of a few years.

Introduction

Low back pain (LBP) is a common health condition in working populations. Considering the lifetime prevalence of 60-85%, it will eventually affect almost everyone during working life, men and women equally (1). LBP is a frequent reason for medical care seeking with an estimated 6-7% of the adult population annually consulting a general practitioner for their complaints (2). In the majority of patients LBP seems a limiting condition from which 90% of all patients stop consulting their medical practitioner within 1 month and about 80% recover sufficiently to return to work in about six weeks (3,4). Among patients with acute LBP lasting less than 3 days 90% reported to be without pain or disability 2 weeks after first presentation to their general practitioner (5).

Although these findings suggest that most LBP problems will have resolved within a few weeks, high recurrence rates have been reported. Within 12 months over 60% of LBP patients from general practices experienced relapses of pain (3). Croft and colleagues (2) reported that only 25% of all patients with a new episode of LBP had completely recovered from pain and disability within 12 month after their initial visit to a general practice. In an occupational cohort the annual recurrence rates of LBP varied between 64% and 77%, with only few workers consistently reporting the presence or the absence of LBP during a 4-year period (6). These prospective studies indicate that LBP is quite persistent with strong fluctuations in severity of complaints, expressed by recurrent episodes interspersed with periods free from pain (7).

In the past two decades it has been well documented that physical load caused by frequent lifting, awkward back postures, and whole body vibration is a risk factor for the occurrence of LBP (8). However, little is known about the impact of physical load on the long-term course of LBP and associated consequences for work disability. Frequent lifting has been identified as a risk factor for recurrence of LBP (6) and as a determinant in the transition from acute to chronic back pain (9). A few studies have shown that physical load was a risk factor for sickness absence due to LBP (10-12) whereas other studies have failed to demonstrate an effect of physical load on sickness absence duration (13,14). Thus, it remains largely unknown whether work-related risk factors for the occurrence of LBP also are important prognostic factors for aggravation of LBP and associated disability. This ambiguity may be partly explained by the lack of cohort studies with sufficiently long follow-up periods to identify determinants of persistence and/or recurrence of LBP and subsequent morbidity. However, the information from cohort studies with a limited time horizon may be used to predict the long-term course of LBP in these cohorts. In this regard, a particularly useful technique is a Markov model of prognosis which can be used for health events of discrete nature that happen more than once over time (15). A Markov model assumes that the patient is always in one of a finite number of health states, for example no complaints, back pain, and sickness absence due to back pain. The course of disease is modeled by transitions from one state to another during a specified period of time. Under the assumption that these transition probabilities are constant over time, a Markov chain may be created by repeating each cycle a certain number of times to represent a meaningful time interval, for example employment in the same job for 30 years or more.

In order to understand the long-term course of back complaints and associated disability, we studied the dynamic pattern of incidence, recurrence, and severity of back complaints in an occupational cohort study and applied a Markov model to mimic the long-term consequences of LBP in this cohort of workers. The aims of this study were 1) to analyze the effects of work-related risk factors, especially physical load, on the occurrence of LBP and the transition from LBP into sickness absence due to LBP, and 2) to predict the long-term consequences of prolonged exposure to high levels of work load on LBP and associated permanent disability.

Material and methods

Study population

A longitudinal study was conducted among workers from 7 nursing homes and homes for the elderly in The Netherlands who were employed for at least 10 hours per week. During the baseline survey self-administered questionnaires were used and detailed assessments of physical load in each occupation title group were carried out. Follow-up questionnaires were applied one and two years after the baseline survey. Of the 1,208 subjects invited to enroll in the study, 769 (64%) subjects agreed to participate. This study population consisted of 9 different occupational groups: 129 nurses, 264 caregivers, 58 kitchen workers, 49 housekeepers, 14 transportation and technical workers, 9 laundry workers, 38 (physical) therapists, 146 office workers, and 62 miscellaneous workers. At 1 year follow-up 541 (70%) of the 769 subjects responded again, of which 523 (68%) provided sufficient information for the current analysis. After 2 years of follow-up 346 out of 541 (64%) subjects responded with 341 (63%) complete questionnaires.

Data collection

Questionnaire survey

A questionnaire was used to collect information on personal characteristics, including age, sex, length, weight, education, family status, and employment history, psychosocial factors at work, and the occurrence of musculoskeletal complaints (6).

Psychosocial factors at work were derived from the Karasek model on job control and work demands (16). Job control consisted of eleven questions on decision authority and reflected aspects such as influence on the planning of tasks, influence on the pace at work, brief pauses when needed, and decisions on time spent on given tasks (Cronbach's alpha 0.90), and six questions on skill discretion, such as skills required, task variety, learning new things, and amount of repetitive work (Cronbach's alpha 0.80). Eleven questions on work demands related to working fast, working hard, excessive work, insufficient time to complete the work, and conflicting demands (Cronbach's alpha 0.88). The response to each question was scored on a 4-point ordinal scale, ranging from 'seldom or never' to 'always' during a regular workday. For both dimensions a sum score was computed and expressing on a 0-100 scale. A score of 100 was defined as the worst possible situation and 0 as the best possible situation. In the statistical analysis these scores were dichotomized at the mean of the overall distribution.

Information on the occurrence and nature of low back complaints was gathered with the Nordic questionnaire for the analysis of musculoskeletal symptoms (17). LBP was defined as any episode of pain that lasted for at least a few hours in the previous 12 months. An incident case of LBP was defined as the presence of an episode of LBP during the follow-up year among subjects who reported the absence of LBP at baseline.

The occurrence of sickness absence due to an episode of LBP was determined by a questionnaire on frequency and duration of sickness absence which showed a high specificity (97%) and sensitivity (88%), and a good agreement for back pain absence (Cohen's κ 0.65) (18).

Quantitative assessment of physical load

In a group of 212 workers randomly sampled at baseline, observations were made at the workplace on physical load during work for each of the 9 occupations. The proportion of observed subjects per group ranged from 16% for the nurses to 64% for the transportation and maintenance workers, thereby oversampling those occupations with fewer subjects. The primary aim was to have at least 10 workers in each occupation in order to arrive at a reasonable estimate of the average exposure of each group (19). In the 3 largest occupational groups at least 10 workers were sampled in 4 different nursing homes in order to increase generalisibility across homes. An observational multimoment method was used to describe three measures of physical load: trunk flexion between 20 degrees and 45 degrees, trunk flexion over 45 degrees, and lifting or carrying loads over 10 kg, all expressed in percentage of work time. Observations were made on selected workers every 20 seconds during 4 periods of 30 minutes on a regular workday, thus, collecting 360 observations per worker. For every occupational group the exposure to each measure of physical load was calculated as the mean percentage of work time across all subjects selected for observation in that occupational group. Subsequently, the arithmetic mean for the occupational group was used as a proxy for exposure in all subjects, both observed and unobserved, in that occupation. An underlying assumption of this strategy is that the average physical load of the observed workers is equal to the average physical load of the total occupational group (20,21). In order to estimate the average exposure to physical load of each individual worker, the occupation-specific exposure expressed in percentage of work time was multiplied by self-reported number of hours worked per week. A detailed description of the effects of this measurement strategy on dose-response relations between physical load and LBP has been published elsewhere (21).

Data analysis

A simulation was carried out of a hypothetical cohort of workers in nursing homes and homes for the elderly, all aged 25 years, who were free of LBP in the previous 12 months and followed up for a period of 40 years. A Markov chain approach was used with one year increments of time during which a subject may make a transition from one health state to another (15). In this analysis, four health states were defined: healthy subjects, LBP in the past 12 months, sickness absence in the past 12 months due to LBP, and permanently disabled after a prolonged sickness absence of 365 days. The latter health state was considered an absorbing state, i.e. transition to another state from within this state is regarded to be impossible. The transition probabilities were assumed to be constant over time, i.e. the transition from one health state to another health state in a given year is independent from the health status in earlier one year cycles.

Logistic regression analysis was conducted on the study population that completed the first follow-up (n=523) in order to evaluate the effect of physical work load, psychosocial work load, and individual characteristics on the occurrence of LBP and sickness absence due to LBP during the 1 year follow-up period. Three levels of physical load were assigned, based on tertiles of the exposure distributions of trunk flexion between 20 degrees and 45 degrees, trunk flexion over 45 degrees, and lifting or carrying loads over 10 kg (21). The highest level of physical load was defined as lifting and carrying loads at least 30 min per week and trunk flexion over 45 degrees during 75 minutes per week or more. An intermediate level of physical load was defined as lifting and carrying loads at least 30 min per week or trunk flexion over 45 degrees during 75 minutes per week or more. The two psychosocial factors were dichotomized at the mean value of their underlying scales. Individual characteristics were age (y), height (cm), weight (kg), body mass index (weight/(height)^2), and education. Age, physical load, and psychosocial aspects were forced into a multivariate model, independent of their level of significance. Other individual characteristics were retained in the model when reaching a level of significance of $p < 0.05$. Wald statistics were used to estimate the 95% confidence intervals around the odds ratios.

The Markov chain approach was based on a polytomous logistic regression analysis on the associations of work-related risk factors with LBP and sickness absence due to LBP. The simulation approach was restricted to evaluation of the effect of physical load, since a previous analysis demonstrated that physical load was the most important work-related risk factor for aggravation of LBP (22). The polytomous logistic regression model was fitted on data of the study population that completed the first follow-up (n=523). The population that completed the second follow-up (n=341) was used to evaluate whether systematic differences in risk estimates were present between both years of follow up. The odds ratios from the univariate polytomous logistic regression models were converted into transition probabilities for the health states: healthy, LBP, and sickness absence due to LBP (23). Since the actual follow-up of the study population was too short to determine the risk of becoming permanently disabled due to LBP (duration of sickness absence exceeds 365 days), the transition probability from sickness absence to permanently disabled was estimated, on average, as $p = 0.01$, derived from a prognostic study among workers with sickness absence due to LBP (24). This average transition probability was assigned to subjects with exposure to intermediate levels of physical load and subjects with higher and lower exposure to physical load were assigned transition probabilities weighted by the probability of recurrence of an episode of sickness absence due to LBP.

The estimates of transition probabilities were carried out with proc CATMOD in SAS statistical software version 8.2 (25). With the Markov chain approach a cohort simulation was conducted with software program DATA TreeAge Pro (26). The sampling uncertainty (i.e. standard errors) of the transition probabilities was taken into account by means of a second order Monte Carlo simulation. The cohort simulation started with all subjects at age 25 years, who were followed up for a 40 year career in the same job with a constant level of physical load. For each level of physical load the average number of weeks with sickness absence was calculated as well as the number of years with permanent disability during this 40 year working life.

Results

Of the 769 subjects included at baseline, 246 (32%) were not available to provide suitable outcome information at follow-up. The participation rate among the 9 professions and 7 nursing homes varied considerably, but was not related to the prevalence or severity of LBP at baseline. Of those lost to follow-up, 39 subjects changed jobs to employers not participating in the study. The prevalences of LBP and sickness absence due to low back pain at baseline among subjects lost to follow-up were similar to those among subjects available for follow-up. Among those subjects without LBP at baseline no differences in physical load was found between workers available for follow-up and those lost to follow-up. Those lost to follow-up, however, were slightly younger and had fewer years of employment at the facility.

Personal characteristics and work-related physical load and psychosocial aspects of the study population are presented in Table 7.1. About 84% of the subjects were women with a mean age of 41 years and approximately 9 years of employment in their current job. In the total study population the prevalence for LBP varied between 50% (n=171, second year of follow-up) and 58% (n=303, baseline survey) and for sickness absence due to LBP between 9% (n=48, baseline survey) and 13% (n=69, first year of follow-up) (Table 7.2). The estimated one-year cumulative incidences of both health states were 26% and 7%-11%, respectively. A high recurrence was observed for both LBP and sickness absence due to low back pain. During the first year of follow-up 43% (n=30) of the subjects with sickness absence due to LBP reported a total duration of 7 days or less, 13% (n=9) reported 8-14 days, and 30% (n=30) reported more than 14 days. The average duration of an episode of sickness absence due to LBP in the study population was assumed to be around 2 weeks.

Table 7.1 Personal characteristics and work-related physical load among personnel of nursing homes and homes for the elderly (n=523)

	Mean (SD)[a]
Individual characteristics	
Age (y)	40.7 (9.7)
Duration on employment current job (years)	9.3 (6.9)
Female (n, %)	439 84%
Work-related physical factors	
Trunk flexion between 20-45 degrees (hour/week)	4.5 (1.6)
Trunk flexion over 45 degrees (hour/week)	1.1 (0.6)
Lifting or carrying loads over 10 kg (minutes/week)	18.8 (16.1)
High physical work load (n, %)	108 20.7%
Intermediate physical work load (n, %)	142 27.2%
Low physical work load (n, %)	273 52.1%
Work-related psychosocial aspects	
Work demands (0-100)	47.0 (16.3)
Job control (0-100)	41.2 (16.0)

[a] SD=Standard deviation

Table 7.2 Prevalence, incidence, and recurrence of low back pain in the past 12 months and sickness absence due to low back pain in the past 12 months among personnel of nursing homes and homes for the elderly during the first and second year of follow-up

	Low back pain			Low back pain with sickness absence		
	Baseline (n=769)	*Follow-up 1 (n=523)*	*Follow-up 2 (n=341)*	*Baseline (n=769)*	*Follow-up 1 (n=523)*	*Follow-up 2 (n=341)*
Prevalence	57.9% (54.7-61.2)	54.5% (51.3-57.6)	50.2% (46.4-53.9)	9.2% (8.4-9.9)	13.2% (12.1-14.2)	11.4% (10.3-12.6)
Incidence	-	26.4% (23.4-29.4)	25.8% (22.3-29.3)		10.7% (9.8-11.6)	7.2% (6.4-8.0)
Recurrence	-	74.9% (70.7-79.1)	70.4% (64.9-75.9)		37.5% (29.1-45.9)	36.0% (28.0-44.0)

Work-related risk factors were not associated with the occurrence of LBP during the first year of follow-up, but a significant trend was observed for level of physical load and sickness absence due to LBP (Table 7.3). Age had a statistically significant association with LBP (OR=0.98) but not with sickness absence, although a similar magnitude of effect was found. Other individual characteristics, such as height, weight, body mass index, and education were not associated with either LBP or sickness absence due to LBP. The analysis of risk factors for LBP during the second year of follow-up showed comparable results but the determinants of sickness absence because of LBP were highly instable due to the small number of occurrences (n=39).

Table 7.3 The association between work-related physical factors and psychosocial aspects at baseline and the occurrence of low back pain and sickness absence due to low back pain during a 1 year follow-up among personnel of nursing homes and homes for the elderly (n=523)

Risk factor		Low back pain		Sickness absence due to low back pain	
	n	*OR*	*95% CI*	*OR*	*95% CI*
Age (y)		0.98	0.96-0.99	0.98	0.95-1.01
Low physical load	273	1.00	reference	1.00	reference
Intermediate physical load	142	0.97	0.63-1.49	2.00	1.04-3.85
High physical load	108	1.01	0.63-1.63	2.95	1.52-5.71
High work demands (1/0)	277	1.10	0.76-1.58	0.83	0.48-1.44
Low job control (1/0)	234	1.12	0.78-1.60	0.88	0.51-1.51

Figure 7.1 describes the Markov process used in the simulation of the hypothetical cohort of workers, all 25 years old and without LBP, with different levels of exposure to physical load. This model incorporates all events of interest with long-term sickness absence (> 52 weeks) as absorbing state, i.e. recovery from this state was

assumed to be impossible. The Markov sign (M) indicates that repeated cycles of 1 year follow.

Figure 7.1 The Markov process used in the simulation of a hypothetical cohort of workers, all 25 years old and without low back pain, with different levels of exposure to physical load

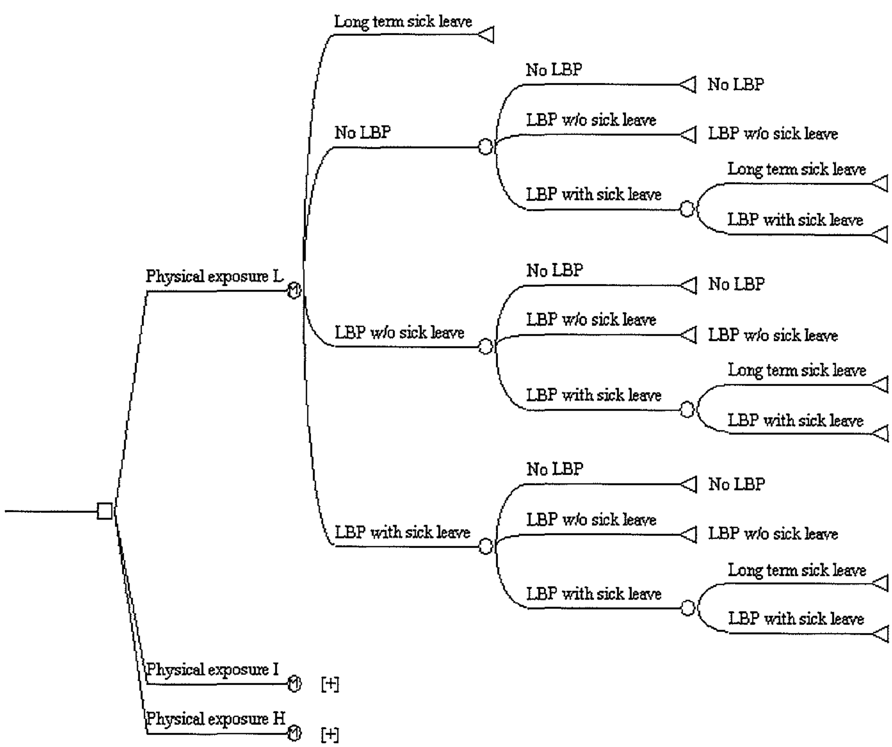


Table 7.4 presents the matrix with transition probabilities for different levels of physical load among the distinguished health states, as derived from the polytomous logistic regression analysis. Among subjects with LBP the probability to take sick leave was p=0.25 for those exposed to high physical load and p=0.09 for those with a low physical load. Taking sick leave during the follow-up among healthy subjects at baseline was higher among those with a high exposure to physical load than those with low exposure, p=0.10 and p=0.05, respectively. A comparable difference was observed for recurrence of sickness absence with p=0.50 and p=0.27, respectively. This latter difference was used to adjust the average transition probability from sickness absence to becoming permanently disabled of p=0.01 to the level of physical load, resulting in an increased probability of p=0.0135 (0.50/0.37) among subjects with the highest exposure and a decreased probability of p=0.007 (0.27/0.37) among subjects with the lowest exposure.

Table 7.4 Matrix of transition probabilities (and standard error) for three levels of physical load among the distinguished health states for low back pain during a 1 year follow-up among personnel of nursing homes and homes for the elderly (n=523)

Baseline		Follow-up	
	No LBP	*LBP w/o sick leave*	*LBP with sick leave*
Low physical load (L)			
No LBP	0.75 (0.04)	0.20 (0.04)	0.05 (0.02)
LBP w/o sick leave	0.28 (0.04)	0.63 (0.04)	0.09 (0.02)
LBP with sick leave	0.20 (0.10)	0.53 (0.13)	0.27 (0.11)
Intermediate physical load (I)			
No LBP	0.75 (0.05)	0.19 (0.05)	0.06 (0.03)
LBP w/o sick leave	0.18 (0.05)	0.64 (0.06)	0.18 (0.05)
LBP with sick leave	0.32 (0.11)	0.32 (0.11)	0.37 (0.11)
High physical load (H)			
No LBP	0.71 (0.07)	0.19 (0.06)	0.10 (0.05)
LBP w/o sick leave	0.25 (0.06)	0.50 (0.07)	0.25 (0.06)
LBP with sick leave	0.17 (0.11)	0.33 (0.14)	0.50 (0.14)

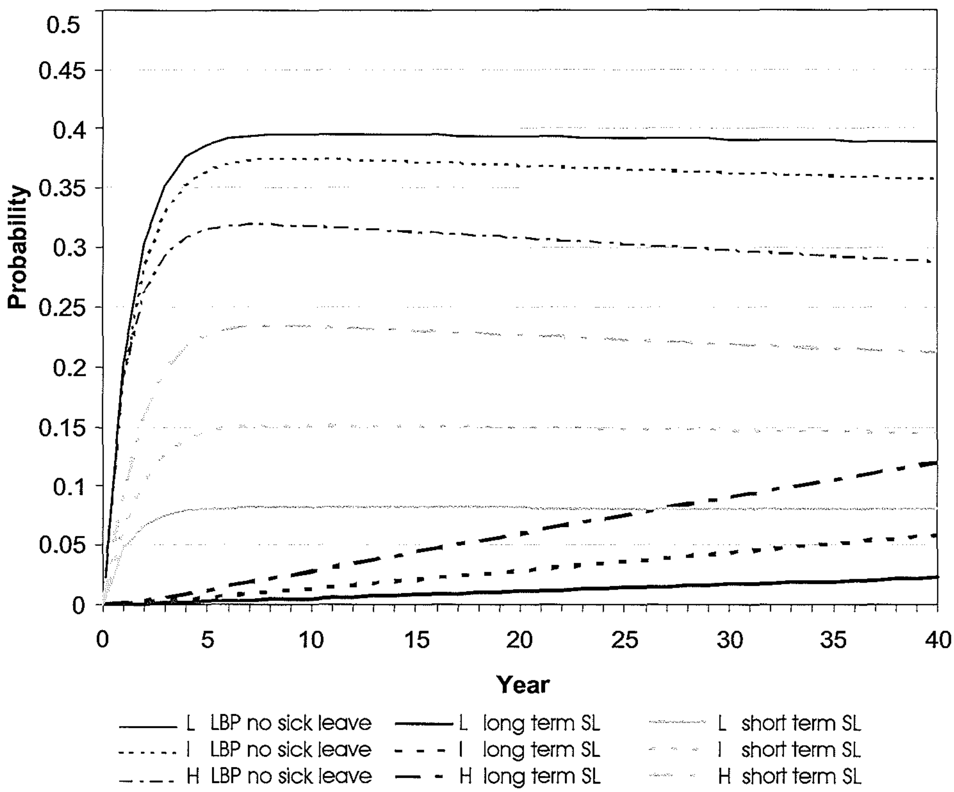
Figure 7.2 depicts the results of the simulation of the hypothetical cohort. The prevalence of LBP without sickness absence in the past 12 months reached a maximum after about 5 years of exposure to physical load and subsequently remained stable, albeit at different proportions for each level of physical load. A similar pattern was observed for sickness absence due to LBP, whereas the proportion of subjects becoming permanently disabled (> 52 weeks of sickness absence) increased with linear trend over time.

Table 7.5 Work weeks lost because of sickness absence due to low back pain and to permanent disability (> 52 weeks sick leave) due to low back pain during a 40 year career working in nursing homes and homes for the elderly

	Weeks of sickness absence due to low back pain		Weeks of permanent disability due to low back pain	
	Mean	*95% CI*	*Mean*	*95% CI*
Low physical load	6.26	3.61- 9.57	22.36	13.00- 34.32
Intermediate physical load	11.29	6.86-16.92	57.20	32.76- 83.20
High physical load	17.47	10.62-26.43	121.16	69.68-190.84

Table 7.5 summarizes the impact of physical load on weeks of work lost during a working life due to sickness absence and permanent disability. Among workers with the highest exposure to physical load about 6.6% of their working life was lost due to sick leave because of LBP, whereas the corresponding loss was 1.4% among workers with a low exposure to physical load.

Figure 7.2 Projected effect of three levels of physical load (High, Intermediate, Low) on the prevalence of low back pain and sick leave due to low back pain and the proportion of workers with long-term sickness absence (> 52 weeks) in a hypothetical cohort with 40 years of follow-up among personnel in nursing homes and homes for the elderly



Discussion

In this longitudinal study in a working population we observed 12-month incidences for LBP of 26%, 12-month prevalence roughly twice as high, and 12-month recurrences approximately threefold the incidence figures. Associated sickness absence was high with 16%-24% of all subjects with LBP in a given year taking sick leave for these complaints. The level of exposure to physical load was not associated with the occurrence of LBP but a risk factor for sickness absence due to LBP. The excess working lifetime lost due to sickness absence because of LBP was 6.6% among workers with the highest exposure to physical load compared with 1.4% among those with low exposure to physical load.

Since the participation rate among the 7 nursing homes was not associated with the characteristics of LBP in the baseline survey, selective participation at the start of the cohort does not seem to pose an important problem. No differences in the distribution of duration, frequency, and severity of LBP were found between subjects available and lost to follow-up. Subjects were partly lost to follow-up due to change of employer, especially during the first years of employment. Non-respondents during the follow-up reported slightly less job control and were more likely to have received medical treatment because of LBP than subjects not lost to follow-up. Thus, the presence of selection bias during the follow-up cannot be ruled out.

In this study the physical load was assessed by detailed observations at the workplace among a random sample of workers within each occupational group. Such approach is sensitive to substantial measurement error in exposures with a low frequency of occurrence during work time. Lifting and carrying loads had a low frequency and the within-subject variance capturing up to 80% of the total variance (21). In order to reduce the influence of within-subject variance the average level of physical load in each occupational group was multiplied by the individual's self-reported number of hours worked per week. In a cross-sectional analysis of associations between physical load and LBP this strategy resulted in the strongest associations, most likely reflecting the smallest attenuation due to random measurement error in exposure (21).

A good consistency was found between prevalence, incidence, and recurrence during the consecutive follow-up periods in this occupational cohort. The 12-month prevalence of LBP in the annual surveys varied between 50%-58% and were within the range of reported prevalences of 42%-76% among nurses in cross-sectional studies, using a similar questionnaire on LBP (27-30). The annual incidence of 26% is consistent with other occupational populations (6,31). The high yearly recurrence of LBP compares well with previous reports and reflects the finding that a history of LBP is a strong predictor of future episodes (3,6,30,32). A disadvantage of this study was that prevalence, incidence, and recurrence of LBP were determined by a recall period of 12 months. During this long recall period subjects may have experienced several episodes of back pain within the previous year and, thus, an incident case may have had recurrent episodes within that year. In addition, the subjects with persistent pain are a combination of subjects with continuous pain and those who had several recurrences during one year. A shorter recall period would undoubtedly have resulted in lower estimates for incidence and recurrence of LBP and a better distinction between acute and chronic LBP.

In this longitudinal study physical load and psychosocial factors were not associated with the occurrence of LBP during the 1 year follow-up, although these risk factors have been associated with the incidence and prevalence of LBP (8). Given the high prevalence and recurrence of LBP in the study population, this study may have had too little discriminatory power to identify an independent effect of work-related risk factors. However, physical load was a clear risk factor for sick leave due to LBP as observed in other studies (11,33), but the effects of psychosocial aspects could not be corroborated (34). The findings on sick leave may partly reflect the transition from acute to chronic back pain whereby physical load aggravates pain, resulting in increased functional limitations (9). The absence of any effect of psychosocial factors in this study population is noteworthy since psychosocial factors are hypothesized to be more important for the risk of recurrence or progression to chronic disability than objective biomechanical measures (35).

The input for the modeling approach was limited to the effect of physical load on LBP and associated health states. Hence, the estimated consequences in terms of total work time lost during working lifetime are influenced by a substantial degree of uncertainty, for example due to the lack of adjustment for other potentially relevant confounders, the assumptions on transition probabilities to permanent disability, the subsequent assumption that permanent disability was a definite state whereby the worker remains disabled and no rehabilitation was possible, and not taking into account change of job to less strenuous activities. Hence, the confidence intervals of the average number of work weeks lost only reflect the effect of random error in estimates of the transition probabilities. A sensitivity analysis addressing other sources of uncertainty would have resulted in a much larger range of work weeks lost due to prolonged exposure to physical load. Notwithstanding these uncertainties, it is of interest to note that the hypothetical cohort quickly reaches equilibrium, with the prevalence of LBP without sick leave stabilizing around 32-40% after 5 to 6 years, depending on the level of physical load. This complies well with the estimated annual incidence of LBP of 26% and suggests an average latency period of 5 – 6 years. The quickly reached equilibrium also illustrates that in longitudinal studies the overall prevalence will remain very stable, whereas individual trajectories of LBP over time will show a dynamic pattern. Indeed, in a longitudinal study across eight years is was observed that the annual prevalence varied between 73% and 76% and that the proportion of repeated increase of LBP (19%) was approximately as large as the proportion of repeated decrease of LBP (17%) (29). As a consequence, it may be difficult to distinguish incident cases from recurrent cases since the case definition largely depends on the particular time window of study (6). Hence, this implies that studies on risk factors for LBP should include both incidence and recurrence of complaints.

The Markov chain used in the current analysis was completely defined by the transition distribution among the distinguished health states of LBP, which was assumed to be constant over time. Thus, the process does not take into account the full history of complaints of an individual worker, such as nature and severity of previous LBP, although chronicity of LBP will have a worse prognosis than acute LBP (2,3,35). However, there are only few longitudinal studies available to evaluate whether this important assumption may be reasonable over a prolonged period of many years. One study among nurses with eight years of follow up concluded that LBP has more a recurrent than a progressive nature (29). Another study among nurses with 8 consecutive questionnaires each 3 months apart during 2 years of follow-up showed that the presence of symptoms within the past 9 to 12 months were most relevant for the probability of recurrence (36). Although the Markov model may be expanded with features such as cycle specific covariates (e.g. a lower transition probability for LBP to sickness absence in the first few years), and non-constant transition probabilities (e.g. a progressively higher probability of permanent disability with increasing cycle number, reflecting an effect of cumulative exposure), in the absence of epidemiological information the risks were considered constant over time. Thus, the estimated number of weeks lost to sickness absence due to LBP highly depends on the particular characteristics of the cohort of nursing personnel studied and the assumptions underlying the Markov modeling approach.

Although the calculated odds ratios illustrate the influence of physical load on LBP and associated disability, these measures may not be sufficient for conveying the impact of physical load on public health. The assessment of years of work time lost due to back pain may be more useful to decision makers to appreciate the necessity for workplace interventions. The adopted approach of modeling a hypothetical cohort presents an assessment of the long-term benefits of interventions directed at reducing physical load by calculating the average number of cycles spent in each health state. By applying a quality factor to each state (utility) the expected cumulative utility accrued for the entire Markov process may be compared for alternative intervention strategies in a cost-effectiveness analysis. The expected benefits may also be tailored to an existing occupational population by estimating the cohort-specific transition probabilities and by using the actual distribution of health states as starting composition of the hypothetical cohort to be followed over time.

In conclusion, the Markov model presents a methodology that demonstrates the profound impact of long-term exposure to high physical load on LBP and associated disability. The approach of years of work lost is a more adequate description for work-related risk factors that accelerate the onset of a more or less inevitable disease, such as LBP, than relative risks or attributable risk fractions (36). The perceived significance of a loss of 6.6% of work time during a working life due to high physical load may provide for decision makers a better measure of adverse effect than an odds ratio of 2.95 for sickness absence due to LBP. The concept of work years lost may also facilitate a better appreciation of the potential benefits of preventive measures.

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Chapter 8

General discussion

The overall objective of the thesis was to study the occurrence of low back pain (LBP) in several occupations, with a specific focus on the onset and aggravation of LBP in relation to exposure to physical load at work. In this chapter the main findings in the context of the specific aims (see Chapter 1) are summarized. Furthermore, methodological issues of the study are discussed and final conclusions and implications for research and practice are presented.

Summary of findings

Quantification of physical load at the workplace

In Chapter 2 the scientific literature of the past 20 years was reviewed in order to evaluate the strength of associations between physical load and back problems in different study designs, and to evaluate whether the magnitude of the risk estimate was influenced by the measurement technique used. In most studies the information on physical load at work was collected by means of self-reports, either in an interview or in a questionnaire. The meta-regression analysis in the review demonstrated that studies with observations and direct measurement techniques showed higher risk estimates than studies based on questionnaires. This finding may be explained by a larger (nondifferential) misclassification of exposure in questionnaire studies or by a larger contrast in exposure in studies with actual workplace surveys to determine exposure levels. Self-reported physical load has a low accuracy and precision and, at best, can be used to rank occupational groups on an ordinal scale with crude exposure categories (1,2).

It is well known that the dynamic and static aspects of postural movements are important in explaining why physical load may cause musculoskeletal problems (3-5). Hence, exposure characterization of physical load should take into account three essential parameters: level, frequency, and duration. In Chapter 3 the differences in exposure to postural load between three occupational groups were determined, using continuous recordings of lumbar posture during an average workday. The use of hierarchical models in analyzing exposure level, frequency, and duration of postural load simultaneously offered a promising alternative to the conventional analysis of continuous exposure data in ergonomics whereby dynamics of exposure are often ignored. The analysis demonstrated that nurses and housekeepers spent a considerable larger amount of their work time in larger trunk angles in combination with shorter time periods within the same posture than office workers; the office workers spent a larger amount of their work time in smaller angles for longer time periods. An implication of the results is that the often adopted measure of physical load -percentage of work time with the back bent for 20 degrees or more-- does not discriminate between nurses (or housekeepers) and office workers, since this traditional measure ignores the frequency aspects of the exposure pattern. In order to have sufficient contrast in observed exposure to trunk flexion in epidemiological studies on dose-response relations a cutoff of at least 30 degrees is advised.

Observational techniques have the advantage of being easily applicable in many work situations, combining sufficient detail of the important dimensions of physical load (6,2). In general, two measurement strategies can be identified: the individual approach and the group approach. Although there are limitations to draw conclusion from one data set, Chapter 4 showed that the choice for a particular measurement strategy of physical load influences the strength of the associations between physical load and LBP.

Not only the measurement technique (self-reports versus observations or direct measurements) and observation strategy influence the relation between physical load and LBP, but the assumed nature of the dose-response relation is of importance as well. Chapter 4 showed that statistical models that anticipate a linear relation between physical load and severe LBP may be unable to identify specific patterns of exposure and associated risks when applied over the whole exposure range. Categorical models have also drawbacks, since the choice of particular cutoff values, often based upon percentiles of the underlying distribution, may not reflect relevant effects of physical load on LBP. When quantitative estimates of physical work load are obtained, this enormous measurement effort asks for statistical techniques that make full use of the informational content. Spline models are a promising approach to identify quantitative dose-response patterns between physical load and LBP.

Dose-response relations of occupational exposures to physical and psychosocial factors and the onset and aggravation of LBP

In Part 2 of this thesis the dose-response relations of physical load and psychosocial aspects with the onset and aggravation of LBP were evaluated. The estimated one-year cumulative incidence (risk) of LBP among persons employed in elderly facilities was more than 20%, and the estimated one-year cumulative incidence of severe or disabling LBP was about 9%. About 25% of the individuals reported aggravation of their course of LBP in a two-year period.

In Chapter 5 it was shown that trunk flexion over 45 degrees was monotonically associated with the risk for more severe or disabling LBP but not with less severe or transient LBP. The risk was about 2-fold greater among subjects with an exposure of more than 1 hour per week (>50th percentile) in comparison with subjects with an exposure of 30 minutes or less per week. Exposure to trunk flexion over 45 degrees for more than 1 hour and 45 minutes per week resulted in a more than 3-fold greater risk. Hence, occupational exposure to trunk flexion over 45 degrees appears to be a risk factor for LBP with disability. In Chapter 6 it was observed that lifting and carrying loads over 10 kg was consistently associated with aggravation of LBP in terms of severity of complaints. An increased risk for a longer duration of LBP episodes was found as well. The risk of aggravation of LBP was more than 2 times greater for subjects lifting and carrying loads for more than 45 minutes per week (90th percentile) than for subjects lifting and carrying loads for less than 1 minute per week. It appears, therefore, that among LBP patients lifting and carrying loads over 10 kg is a risk factor for future aggravated LBP episodes, characterized by increased levels of pain and prolonged duration. Although a few other work-related factors, including some psychosocial aspects, showed associations with the incidence and aggravation of LBP as well, these associations had large uncertainties in their risk estimates and, hence, their importance is difficult to appreciate.

The dynamic pattern in the long-term course of low back pain and associated disability in occupational populations

In Chapter 7 it was shown that in the longitudinal study in a working population the 12-month incidences for LBP were about 26%, the 12-month prevalences roughly twice as high, and 12-month recurrences approximately threefold the incidence figures. Associated sickness absence was high with 16%-24% of all subjects with LBP in a given year taking sick leave for these complaints. In Chapter 6 it appeared that at group level there seems a relatively constant prevalence of more serious LBP, whereas individuals experience dynamic changes in the duration, frequency, and severity of their LBP episodes over time. As a consequence, it may be difficult to distinguish incident cases from recurrent cases since the case definition depends largely on the particular time window of study. Hence, this implies that studies on risk factors for LBP should include both incidence and recurrence of complaints and, preferably, also study the aggravation of existing complaints.

In order to understand the long-term course of back complaints and associated disability, we studied the dynamic pattern of incidence, recurrence, and severity of LBP in the occupational cohort and applied a Markov model to mimic the long-term consequences of LBP in this cohort of workers. In Chapter 7 the level of exposure to physical load was not associated with the occurrence of LBP but a risk factor for sickness absence due to LBP. The excess working lifetime lost due to sickness absence because of LBP was 6.6% among workers with the highest exposure to physical load compared with 1.4% among those with low exposure to physical load. The approach of years of work lost is a more adequate description for work-related risk factors that accelerate the onset of a more or less inevitable disease, such as LBP, than relative risks or attributable risk fractions. The perceived significance of a loss of 6.6% of work time during a working life due to high physical load may provide for decision makers a better measure of adverse effect than an odds ratio of 2.95 for sickness absence due to LBP. The concept of work years lost may also facilitate a better appreciation of the potential benefits of preventive measures.

Methodological issues

Selection

The study population consisted of workers with different jobs in 7 nursing homes and homes for the elderly in the Netherlands. Workers employed for more than 10 hours per week were eligible to participate in the study. Baseline measurements were performed between March 1998 and March 1999. Follow-up measurements were performed one and two years after the baseline measurements.

Since the participation rate for each facility was not related to the prevalence of LBP at baseline, selective participation does not seem to have been an important problem in this study. Subjects lost to follow-up were younger, had fewer years of employment, reported less exposure to lifting and carrying loads, and reported less skill discretion than did subjects not lost to follow-up. Thus, the presence of bias due to selective loss to follow-up cannot be ruled out. Loss to follow-up was determined by non-response and job change (to an employer other than those participating in the study) during follow-up. Of those lost to follow-up, 39 subjects (16%) changed jobs. Furthermore, we know that there is a high turnover rate in the source population during the first years of employment and that changing jobs was associated with lower age and less years of employment among our subjects. These factors might explain the difference in age and years of employment between subjects lost and not lost to follow-up.

There might also be selection factors that have operated before the start of the follow-up. The study population included both subjects with and without LBP in the previous 12 months at baseline. For the incidence study (Chapter 5) only workers without LBP in the previous 12 months at baseline were included. This selection might have strengthened the impact of a healthy worker effect, with an underestimation of the risk estimates for incident LBP. Indeed, the estimated prevalence of LBP at baseline among nurses and caregivers, characterized by a higher exposure to physical factors, was about 70%, whereas the prevalence in the total study population was about 55%.

Another source of selection might be the use of different study populations for predicting different LBP outcomes (i.e. LBP and LBP with disability). The prediction of incidence LBP was restricted to only those 220 workers who were free of LBP at baseline, while the prediction of LBP with disability was conducted in 479 workers who were free of LBP with disability at baseline (56% of whom had LBP). Thus, the effect of occupational exposures to physical factors on LBP with disability might be greater for workers with existing (nondisabling) LBP than in workers without any LBP. Unfortunately, we could not test that hypothesis in our study because there were too few incident cases of LBP with disability among workers without LBP at baseline.

Outcome assessment

Information on LBP was measured with self-reports. The definition of LBP in the incident analysis - any episode of pain that lasted for at least a few hours in the previous 12 months- is a non-specific complaint, and may have resulted in differential reporting (i.e. misclassification) of LBP cases. It is possible for example that workers with higher exposure to physical load might be less likely to report minor complaints of LBP and only report the more severe episodes, whereas workers without high levels of exposure may report all LBP complaints; highly exposed workers might have a different perception of LBP.

In Chapter 6 aggravation of LBP was defined as an increase in severity, duration, or frequency. Unlike the continuous scales used to measure severity of LBP, duration and frequency were measured on categorical scales. The disadvantage was that not many categories were defined and the categories at the upper end of the scales were rather wide. This limited the sensitivity to detect changes in duration and frequency over time. Subjects with LBP in the upper categories of the duration scale (>3 months) and frequency scale (>5 episodes) were not able to report aggravation, due to the lack of a category reflecting a worse condition. This may have caused an underestimation of the aggravation of LBP over time, and thus an underestimation of effect of physical load on aggravation of LBP.

Exposure assessment of physical factors

Whereas the continuous registration of lumbar posture was used to evaluate the difference in exposure patterns between occupational groups, the observational method was used to estimate physical load at the workplace in the epidemiological study. The advantage of this observational approach is the ability to collect detailed quantitative information on several aspects of physical load simultaneously. A random sample of workers was observed to collect group-based average exposure patterns. The merits of the group approach as compared with the individual approach will largely depend on how uniform exposures are within groups, and also on the contrast in exposure between groups and the variability within and between workers in the same group (2,7-9).

As discussed in Chapter 4 we found that exposure assessment based on the observations was subject to a certain degree of random measurement error, especially for lifting and carrying loads, where the within-subject variance captured up to 80% of the total variance. Assigning workers to pre-defined groups with the group approach resulted in a small reduction of the between-subject variance since less than 10% of the total variation in exposure was captured by the between group-variance. This variance analysis suggested that the *a priori* grouping scheme, based on job title and work tasks, did not reflect distinguishable exposure profiles of physical work loads.

In general, random or nondifferential measurement error will result in underestimation of an effect (9). Simulation studies (10,11) have shown that Berkson measurement error, as is the case with exposure measurements at the group level, may result in bias in logistic and log-linear models with dichotomous outcomes. The bias is away from the null in estimating dose-response relations when, among others, the groups' variance of exposure increases with the groups' mean of the exposure. The correlation coefficient between the mean and the standard deviation of the percentage of work time in trunk flexion over 45 degrees among the different occupational groups was 0.90 and for lifting and carrying loads over 10 kg 0.97.

To measure the individual worker's cumulative exposure to physical load, the average percentage of work time devoted to that activity in the worker's occupation was multiplied by that individual's self-reported number of hours worked per week. Bias may occur in this estimate of average percentage of work time with exposure as well as in total duration of work time in work hours per week. Simulation studies have shown that when cumulative measures of exposure are used based upon a combination of data at group level and individual level estimates may be biased away or towards unity (11).

On the whole, it is difficult to predict whether, and to what extent, the observations resulted in biased estimates of effects of physical load in our study and in which direction the bias is likely to have occurred.

Exposure assessment of psychosocial factors

The psychosocial factors of interest were measured by a Dutch translated version of the Job Content Questionnaire developed by Karasek et al (12) and based on the Demand-Control-Support model. According to Demand-Control-Support model the adverse effect of psychosocial factors on health occurs when high jobs demands are combined with low decision authority and skill discretion (13,14). Obtaining information on psychosocial work factors with this questionnaire is a well accepted method in occupational research (in particular cardiovascular disease and musculoskeletal problems). However, as with any exposure assessment based on self-reports, information bias (e.g. differential reporting) may have biased the results. For example, the presence of LBP may have influenced the subjects' perception of skill discretion and work demands.

Statistical analysis

The evaluation of dose-response relations between physical load and LBP with statistical models that assume a linear form may be unable to identify patterns of exposure and associated risks when applied over the whole exposure range. Modeling the dose-response relation by stratifying the exposure (physical load) into several categories and comparing trends in risk estimates between categories also has drawbacks. Among other, it assumes homogeneity of risk within categories of exposure and allows large changes in risk between these categories (15). In Chapter 4 a hierarchy of nested logistic regression models (16) was used to determine a regression model rich enough to capture patterns of exposure and associated risks in the available data. It appeared that in comparison with the linear and quadratic models, the restricted quadratic spline models fitted best the dose response relations between the three physical factors and severe LBP. Like categorical regression analysis, the splines allow changes in risk at the boundaries of the categories but also make use of information within categories of exposure (instead of assuming homogeneity). Splines allow the risk to vary within and between categories of exposure (16).

To study the relative contribution of physical work factors, psychosocial work factors, and individual factors on the occurrence and aggravation of LBP, a multivariate analysis was performed with all these factors taken into account simultaneously. The different physical factors were strongly interrelated with correlation coefficients ranging from 0.29 to 0.59. In order to prevent confounding by physical work factors, we estimated the effect of each physical factor by controlling for all others, first, by including several occupational groups with different physical-exposure distributions; and second in Chapter 5, by using a hierarchical regression approach that enhanced effect estimation for multiple interrelated exposures (17-20).

Hierarchical modeling of the dose-response splines

When in Chapter 5 results from the conventional and hierarchical models were compared, clear differences were found only for the physical factors, especially for the effect of trunk flexion over 45 degrees on LBP with disability. Estimated confidence intervals tended to be narrower with hierarchical modeling than with conventional modeling. These findings are in accordance with the results of earlier research on log-linear hierarchical models (17-19). In general, with hierarchical regression, large and unstable effect estimates are pulled (regressed) towards a common mean. With a hierarchical linear model, the common mean or prior distribution describes a monotonic linear function; in practice, this often means that extremely unstable effect estimates are reduced towards unity. In contrast, with a hierarchical spline model the prior function is nonmonotonic (when the values of the second-stage design matrix are not zero). Essentially, this prior function is the mean of all dose-response curves found with the conventional model in one covariate domain. Unstable effect estimates are regressed towards this mean spline. The implication, in contrast to linear models, is that hierarchical regression affects not only the point estimates of effect, but also the shape of the dose-response relations.

In order to minimize bias in the estimates caused by regression to an inappropriate common mean or prior function, we must assume that parameters are exchangeable, and quantitative exposures must be scaled so that regression estimates for one unit of exposure can be compared (17). Therefore, in this study, we grouped the variables into three domains (physical factors, psychosocial factors, and time-related factors), and we identified exchangeable linear and quadratic parameters as described by positive second-stage covariates. A comparison of regression estimates was possible since the same unit of exposure was used for all variables within a domain. Given the values selected for the second-stage design matrix, the estimated relative risk at a given percentile of the exposure distribution was the same for all exposures in a domain. An alternative strategy for the second-stage design matrix would be to assign values of 1 for all parameters that are assumed to have an effect on LBP. This approach implies that the relative risk for a given unit increase of exposure described by the prior curve is the same for all exposures in a domain. This approach also implies that at a given percentile of exposure, the relative risk is not the same for different exposures in the domain of the physical factors. Unfortunately, this latter prior curve would not be realistic and would probably introduce bias because the range of exposure values may differ among exposures and the risks at these exposure values are not likely to be comparable. For example, an exposure of 6 hours per week to lifting and carrying loads over 10 kg is probably very rare and will not result in the same LBP risk as do 6 hours of exposure to trunk flexion between 20 and 45 degrees. Additional analyses indicated that the hierarchical model was not very sensitive to the actual values of the positive elements in the second-stage design matrix.

A two-step procedure, described Greenland and Witte (17,19,21) was used to do the hierarchical regression analyses. The second-stage variances $\underline{\tau}^2$ could be estimated from the data with empirical Bayes methods; however, the large number of parameters relative to the sample size let us to pre-specify the $\underline{\tau}^2$ to upper and lower bounds for the parameters of the splines (i.e., a semi-Bayes approach) (17-19). We set τ_p^2 to 0.5, which corresponds to a prior certainty of 95% that the relative risk (RR) per unit exposure lies in a 16-fold range, that the RR per unit exposure, reflecting departure from linearity comparing the first and second categories, lies in a 16-fold range, and that the difference in the quadratic term between the second and third categories also lies in a 16-fold range. When $\underline{\tau}^2$ was preset to 0.25 (instead of 0.5), which implies larger regression towards the prior curve (17-19), results were different only for estimates of less stable physical factors. Estimated relative risks for the effects of trunk flexion over 45 degrees were about 20% smaller and 95% confidence intervals were narrower when $\underline{\tau}^2$ was set to 0.25, whereas estimated relative risks for the effects of lifting and carrying loads were somewhat larger. When $\underline{\tau}^2$ was set to 1, estimated relative risks obtained from the hierarchical model were closer to the maximum likelihood estimates and the 95% confidence intervals were wider than when $\underline{\tau}^2$ was set to 0.5.

Markov model

The Markov model used in the current analysis was used to assess the impact of physical on LBP and associated consequences over a time period that is seldom possible in a cohort study. The hypothetical follow-up period of 30 years demonstrated that cohort studies with follow-up of 2 years or less may not be able to capture the important effects of physical load on aggravation of LBP and long-term sick leave resulting in workers becoming permanently disabled. Although the Markov model used was very straightforward without application of important covariates, such as age and duration of employment, and assuming constant transition probabilities, the concept of work time lost due to LBP may be very useful to decision makers to appreciate the necessity for workplace interventions. In order to adopt the approach of modeling a hypothetical cohort, it is advised in cohort studies to have a sufficiently long follow-up (to reduce uncertainty in risk estimates which may vary between years due to selective loss-to-follow-up) and to increase the frequency of questionnaires (to reduce recall bias and to increase information on transition probabilities). This approach may also be used to compare the expected cumulative utility of LBP accrued for the entire Markov process with occupational diseases with a more dramatic impact on human life, such as cancer.

Final conclusions

Based on a literature review, it seems that a quantitative assessment of physical load by means of observations and direct measurement techniques results in stronger associations between physical load and LBP than exposure assessment with self-reports. The choice for a particular measurement strategy –individual versus group approach- influences the strength of the associations as well. Hierarchical models to analyze level, frequency, and duration of exposure data obtained with direct measurement techniques offer great possibilities to pinpoint the relevant aspects of the exposure of interest to be used for observations in epidemiologic designs. It is concluded that occupational studies with quantitative characterization of physical load in combination with statistical models that anticipate a non-linear relation between physical load and LBP can provide an objective picture of the dose-response relation.

Among workers in nursing homes and homes for the elderly LBP as a health problem seems less linked with occupational factors, whereas the health condition-- disabling low-back down-- does. Trunk flexion over 45 degrees at work affects the risk of disabling LBP with a clear dose-response relation. For LBP patients, lifting and carrying loads over 10 kg at work is a risk factor for more serious future LBP episodes characterized by aggravation in terms of pain and duration.

During a 40 year career, the average worker with exposure to the highest level of physical load lost at least 17 weeks due to sickness absence because of LBP and about 2 years due to permanent disability.

Implications

Implications for practice

In order to institute effective interventions for work-related LBP a quantitative description is needed of the impact of work-related factors on both the onset and the aggravation of LBP. On the basis of results of this thesis the following recommendations can be made:

The high risk for disabling LBP associated with exposure to trunk flexion over 45 degrees indicates that a reduction of exposure to this physical factor will reduce the incidence of disabling LBP among workers in nursing homes and homes for the elderly.

Aggravation of LBP in terms of severity and longer lasting future episodes was associated with exposure to lifting and carrying loads over 10 kg. This result suggests that a reduction of manual materials handling among worker with a history of LBP is required to prevent future episodes of LBP among these workers.

Implications for research

Based on the evaluation of methods used to study dose-response relations between physical load and LBP the following recommendations can be made for musculoskeletal epidemiological research.

Assessment of physical load should quantitatively define level, duration, and frequency simultaneously in order to describe the dynamics of exposure.

In the analysis of dose-response associations between physical work load and LBP statistical techniques should be used that allow the risk of physical load to vary over the complete exposure range.

In epidemiological studies on LBP the full spectrum of LBP must be considered, including minor episodes of short duration as well as severe and disabling episodes that persist for long periods because different risk factors may be associated with onset and aggravation of these complaints.

When evaluating the relative impact of correlated types of exposure to physical load on LBP, avoid conventional approaches such as deleting certain variables from the model or adjusting the alpha level. Hierarchical regression analysis provides an alternative for multiple comparisons and has important advantages in the adjustment for covariates that are strongly interrelated.

The approach of years of work lost is a more adequate description for work-related risk factors that accelerate the onset of a more or less inevitable disease, such as LBP, than relative risks or attributable risk fractions. The perceived significance of a lost work time during a working life due to high physical load may provide for decision makers a better measure of adverse effect than an odds ratio or relative risk for sickness absence due to LBP. The concept of work years lost includes not only the risk of an event but the impact of the disease as well, i.e. the duration of sick leave.

Suggestions for future research

Several aspects of dose-response evaluations in LBP and occupational exposure have been evaluated in this thesis, but due to the limitations of the study several important issues could not be addresses. Some observations on future research are presented:

The simultaneous evaluation of exposure to physical load in terms of the tree parameters -duration, frequency, and intensity- and the occurrence of different dimensions of LBP can pinpoint the causative mechanism between physical load and development of LBP

In addition to the differentiation of LBP in terms of intensity, i.e. ranging from minor episodes to disabling conditions, it is advised to characterize LBP also in terms of duration and frequency of recurrence. With a more specific disease characterization the relation of exposure to physical load or the effect of interventions with the course of LBP can be evaluated more precise.

Back problems are a recurrent phenomenon. In a population with high physical load the prevalence of LBP observed at the start of the study is strongly influenced by this past exposure. In order to avoid this 'window effect' in the evaluation of physical load on the course of LBP, it is advised to perform a study with a 'fresh cohort' of workers entering in physical demanding jobs. With such a cohort selection factors that operate before the start of the study can be ruled out. The follow-up of such a study should be sufficiently long to reduce uncertainty in risk estimates which may vary between years due to selective loss-to-follow-up.

In future research it is recommended to develop, validate, and compare simulation models that are capable to represent the dynamics of LBP using different techniques, health states, and input parameters. Promising techniques are Markov state-transition models and discrete event simulation models.

It is recommended to use validated decision analytic models for the course of low back pain in order to evaluate the cost-effectiveness of interventions on the reduction in physical load at the workplace.

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Summary

The overall objective of the current thesis is to study the course of low back pain (LBP) in several occupations, with a specific focus on the onset and aggravation of LBP in relation to quantitative exposure to physical and psychosocial factors at work. The specific aims of this thesis are: 1) To evaluate methods to quantify physical load at the workplace; 2) To describe dose-response relations of occupational exposure to physical and psychosocial factors with the onset and aggravation of LBP; and 3) To describe the dynamic pattern in the long-term course of LBP and associated disability in occupational populations.

In order to answer these research questions a longitudinal study with two follow-up measurements was conducted among a population of workers with different jobs in 7 nursing homes and homes for the elderly in the Netherlands. Baseline measurements included the assessment of physical load for each occupation at the workplace and the application of self-administered questionnaires. Follow-up questionnaires were administered one year and two years after the baseline measurements and included questions on working conditions, LBP symptoms, and associated disability and sickness absence.

The thesis is divided in three parts. Part 1 focused on the methodology used to characterize physical work load as risk factor for of LBP. In Part 2 dose-response relations of occupational exposure to physical and psychosocial factors and LBP were evaluated. In part 3 the information on dose-response relations was used to simulate the dynamic course of LBP over time by continuing exposure to physical load.

Part 1: Quantification of physical load at the workplace

In Chapter 2 the scientific literature of the past 20 years on work-related back disorders was reviewed in order to evaluate the strength of the associations between physical load and back problems among different studies, and, second, to analyze whether the strength of the associations can partly be explained by the measurement strategy chosen. In most studies the information on physical load at work was collected by means of self-reports, either in an interview or in a questionnaire. The meta-analysis demonstrated that the strength of association, next to the specific work-related risk factor studied, is partly explained by independent effects caused by the measurement technique and study design. Studies with observations and direct measurement techniques showed higher risk estimates than studies based on questionnaires. This finding may be explained by a larger (nondifferential) misclassification of exposure in questionnaire studies or by a larger contrast in exposure in studies with actual workplace surveys to determine exposure levels.

In Chapter 3 a novel approach was presented to evaluate simultaneously level, frequency, and duration of lumbar posture during work in order to determine the essential characteristics in postural load. Differences in exposure to postural load between three occupational groups were determined using continuous recordings of lumbar posture during an average workday. The use of hierarchical models in analyzing exposure level, frequency, and duration of postural load simultaneously offered a promising alternative to the conventional analysis of continuous exposure data in ergonomics whereby dynamics of exposure are often ignored. The analysis demonstrated that nurses and housekeepers spent a considerable larger amount of their work time in larger trunk angles in combination with shorter time periods within the same posture than office workers; the office workers spent a larger amount of their work time in smaller angles for longer time periods. The distinction in postural load between nurses or housekeepers and office workers is best determined by the combination of trunk angle and time period. This finding has an implication for observations to characterize physical load at the workplace. In order to have sufficient contrast in exposure to trunk flexion in epidemiological studies, observations with a cutoff of at least 30 degrees flexion are advised.

In Chapter 4, two aspects in modeling dose-response relations between physical work load and LBP were evaluated: the measurement strategy of the exposure and the nature of the dose-response relation that is assumed. In general, two measurement strategies for observations of physical load at the workplace can be identified: the individual approach and the group approach. Although there are limitations to draw conclusion from one data set, the analysis showed that the choice for a particular measurement strategy of physical load influences the strength of the associations between physical load and LBP. Next, the assumed nature of the dose-response relation between physical load and LBP is of importance as well. Statistical models that anticipate a linear relation between physical load and severe LBP may be unable to identify specific patterns of exposure and associated risks when applied over the whole exposure range. Categorical models have also drawbacks, since the choice of particular cutoff values, often based upon percentiles of the underlying distribution, may not reflect relevant effects of physical load on LBP. When quantitative estimates of physical work load are obtained, this enormous measurement effort asks for statistical techniques that make full use of the informational content. Spline models are a promising approach to identify quantitative dose-response patterns between physical load and LBP.

Part 2: Dose-response relations of occupational exposures to physical and psychosocial factors and the onset and aggravation of low back pain

In Chapter 5 the objective was to assess dose-response relations between occupational exposures to physical and psychosocial factors and the risk of LBP. Two outcome measures of LBP incidence were used: any new episode of LBP lasting for at least a few hours during follow-up; and any new episode of disabling LBP that interfered with daily activities during follow-up. Hierarchical regression analysis with a spline function was used to estimate the dose-response relations. It was shown that trunk flexion over 45 degrees was monotonically associated with the risk for more severe or disabling LBP but not with less severe or transient LBP. The risk was about 2-fold greater among subjects with an exposure of more than 1 hour per week (>50th percentile) in comparison with subjects with an exposure of 30 minutes or less per week (<10th percentile). Exposure to trunk flexion over 45 degrees for more than 1 hour and 45 minutes per week (>90th percentile) resulted in a more than 3-fold greater risk. Although some psychosocial aspects showed weak associations with less severe or transient LBP, these associations had large uncertainties in their risk estimates and, hence, their importance is difficult to appreciate. Occupational exposure to trunk flexion over 45 degrees appears to be a risk factor for LBP with disability.

In Chapter 6 the effect of occupational exposures to physical and psychosocial factors on the aggravation of the course of LBP was assessed. Three measures of aggravation of LBP were used: increase in duration, increase in frequency, and increase in pain severity reported at follow-up in reference to LBP at baseline. It was observed that individuals experience changes in the duration, frequency, and severity of their LBP episodes over time, with a relative constant prevalence of more serious LBP in terms of duration, frequency, and severity. Aggravation of LBP was unassociated with the psychosocial factors. Lifting and carrying loads over 10 kg was consistently associated with aggravation of LBP in terms of severity of complaints. An increased risk for a longer duration of LBP episodes was found as well. The risk of aggravation of LBP was more than 2 times greater for subjects lifting and carrying loads for more than 45 minutes per week (90^{th} percentile) than for subjects lifting and carrying loads for less than 1 minute per week. It appears, therefore, that among LBP patients lifting and carrying loads over 10 kg is a risk factor for future aggravated LBP episodes, characterized by increased levels of pain and prolonged duration.

Part 3: The dynamic pattern in the long-term course of LBP and associated disability in occupational populations

In order to understand the long-term course of back complaints and associated disability, in Chapter 7 the dynamic pattern of incidence, recurrence, and severity of LBP in the occupational cohort was studies and applied in a Markov model to mimic the long-term consequences of LBP in this cohort of workers. In Chapter 7 the level of exposure to physical load was not associated with the occurrence of LBP but a risk factor for sickness absence due to LBP. The excess working lifetime lost due to sickness absence because of LBP was 6.6% among workers with the highest exposure to physical load compared with 1.4% among those with low exposure to physical load. The approach of years of work lost is a more adequate description for work-related risk factors that accelerate the onset of a more or less inevitable disease, such as LBP, than relative risks or attributable risk fractions. The perceived significance of a loss of 6.6% of work time during a working life due to high physical load may provide for decision makers a better measure of adverse effect than an odds ratio of 2.95 for sickness absence due to LBP. The concept of work years lost may also facilitate a better appreciation of the potential benefits of preventive measures.

Conclusions

Based on a literature review, it seems that a quantitative assessment of physical load by means of observations and direct measurement techniques results in stronger associations between physical load and LBP than exposure assessment with self-reports. The choice for a particular measurement strategy –individual versus group approach- influences the strength of the associations as well. Hierarchical models to analyze level, frequency, and duration of exposure data obtained with direct measurement techniques offer great possibilities to pinpoint the relevant aspects of the exposure of interest to be used for observations in epidemiologic designs. It is concluded that occupational studies with quantitative characterization of physical load in combination with statistical models that anticipate a non-linear relation between physical load and LBP can provide an objective picture of the dose-response relation.

Among workers in nursing homes and homes for the elderly the occurrence of LBP episodes was not influenced to a large extent by occupational factors, whereas physical load clearly resulting in a disabling effect of LBP. Trunk flexion over 45 degrees at work affected the risk of disabling LBP with a clear dose-response relation. For LBP patients, lifting and carrying loads over 10 kg at work was a risk factor for more serious future LBP episodes characterized by aggravation in terms of pain and duration.

During a 40 year career, the average worker with exposure to the highest level of physical load is expected to lose at least 17 weeks due to sickness absence because of LBP and about 2 years due to permanent disability.

Dutch summary

Nederlandse samenvatting

In dit promotieonderzoek is het verloop van lage rugklachten bij verschillende beroepsgroepen geëvalueerd, waarbij de nadruk ligt op het ontstaan en verergeren van lage rugklachten in relatie tot blootstelling aan fysieke en psychosociale factoren op het werk. Meer specifiek, de doelstellingen van het onderzoek zijn: 1) evaluatie van onderzoeksmethoden om fysieke belasting op de werkplek op kwantitatieve wijze te bepalen, 2) het beschrijven van dosis-respons relaties tussen blootstelling aan fysieke en psychosociale belasting op het werk en het ontstaan en verergeren van lage rugklachten; en 3) het beschrijven van de dynamiek van rugklachten over de lange termijn.

Om de onderzoeksvragen te beantwoorden is een longitudinaal onderzoek met drie meetmomenten opgezet onder werknemers in 7 verpleeg- en verzorgingshuizen in Nederland. Bij aanvang van het onderzoek is fysieke belasting op de werkplek gemeten en zijn vragenlijsten uitgezet waarmee individuele informatie over onder andere arbeidsomstandigheden, aanwezigheid van lage rugklachten, beperkingen en ziekteverzuim zijn verkregen. Vervolgens zijn één en twee jaar later nogmaals vragenlijsten uitgezet.

In Deel 1 van dit proefschrift zijn methoden geëvalueerd om fysieke belasting op de werkplek, als risicofactor voor lage rugklachten, te karakteriseren. In Deel 2 zijn dosis-respons relaties van bloostelling aan fysieke en psychosociale factoren op het werk en lage rugklachten gepresenteerd. Ten slotte is in Deel 3 de verkregen informatie over dosis-respons relaties gebruikt om het verloop van rugklachten over de tijd te modelleren als functie van continue blootstelling aan fysieke belasting.

Deel 1: Kwantificeren van fysieke belasting op de werkplek

In hoofdstuk 2 is de wetenschappelijke literatuur van de afgelopen 20 jaar op het gebied van arbeidsgerelateerde rugklachten geëvalueerd. Het doel van deze review was ten eerste om de sterkte van de associaties tussen fysieke belasting en rugklachten samen te vatten en ten tweede om te onderzoeken in welke mate de sterkte van deze associaties verklaard wordt door de gebruikte meettechnieken. In de meeste studies is informatie over fysieke belasting verzameld door middel van interviews of door werknemers vragenlijsten te laten invullen. Een meta-analyse van de gerapporteerde resultaten in de verschillende studies laat zien dat de sterkte van de associaties tussen fysieke belasting op het werk en het optreden van lage rugklachten wordt bepaald door het type fysieke belasting en de gekozen meettechniek. Dit laatste kan verklaard worden door het feit dat observaties op de werkplek en continue registratie van houding minder gevoelig zijn voor ruis en zodoende resulteren in een betere schatter van het ware effect van fysieke belasting op rugklachten dan onderzoek door middel van interviews of vragenlijsten.

In Hoofdstuk 3 is een nieuwe statistische methode gepresenteerd om niveau, duur, en frequentie van de dynamiek van het buigen van de rug te analyseren om zodoende de belangrijkste kenmerken van deze fysieke belasting te karakteriseren. Verschillen in de dynamiek van de houding van de rug tussen 3 verschillende beroepsgroepen is bepaald door middel van continue registratie van de rughoek over een gemiddelde werkdag. Met hiërarchische regressie modellen is tegelijkertijd niveau, duur en frequentie van deze fysieke belasting geanalyseerd. De statistische techniek bleek een veelbelovend alternatief voor conventionele data analyse in de ergonomie waar de dynamiek vaak wordt genegeerd. De analyses lieten zien dat de dynamiek van de houding van verpleegkundigen en schoonmakers in vergelijking tot kantoor personeel gekenmerkt wordt door een langere totale werktijd in een grote rughoek in combinatie met een frequente afwisseling in houding; kantoor personeel liet een langere totale werktijd zien in kleinere hoeken in combinatie met weinig dynamiek in hun houding. Het onderscheid tussen verpleegkundigen en schoonmakers aan de ene kant en kantoor personeel aan de andere kant wordt dus bepaald door de combinatie van rughoek en tijdsduur. Deze bevinding heeft implicaties voor het meten van fysieke belasting op het werk door middel van observaties. Om voldoende onderscheidend vermogen te hebben in blootstelling aan fysieke belasting in epidemiologische studies worden dan ook observaties van een rughoek van minimaal 30 graden geadviseerd.

In Hoofdstuk 4 zijn twee aspecten van het modelleren van dosis-respons relaties tussen fysieke belasting en lage rugklachten bestudeerd: de meetstrategie van observaties op het werk om fysieke belasting te meten, en de karakteristiek van de veronderstelde dosis-respons relatie. Twee strategieën voor het meten van fysieke belasting op de werkplek kunnen worden onderscheiden: individuele metingen en groep metingen. Hoewel het moeilijk is om op basis van één dataset conclusies te trekken, heeft de analyse laten zien dat de keuze voor een bepaalde meetstrategie invloed heeft op de sterkte van de gevonden relatie tussen fysieke belasting en het optreden van lage rugklachten. Verder is gebleken dat de veronderstelde karakteristiek van de dosis-respons relatie tussen fysieke belasting en lage rugklachten ook van belang is. Statistische modellen die een lineair verband veronderstellen zijn niet flexibel genoeg om specifieke patronen van fysieke belasting en het risico op lage rugklachten voldoende nauwkeurig te identificeren. Categorische modellen hebben als nadeel dat de keuze van grenswaarden vaak berust op percentielen van de verdeling van blootstelling en daarmee mogelijk relevante effecten van fysieke belasting op lage rugklachten niet opgepikt worden. Wanneer op kwantitatieve wijze informatie over fysieke belasting is verkregen, dan vraagt de hoeveelheid werk die hiermee samenhangt om statistische technieken waarmee volledig gebruikt wordt gemaakt van de beschikbare hoeveelheid informatie. Modellen met een spline functie blijken een goede methode om kwantitatieve dosis-respons patronen te identificeren tussen fysieke belasting en lage rugklachten

Deel 2: Dosis-respons relaties tussen blootstelling aan fysieke en psychosociale belasting op het werk en het ontstaan en verergeren van lage rugklachten

De doelstelling van Hoofdstuk 5 was om dosis-respons relaties te bepalen tussen fysieke en psychosociale belasting op het werk en het risico op het ontstaan van lage rugklachten. Twee uitkomstmaten zijn gebruikt: het optreden van lage rugklachten die minimaal een paar uur duren; en een episode van rugklachten met beperkingen ten aanzien van activiteiten van het dagelijks leven. Met behulp van hiërarchische regressie analyse met een spline functie zijn de dosis-respons relaties geschat. Fysieke belasting door buigen van de rug in een hoek van meer dan 45 graden liet een positieve associatie zien met het optreden van rugklachten met beperking. Het risico van een gebogen houding in een hoek van meer dan 45 graden was bij een totale duur van 1 uur per week (50^e percentiel) ongeveer 2 keer zo groot dan het risico bij een half uur (10^e percentiel). Buigen gedurende meer dan 1 uur en 45 minuten per week (90^e percentiel) resulteerde in een 3-keer zo groot risico op rugklachten met beperkingen. Een gebogen houding van meer dan 45 graden kan daarom beschouwd worden als een risicofactor voor het optreden van ernstige rugklachten met beperkingen. Hoewel enkele psychosociale factoren zwakke positieve associaties lieten zien met het optreden van rugklachten werden deze gekenmerkt door een grote mate van onzekerheid, en zijn derhalve moeilijk op waarde te schatten.

In hoofdstuk 6 is het effect van fysieke en psychosociale belasting op het werk op de verergering van rugklachten geanalyseerd. Drie uitkomstmaten voor verergering van lage rugklachten zijn gedefinieerd: een toename in de duur, frequentie of pijn van episoden van rugklachten gedurende follow-up. Het bleek dat ondanks dat individuele patiënten over de tijd veranderingen in duur, frequentie en pijn van rugklachten ervaren, de prevalentie van ernstige rugklachten in termen van duur, frequentie en pijn relatief constant blijft. Het tillen en dragen van lasten van meer dan 10 kg bleek gerelateerd te zijn aan de verergering van rugklachten, zowel in termen van pijn als in duur van de volgende episodes. Het risico van tillen en dragen van lasten van meer dan 10 kg was bij een totale duur van 45 minuten uur per week (90^{e} percentiel) meer dan 2 keer zo groot dan het risico bij een totale blootstelling van 1 minuut per week (10^{e} percentiel). Tillen en dragen van lasten van meer dan 10 kg kan daarom beschouwd worden als een risicofactor voor de verergering van rugklachten gekenmerkt door toegenomen pijn en duur van de klachten.

Deel 3: de dynamiek van rugklachten over de lange termijn

In Hoofdstuk 7 is de dynamiek van rugklachten in termen van optreden, verergering en verbetering geëvalueerd met behulp van een Markov model. Hiermee zijn de 2-jaars resultaten geëxtrapoleerd over een lange termijn van 40 jaar. De mate van fysieke belasting had geen associatie met rugklachten in het algemeen, maar bleek wel een risicofactor voor ziekteverzuim ten aanzien van rugklachten. Het extra aantal weken ziekteverzuim door rugklachten gedurende een arbeidsleven was 6,6% voor werknemers met de hoogste fysieke belasting en 1,4% voor werknemers met lage fysieke belasting op het werk. Verloren arbeidsjaren is een betere uitkomstmaat om het effect van werkgerelateerde factoren op het optreden van een min of meer onvermijdelijke ziekte, zoals rugklachten, te beschrijven dan relatieve risico's of attributieve fracties. Een extra verlies van arbeidstijd van 6,6% gedurende een arbeidsleven door fysieke belasting geeft beleidsmakers waarschijnlijk meer informatie over de impact van fysieke belasting dan een odds ratio van 2.95 voor ziekteverzuim door rugklachten. Het concept van verloren arbeidsjaren zal waarschijnlijk ook een betere maat zijn om het effect van preventieve maatregelen te evalueren.

Conclusie

De literatuurstudie heeft laten zien dat het meten van fysieke belasting door middel van observaties op de werkplek of continue registratie van houding resulteren in sterkere associaties tussen fysieke belasting en rugklachten dan het schatten van fysieke belasting met vragenlijsten of interviews. De keuze van een bepaalde strategie van observaties voor het meten van fysieke belasting heeft eveneens invloed op de gevonden sterkte van het effect van fysieke belasting. Hiërarchische modellen bieden goede mogelijkheden om de dynamiek van blootstelling aan fysieke belasting te analyseren en de relevante aspecten van fysieke belasting voor gebruik in epidemiologische studies te bepalen. Er kan geconcludeerd worden dat studies waarbij fysieke belasting op een kwantitatieve wijze wordt gemeten in combinatie met het gebruik van statistische modellen waarbij uitgegaan wordt van een niet-lineair verband tussen fysieke belasting en rugklachten een objectief beeld kunnen geven van de dosis-respons relaties.

Bij werknemers van verpleeg- en verzorgingshuizen is een gebogen houding van meer dan 45 graden een risicofactor voor het optreden van ernstige rugklachten met beperkingen en wordt beschreven door een duidelijke dosis-respons relatie. Het tillen en dragen van lasten van meer dan 10 kg is een risicofactor voor de verergering van episodes van rugklachten, gekenmerkt door een toename in pijn en duur.

Gedurende een arbeidsduur van 40 jaar verzuimt de gemiddelde werknemer met een hoge fysieke belasting naar verwachting 17 weken dankzij lage rugpijn en verlaat ongeveer 2 jaar eerder het werk vanwege permanente arbeidsongeschiktheid.

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About the Author

Jeroen Jansen was born on September 25th, 1974 in Hengelo (Overijssel), The Netherlands. After graduation in 1992 from secondary school, he studied at the Vrije Universiteit Amsterdam and obtained a degree in human movement sciences with a focus on functional anatomy and epidemiology in 1998. The same year he became a PhD student at the Department of Public Health of Erasmus MC, University Medical Center Rotterdam. During his PhD project he obtained a MSc-degree in Epidemiology of the Netherlands Institute of Health Sciences, and spent a year in the United States (Department of Epidemiology, University of California, Los Angeles). Since 2002, Jeroen Jansen has been employed at Mapi Values, The Netherlands. Mapi Values is an international consultancy that specializes in health economics research and the development and evaluation of patient-reported outcome measures. He is married to Suzanne ten Broeke and has two children: Jasmyn and Lilian.

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Back disorders are a major health problem. Since the burden of work-related low back pain is high, prevention is important. In order to institute effective interventions for work-related low back pain, a quantitative description of the impact of work-related factors on both the onset and the aggravation of low back pain is needed. • The overall objective of this thesis is to study the course of low back pain in several occupations, with a specific focus on the onset and aggravation of low back pain in relation to exposure to physical and psychosocial factors at work. • This thesis is divided in three parts. • Part 1 focuses on the methodology used to quantify physical work load as risk factor for low back pain. • In part 2 dose-response relations of occupational exposure to physical and psychosocial factors and low back pain are evaluated. • In part 3 the information on dose-response relations is used to simulate the dynamic course of low back pain over time by continuing exposure to physical load.