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Occupational loading, health behavior and sleep disturbance as predictors of low-back pain

by Helena Miranda, MD,¹ Eira Viikari-Juntura, MD,¹ Laura Punnett, ScD,² Hilikka Riihimäki, MD¹

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Objectives Risk factors for low-back pain are known to co-occur, but their joint effect has not often been studied. Little is also known about the variation of the risk factors or their effects with age.

Methods This prospective study assessed the 1-year incidence of low-back pain by age group in a Finnish industrial population. The effects of the baseline variables on the risk of low-back pain in the follow-up were estimated with a log-binomial regression.

Results Among 2256 blue- and white-collar workers free of low-back pain 12 months preceding the baseline, 21% reported low-back pain after 1-year of follow-up. Physical work load (sum of heavy lifting, awkward postures, and whole-body vibration) predicted low-back pain among those younger than 50 years [highest relative risk (RR) 2.4, 95% confidence interval (95% CI) 1.4–4.2], whereas health behavior (sum of smoking, overweight, and lack of physical exercise) increased the risk only among those 50 years or older (RR up to 2.8, 95% CI 1.4–5.4). Mental stress, dissatisfaction with life, and sleep problems were significant predictors in the group of 40- to 49-year-old workers. Work-related psychosocial factors were not associated with the outcome.

Conclusions In this study, workers of different ages were affected by slightly different risk factors. The results support the provision of health promotion and stress management as part of programs to prevent work-related low-back pain. In particular, aging workers may benefit from such an integrated approach. More prospective studies on the joint effects of age-specific risk factors of low-back pain are warranted.

Key terms age; lifestyle; musculoskeletal pain; physical work; risk factor.

Low-back pain is a major global occupational and public health burden. It affects millions of workers every year worldwide, causing frequent medical visits, sickness absence, disability, and early retirement (1, 2). It has been estimated that 60–70% of people in industrialized countries experience low-back pain at some point in their lives (1). In reality, the lifetime prevalence may be closer to 100% in that it is known that a considerable percentage of people, in some studies 30–40% or even higher, forget their prior symptoms (3–5).

Work-related physical exposures, especially heavy lifting and manual materials handling, awkward postures, and whole-body vibration, are well-established risk factors for low-back pain (6, 7). Some psychosocial factors have also been linked to low-back pain in earlier studies, but the results have been somewhat inconsistent (7, 8). Personal health factors, such as smoking, overweight, and lack of physical activity, are often listed among the most important risk factors for low-back

pain, but the scientific evidence is surprisingly vague and inconsistent (9–14).

The independent effects of the risk factors for multifactorial conditions such as low-back pain may be difficult to assess due to their accumulation in the same persons (15–17). It can be debated whether it is meaningful to assess the separate effects only, as is often done in occupational epidemiology, knowing that exposures co-occur and may also act synergistically (18, 19). For example, in industrial populations, workers are rarely exposed to whole-body vibration alone, without being affected by awkward work postures or lifting. Similarly, overweight and smoking have both been found to be associated with a physically inactive lifestyle. The joint effects of multiple physical workload factors and health behavior have not often been studied, however, in relation to low-back pain. In addition, little is known about the extent to which these effects vary by age. Thus the aim of this prospective study in an industrial population

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was to assess the 1-year incidence of low-back pain and its risk factors by age group.

Study population and methods

This study is a part of a larger network of projects in the Finnish Institute of Occupational Health called MUSKELI (preventing musculoskeletal diseases in industry). The project was approved by the Ethics Committee of the Finnish Institute of Occupational Health. In 1992, all employees of a large company in the Finnish forest industry received a questionnaire on musculoskeletal pain and its potential risk factors. The self-administered questionnaire was sent by the occupational health service of the company. The 7000 employees consisted of all workers in mechanical and chemical forest industry processes and their maintenance tasks, as well as foremen, laboratory staff, technical designers, office clerks, and management. After two reminders, 75% filled out and returned the questionnaire. Part-time workers and a small number of employees with rheumatoid arthritis were excluded from the study, leaving 5180 workers in the baseline study population. A follow-up questionnaire was sent after 1 year (in 1993), to which 4283 workers (83%) responded. Information on low-back pain at baseline or follow-up was available for 3873 workers. Altogether 74% of the study participants were men.

Outcome

The outcome of this study was the 1-year incidence of a new episode of low-back pain. The questions on low-back pain both at the baseline and the follow-up were based on a Nordic questionnaire asking the workers to estimate the number of days with low-back pain during the preceding 12 months (20). To assess the incidence at follow-up, those with low-back pain at the baseline (reported having pain for more than 7 days during the preceding 12 months) were excluded from the analyses ($N=1617$), leaving a baseline population of 2256 workers with no low-back pain (or for only a few days). Cases of low-back pain were those who reported low-back pain (>7 days) at the follow-up, and the reference group was formed from those who had no low-back pain (0–7 days) at the follow-up.

Predictors

The baseline questionnaire contained several questions on work-related physical and psychosocial exposures, individual demographics, health, health behavior, sleep, and psychological factors. The following separate items assessed physical workload on the back in the current job during an average workday: heavy lifting (exposed,

if the worker reported lifting loads of >25 kg), working with the trunk in awkward postures (exposed, if working with the trunk flexed forward for >2 hours, twisting the trunk moderately or much, or working with a twisted neck for >1 hour), or whole-body vibration (exposed for >4 hours) (21). The number of exposures was used to represent the total physical loading at work, varying from none to all three being present.

The perceived risk of acute injury ("accidents") at work due to tripping, slipping, or climbing stairs was formed by summing four separate items that were designed for this study (eg, "How much do you estimate moving on slippery surfaces, for example, ice or oil, to increase the risk of accidents in your own work?", 1=not at all to 4=much; cut-off from median, ie, 1). The questionnaire contained one question about skill discretion ("Are you able to use your skills and knowledge in your work?", 1=very much to 5=very little) and one question about decision authority ("Do you have the possibility to influence the issues related to your work?", 1=very much to 5=not at all). These variables were summed to form a job-control variable (sum scale 2–10). The questionnaire also included two questions on psychological demands at work, which were also summed ("Do you need to hurry to get your work done?", 1=never to 5=all the time; "Does your work have phases that are too difficult?", 1=never to 5=all the time). The demand questions were from the Occupational Stress Questionnaire (22). The combination of low job control (lower than the median of the study population, ie, 5) and high work demands (higher than the median, ie, 5) was classified as high job strain and was compared with low job strain (either high control or low demands or both). Supervisory and coworker support were also assessed with one item each ("Do you get support from your supervisor if needed?", 1=very much to 5=very little; "What kind of relationship do you have with your coworkers?", 1=very good to 5=very poor), as well as job satisfaction ("Are you satisfied with your work?") and satisfaction with life ("Are you satisfied with your life?").

The following three aspects of health behavior were assessed: body mass index (classified as 0 = ≤ 24.9 , 1 = 25.0–29.9, 2 = ≥ 30.0 kg/m²), physical exercise (eg, bicycling, swimming, etc, weekly during the preceding year, at least 20 minutes per session, classified as 0 = average of ≥ 2 –3 times/week; 1 = 1 time/week; 2 = not at all or <1 time/week), and smoking (0 = never smoked, 1 = former smoker, 2 = current smoker). To form a composite variable, the values were summed and classified into three categories of 0, 1–3, and 4–6 (0 being the reference class, representing a normal-weight, never smoking, and actively exercising worker).

Sleep disturbance was considered to be mild if the workers reported either not sleeping well during the preceding 3 months or having been extremely tired after

waking up most of the mornings in a week and to be severe if they had reported both (23). Mental distress was based on questions about being stressed, nervous, or tense, and it was classified into three categories (no, somewhat, or much or very much) (24). The workers were asked if they had any chronic illnesses (eg, diabetes) that required medical treatment or follow-up. Information on pain in other areas of the musculoskeletal system (neck, shoulder, upper extremities, hip or knee) at baseline was obtained with questions similar those used for low-back pain.

Data analyses

The main aim of the study was to assess the predictors among the younger (<40 years), middle-age (40–49 years), and older (≥ 50 years) workers. These cut-offs were chosen on the basis of practicality (to provide easily interpretable categories), as well as on the age distribution of the population. Log-binomial regression with the PROC GENMOD procedure was used to estimate the relative risks (RR) and their 95% confidence intervals (95% CI) (25).

Gender- and age-adjusted associations (age as a continuous variable within the age strata) were computed for the variables of main interest (ie, physical exposures and health risk behavior). Each multivariable model included all of the covariates that were statistically significant ($P < 0.05$) in any of the age groups. This stage of modeling consisted of 1676 workers with no missing values for any exposure. The chronic disease items contained the most missing values, but no selection based on the outcome occurred among those who were excluded from the analyses due to missing values. However, additional analyses were performed by imputing the value “having chronic disease”, as well as the value “not having chronic disease”, separately for all of workers with a missing value for chronic diseases. The statistical analyses were carried out with the statistical software package SAS (version 9.1, SAS Institute Inc, Cary, NC, USA).

Results

Altogether 29% of the participants worked in “white-collar” occupations, and 71% worked in “blue-collar” jobs. Of the blue-collar workers, most (85%) worked in industrial paper manufacturing, whereas 15% worked in forest lumbering, the heaviest form of work in this industry. The distributions of the occupational groups were similar in the three age groups, except that the percentage of lumbermen was lowest in the oldest group (9% compared with 12% in the two younger age groups).

The nonrespondents at follow-up did not differ from the respondents with respect to low-back or any other musculoskeletal pain or exposures to physical work, health risk behavior, or the other baseline variables used as predictors in this study. With regard to the initial participation at baseline, the younger and male workers participated slightly less than the older and female workers, but the differences were small. Because of confidentiality regulations we were not able to collect any other data from the nonrespondents at baseline after their refusal to participate.

Of all the workers who, at baseline, had not experienced low-back pain during the preceding 12 months, 21% developed low-back pain during the 1-year follow-up. The incidence of low-back pain was somewhat higher for the participants over 50 years of age, among both the men and the women. Nine out of ten workers with a new episode of low-back pain reported experiencing considerable problems in daily activities due to low-back pain, and, for most (58%) of these workers, these problems had lasted for more than a week.

The crude associations between the exposures and low-back pain incidence are shown in table 1. In the log-binomial analyses (table 2), exposure to heavy lifting and whole-body vibration was associated with the incidence of low-back pain among the youngest workers, awkward postures and whole-body vibration (latter with borderline significance) were associated with low-back pain in the middle-age group, and whole-body vibration was associated with low-back pain among the oldest workers. The younger workers exposed to three physical risk factors had an increased risk of low-back pain (RR 2.4, 95% CI 1.4–4.2 in the final multivariable model) (table 3). In the group of 40- to 49-year-old workers, the risk increased with just one physical exposure present. Tests for trend were statistically significant for these age groups. In the oldest age group, the total physical workload did not increase the risk of low-back pain significantly.

Smoking, overweight, and a lack of physical exercise predicted future low-back pain (BMI and exercise with borderline significance) in the gender- and age-adjusted models for the older workers, whereas no effect was found for the middle-age group. Among the youngest workers, only obesity was associated with low-back pain. The set of three aspects of health behavior had a relative risk of 2.8 (95% CI 1.4–5.4) for the older workers ($P = 0.0018$ for trend), but it did not predict low-back pain in either of the younger age groups.

Psychological factors (ie, mental distress and life satisfaction) as well as the quality of sleep, were predictors of future low-back pain among the 40- to 49-year-old workers (table 3). These factors did not increase the risk significantly among the other groups, except sleep disturbance, which predicted low-back pain among the

Table 1. One-year incidence of low-back pain among forest industry workers in Finland, according to age group and baseline exposure.

	Incidence of low-back pain								
	<40-year-old group			40- to 49-year-old group			≥50-year-old group		
	All (N)	Cases		All (N)	Cases		All (N)	Cases	
	N	N	%	%	N	%		N	%
All participants	948	165	17	826	178	22	482	482	28
Gender									
Male	724	126	17	596	129	22	358	98	27
Female	224	39	17	230	49	21	124	36	29
Physical workload factors									
Work involving heavy lifting									
No	599	95	16	588	124	21	373	105	28
Yes	311	62	20	211	49	23	85	22	26
Working with awkward trunk postures									
No	400	62	16	360	64	18	206	58	28
Yes	544	102	19	457	114	25	265	75	28
Exposed to whole-body vibration									
No	803	123	15	707	151	21	414	111	27
Yes	141	42	30	106	25	24	59	20	34
Number of physical exposures (heavy lifting, awkward postures and whole-body vibration)									
0	305	43	14	304	53	17	180	46	26
1	310	51	16	275	70	25	165	55	33
2	230	44	19	156	34	22	80	18	23
3	60	18	30	49	14	29	19	6	32
Health risk behavior									
Smoking									
Never smoker	414	68	16	337	68	20	249	59	24
Ex-smoker	226	40	18	250	61	24	155	51	33
Current smoker	305	56	18	234	47	20	77	24	31
Body mass index (kg/m ²)									
≤24.9	613	96	16	372	81	22	195	47	24
25.0–29.9	286	56	20	346	75	22	237	73	31
≥30.0	42	12	29	92	21	23	43	13	30
Physical exercise									
≥2–3 times/week	613	107	17	528	113	21	317	80	25
1 time/week	203	30	15	157	39	25	90	30	33
0–<1 time/week	125	28	22	136	25	18	68	21	31
Health risk behavior (overweight, lack of exercise and smoking), sum index (0–6)									
0	187	32	17	135	28	21	90	15	17
1–3	642	106	17	526	114	22	313	92	29
4–6	102	25	25	139	32	23	64	23	36
Other factors									
Sleeping disturbance									
No	558	85	15	431	64	15	202	33	16
Mild	335	68	20	363	99	27	252	92	37
Severe	54	12	22	30	15	50	26	9	35
Mental distress (being stressed, nervous or tense)									
No	420	60	14	357	51	14	199	39	20
Somewhat	416	82	20	384	101	26	225	67	30
Much or very much	106	22	21	82	26	32	54	27	50
Satisfaction with life									
Satisfied	804	138	17	700	138	20	393	111	28
Not satisfied	141	27	19	124	39	31	87	23	26
Chronic diseases									
No	715	114	16	554	106	19	258	58	22
Yes	102	32	31	153	35	23	150	51	34
Pain in other areas (neck, upper extremities, hip or knee)									
No	433	56	13	331	47	14	168	31	18
Yes	464	102	22	425	114	27	278	94	34
Job strain (high demands–low control)									
No	796	134	17	671	144	21	383	99	26
Yes	147	30	20	150	33	22	94	33	35
Risk of accidents									
No	474	79	17	507	104	21	332	90	27
Yes	468	85	18	300	70	23	141	39	28

Table 2. Adjusted relative risks of the effects of the physical exposures and the risk factors for health risk behavior on the 1-year incidence of low-back pain among the forest industry workers in Finland, according to age group. (RR = relative risk, 95% CI = 95% confidence interval)

Baseline variables	Incidence of low-back pain											
	<40-year-old group				40- to 49-year-old group				≥50-year-old group			
	Model 1a ^a		Model 1b ^b		Model 2a ^a		Model 2b ^b		Model 3a ^a		Model 3b ^b	
	RR	95% CI	RR	95% CI	RR	95% CI	RR	95% CI	RR	95% CI	RR	95% CI
Heavy lifting												
No	1.0	..	1.0	..	1.0	..	1.0	..	1.0	..	1.0	..
Yes	1.5	1.1–2.1	1.4	1.0–2.1	1.1	0.8–1.6	1.0	0.7–1.4	1.0	0.6–1.6	0.9	0.6–1.5
Awkward postures												
No	1.0	..	1.0	..	1.0	..	1.0	..	1.0	..	1.0	..
Yes	1.2	0.8–1.6	0.9	0.7–1.3	1.6	1.2–2.3	1.6	1.1–2.3	0.9	0.7–1.3	0.8	0.6–1.2
Whole-body vibration												
No	1.0	..	1.0	..	1.0	..	1.0	..	1.0	..	1.0	..
Yes	2.0	1.4–2.9	1.9	1.3–2.9	1.5	1.0–2.2	1.2	0.8–1.8	1.7	1.1–2.6	1.8	1.1–3.0
Smoking												
Never smoker	1.0	..	1.0	..	1.0	..	1.0	..	1.0	..	1.0	..
Ex-smoker	1.0	0.7–1.5	1.0	0.7–1.4	1.3	0.9–1.8	1.2	0.9–1.8	1.7	1.1–2.5	1.6	1.1–2.2
Current smoker	1.0	0.7–1.5	1.0	0.7–1.4	1.1	0.8–1.7	1.0	0.7–1.7	1.6	1.0–2.7	1.4	0.9–2.4
Body mass index (kg/m ²)												
≤24.9	1.0	..	1.0	..	1.0	..	1.0	..	1.0	..	1.0	..
25.0–29.9	1.1	0.8–1.6	1.0	0.7–1.4	1.0	0.7–1.4	1.0	0.7–1.4	1.4	1.0–2.1	1.3	0.9–1.9
≥30.0	1.8	1.0–3.2	1.9	1.1–3.3	1.2	0.7–1.9	1.1	0.7–1.8	1.3	0.7–2.4	1.2	0.6–2.2
Physical exercise												
≥2–3 times/week	1.0	..	1.0	..	1.0	..	1.0	..	1.0	..	1.0	..
1 time/week	0.9	0.6–1.3	0.8	0.5–1.2	1.0	0.7–1.6	1.1	0.7–1.6	1.1	0.7–1.8	1.1	0.7–1.7
0–<1 time/week	1.1	0.7–1.7	1.0	0.7–1.5	0.9	0.6–1.5	0.9	0.6–1.5	1.5	1.0–2.4	1.4	0.9–2.1

^a Models 1a–3a adjusted for gender and age.^b Models 1b–3b adjusted for all of the variables in the table, and also gender and age.

oldest workers. Moreover, although, at the baseline, the workers were free of low-back pain, many had reported pain in other anatomical areas (neck pain the most frequently). Pain in other areas predicted future low-back pain in all of the age groups, but it retained its statistical significance in the multivariable models only in the youngest age group. The presence of a chronic disease was a significant predictor only in this age group as well. Work-related psychosocial factors (job strain, supervisory or coworker support, or job satisfaction), education, and perceived risk of “accident” at work were not associated with the outcome. Since we detected differences in the risk factors and their effects when the analyses were stratified by age, we also tested the interactions between age and physical workload and health behavior in the whole cohort. These interactions did not reach statistical significance when the standard P-value was 0.05

Discussion

In this moderately large and heterogeneous group of industrial workers, every fifth worker developed a new

episode of low-back pain during the 1-year follow-up. This finding is similar to or somewhat higher than those reported in other occupational studies (26–28). The differences in the definition of low-back pain partly explain the discrepancies across studies. For instance, in a study by Van Nieuwenhuysse et al (28), the 1-year incidence of low-back pain was 13%, a value that is markedly lower than in our study, but the authors required a case of low-back pain to have ≥7 consecutive pain days during the preceding 12 months (28). We did not collect information on low-back pain severity other than the extent of resulting problems in daily living, which was considerable for nearly all of the workers who had new pain during the follow-up. This finding indicates that the outcome of our study had an important impact on the lives of these workers.

The occupational physical risk factors for low-back pain (ie, awkward postures, heavy lifting, and whole-body vibration) were, as expected, significant predictors, but not uniformly across the age groups. Whole-body vibration had a relatively strong association with low-back pain among the youngest and oldest workers. Vibration may induce low-back pain via several pathophysiological mechanisms, including increased trunk

Table 3. Adjusted relative risks of the effects of the predictors of the 1-year incidence of low-back pain among the forest industry workers in Finland, according to age group. (RR = relative risk, 95% CI = 95% confidence interval)

Baseline variables	Incidence of low-back pain											
	<40-year-old group				40- to 49-year-old group				≥50-year-old group			
	Model 1a ^a		Model 1b ^b		Model 2a ^a		Model 2b ^b		Model 3a ^a		Model 3b ^b	
	RR	95% CI	RR	95% CI	RR	95% CI	RR	95% CI	RR	95% CI	RR	95% CI
Number of physical exposures (heavy lifting, awkward postures of the trunk, and whole-body vibration)												
0	1.0	..	1.0	..	1.0	..	1.0	..	1.0	..	1.0	..
1	1.0	0.7–1.6	1.0	0.7–1.5	1.7	1.2–2.6	1.6	1.1–2.4	1.1	0.7–1.6	1.1	0.7–1.5
2	1.3	0.9–2.0	1.3	0.8–1.9	1.4	0.9–2.3	1.5	0.9–2.4	1.0	0.6–1.7	1.2	0.7–2.1
3	2.5	1.5–4.2	2.4	1.4–4.2	2.3	1.3–4.1	2.1	1.2–3.9	1.4	0.7–2.9	1.5	0.7–3.1
Health risk behavior (overweight, lack of exercise and smoking), sum index												
0	1.0	..	1.0	..	1.0	..	1.0	..	1.0	..	1.0	..
1–3	0.9	0.6–1.4	0.9	0.6–1.4	1.0	0.6–1.6	0.9	0.6–1.4	1.8	1.0–3.3	1.7	1.0–3.1
4–6	1.1	0.7–2.0	0.9	0.5–1.5	1.2	0.7–2.1	1.0	0.6–1.7	2.8	1.5–5.4	2.8	1.4–5.4
Sleeping disturbance												
No	1.0	..	1.0	..	1.0	..	1.0	..	1.0	..	1.0	..
Mild	1.2	0.9–1.7	1.0	0.7–1.5	1.6	1.2–2.3	1.3	0.9–1.8	2.1	1.4–3.2	2.0	1.3–3.0
Severe	1.7	0.9–3.1	0.9	0.5–1.7	3.2	1.9–5.5	2.3	1.3–4.3	2.5	1.2–5.0	2.1	1.0–4.6
Mental distress (being stressed, nervous or tense)												
No	1.0	..	1.0	..	1.0	..	1.0	..	1.0	..	1.0	..
Somewhat	1.3	0.9–1.9	1.1	0.8–1.6	1.8	1.2–2.6	1.6	1.1–2.3	1.5	1.0–2.2	1.2	0.8–1.7
Much or very much	1.5	1.0–2.5	1.4	0.8–2.3	2.2	1.3–3.7	1.5	0.8–2.6	2.1	1.3–3.5	1.5	0.9–2.5
Satisfaction with life												
Satisfied	1.0	..	1.0	..	1.0	..	1.0	..	1.0	..	1.0	..
Not satisfied	1.2	0.8–1.7	1.0	0.7–1.5	1.8	1.2–2.6	1.5	1.0–2.1	1.1	0.7–1.7	0.8	0.5–1.3
Chronic diseases												
No	1.0	..	1.0	..	1.0	..	1.0	..	1.0	..	1.0	..
Yes	1.7	1.2–2.4	1.5	1.1–2.2	1.1	0.7–1.6	0.8	0.6–1.2	1.4	1.0–2.0	1.1	0.8–1.6
Pain in other areas (neck, upper extremities, hip or knee)												
No	1.0	..	1.0	..	1.0	..	1.0	..	1.0	..	1.0	..
Yes	1.8	1.3–2.5	1.6	1.2–2.3	1.7	1.2–2.4	1.4	0.9–1.9	1.7	1.1–2.5	1.2	0.8–1.8

^a Models 1a–3a adjusted for gender and age.^b Models 1b–3b adjusted for all variables listed in the table, and also for gender and age.

muscle fatigue, intradiscal pressure, and microfractures (7, 29). Heavy lifting had a modest association with low-back pain, but only among the youngest workers. This finding is consistent with the results of a study among construction workers that showed that manual materials handling was associated with a higher prevalence of low-back pain among younger, but not older (50 years or older) workers (30). Working with awkward trunk postures primarily involves static muscle work, it increases the amount of force needed to accomplish a worktask, and it generates excess mechanical strain on tendons, ligaments, discs, and other soft tissues as well. Hence its effects on the lower back may be related to the decrease in muscle strength that has been shown to begin around the age of 40 years, as well as to poorer tissue recovery (7). This possibility may explain why, in our study, working with awkward postures increased the risk only after 40 years of age. The risks related to lifting or awkward postures not being elevated among the oldest workers may indicate self-selection out of the heaviest loading jobs by the time workers reach the

age of 50 years, primarily leaving the workers who are the most resistant to the effects of physical loading in this age group. The healthy worker selection effect is often an unavoidable phenomenon in studies of working populations. It is also possible that the quantity of heavy lifting differed across the age groups (eg, the oldest exposed workers lifting less than the younger workers) and, therefore, diluted the associations. Therefore, we investigated the distribution of the frequency of heavy lifting across the age groups. Although fewer workers aged 50 years or older were exposed to heavy lifting in general, those who lifted did it in fact more than the workers under 40 years of age [a mean of 39 (median 10) times a day versus a mean of 31 (median 5) times a day], whereas workers in the middle-age group most often lifted loads heavier than 25 kg [a mean of 48 (median 6.5) times a day]. This difference does not further explain the lack of association between lifting and low-back pain.

Our interest in this study was to assess the risk of low-back pain among those who were exposed to

multiple factors, as is often the reality in industrial populations. The results showed that, among the youngest workers, the risk of low-back pain was increased only when all three exposures were present, whereas, in the middle-age group, even a single physical exposure produced a significant increase in the risk. Being exposed to multiple health risks increased the risk of future low-back pain only among the oldest workers. It is possible that this significant increase in the risk is still an underestimation, in view of the fact that health-based selection is likely to be present in this age group. The joint effects, as presented in table 3, were higher than the multiplication of the risks of the underlying individual health risk factors (eg, for the youngest workers, a relative risk of 1.92 based on the multiplication being lower than the relative risk produced by the composite variables, 2.4, a finding which suggests a significant joint effect).

Of the underlying health risk factors, smoking contributed the most to the risk, being highest for the ex-smokers. Our results are consistent with the finding of several cross-sectional and longitudinal population-based studies, which have shown that current and former smokers have more low-back pain, as well as pain in other areas, than never smokers (10, 12, 13, 31). Cigarette smoking, and nicotine in particular, facilitate degeneration of the intervertebral discs by disturbing disc metabolism and proteoglycan and collagen synthesis, even at the gene expression level (32–34). Smoking may also affect the health of the lumbar spine by inducing atherosclerosis (35).

Some earlier studies have shown a small-to-moderate association between higher body weight or a lack of physical exercise and low-back pain (1, 11, 36). One possible biomechanical explanation is that both a higher body weight and poorer strength of the supporting spinal muscles lead to chronic overloading of the spine. Obese persons generate higher mechanical moments in the same postures than do people of normal weight; they are also less able to maintain and regain their body stature during and after physical exertion than normal-weight persons, and the inability to regain stature has particularly been associated with an increased risk of low-back pain (37, 38). Health behavior may affect low-back pain through other biological mechanisms, such as vascular or inflammatory processes (14). In addition, some psychological factors, such as self-esteem or the self-perception of general well-being, may mediate or modify the associations between health behavior and pain (39, 40).

Only a few prospective studies have investigated the possibility of sleep difficulties in pain-free persons predicting future pain, and the results of these studies support a reciprocal causal association (8, 41–43). In our study, sleep disturbance predicted the risk of future low-back pain, even when additionally assessed in a subgroup of those who, at the baseline, reported never

having experienced low-back pain. As we did not have information on the lifetime history of pain in areas other than the low back, we cannot say whether pain in some other areas before the initiation of this study had preceded sleep disturbance. Nevertheless, sleep disturbance was an independent predictor of low-back pain despite mental distress or aspects of health behavior being in the model, and further adjustment for job strain or education (a crude indicator of socioeconomic status) did not decrease the risk. This finding suggests that sleep problems may independently provoke low-back pain. A causal association is biologically plausible in that sleep deprivation has been shown to produce hyperalgesia (ie, increased sensitivity to pain) in many experimental human and animal studies (44, 45). Inflammation may play a role in this process (46). In addition, other mechanisms, such as perturbations in energy metabolism, may lead to musculoskeletal symptoms via the hampering of tissue rebuilding and adaptation (47).

In addition to sleep problems, low satisfaction with life and mental distress increased the risk of low-back pain in the 40- to 49-year-old workers, even when adjusted for each other, and in the presence of chronic disease and pain in other areas. The incidence of low-back pain among the younger workers was not significantly affected by psychological factors or sleep. Our results suggest that the role of mental well-being, such as sleep quality, becomes more important as a determinant of low-back symptoms as age increases.

This study has strengths but also limitations. We used a prospective design in which the exposures were assessed when the workers were free of low-back pain. The participation rates can be considered good, and there was no indication of the survey response at the follow-up being related to the outcome or exposures. Although the assessment of exposures was based on self-reports, most of the questions concerning physical work and psychosocial factors have been validated (21, 24). For physical exposures, the agreement between self-assessed and observed estimations was relatively good, especially among the pain-free workers in this same cohort (21). Since we detected differences in the risk factors and their effects when the analyses were stratified by age, we also tested interactions between age and physical workload and age and health behavior in the whole cohort. The interactions using the product terms did not reach statistical significance when the standard P-value of ≥ 0.05 was used. Therefore, we cannot rule out the possibility that the age-related differences in this study occurred due to chance. However, our additional calculations using the whole cohort showed that, for a person who had 2 “independent” risk factors [eg, “high age (≥ 50 years)” and “poor health behavior (index 4–6)”] the relative risk for low-back pain would be 1.3. The age-stratified analyses produced a higher risk

(RR 2.8). In this case, the multiplicative model failed to predict the association, and a significant joint effect can be considered. Problems of nonconvergence did not allow us to fit the log-binomial model with many independent variables and their interactions. A relatively large number of workers had missing values in the questions about chronic diseases. Imputation of "having a chronic disease" or "not having a chronic disease" to those with missing values did not change the main results, except that the effect of physical work somewhat decreased among the two oldest age groups.

Information on symptoms was collected with the validated Nordic questionnaire, which has high repeatability and sensitivity, is widely used, and has been considered as an international standard (20, 48). To dichotomize pain outcome, a cut-off of above 7 days of pain is a common criterion with this instrument (49, 50). We also used the standard 12-month time-period for the follow-up and for defining the cohort of workers free of low-back pain at baseline. We believe that this is long enough to exclude at least those with frequently recurring symptoms, but also short enough to decrease the probability of workers forgetting their previous symptoms (5). One-third of the workers reported at baseline that they had never had low-back pain. However, the age distribution did not differ between the whole cohort (free of low-back pain for at least 12 months) and the one-third (never had low-back pain); in other words, it seems that age did not predict whether the new episode of low-back pain that occurred during the follow-up was recurrent or new.

The study population was rather heterogeneous, consisting of workers 19–67 years of age, working in physically loading, as well as sedentary, tasks and living in both rural and urban areas. As in many industrial populations, the gender distribution was predominantly male. Therefore, we did not have sufficient power to examine differences between the genders with respect to the incidence of low-back pain or the effects of the risk factors.

In conclusion, our study showed that younger and older workers were affected by slightly different risk factor patterns. The effects of physical workload diminished with age, whereas the role of health behavior, sleep disturbance, and mental distress in the incidence of low-back pain increased. More prospective studies on the single and joint effects of age-specific risk factors for low-back pain are warranted, noting that very large populations are needed to permit these analyses. Meanwhile, our results support the possible value of health promotion and stress management as a part of prevention programs concerning low-back pain at work, in addition to the more-traditional occupational health and safety measures. Aging workers may benefit particularly from such an integrated approach.

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