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A prospective study on knee pain and its risk factors

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Summary

Objectives: To evaluate the effects of work-related and individual factors as well as physical activity and sports on the incidence and persistence of knee pain among a working population.

Design: Employees of a large Finnish forestry company replied to a questionnaire (a modified version of the Nordic Questionnaire) on musculoskeletal pain and its possible risk factors at the baseline of this study. A cohort of 2122 workers free of knee pain and another cohort of 333 workers with severe knee pain were followed up for one year. The effects of the risk factors on the incidence and persistence of knee pain were studied using multivariable logistic regression models.

Results: A total of 214 (10%) workers developed knee pain during the follow-up. Significant predictors of incident knee pain in the multivariable model were higher age, overweight, smoking, and previous knee injuries. Also, working with the trunk forward flexed in kneeling or standing position and physically strenuous work were non-significant predictors of incident knee pain. Of those 333 workers with severe knee pain at baseline, 220 (66%) still reported severe knee pain after one year. Higher age and job dissatisfaction increased the risk of persistent symptoms. General physical exercise and different sports activities did not predict the incidence or persistence of knee pain.

Conclusions: In this large prospective study, the risk factors for self-reported knee pain seemed to be highly similar to the risk factors for knee osteoarthritis (OA) reported in other papers. Age, previous knee injuries, overweight, and knee-straining work were those risk factors, which contributed to the incidence of knee pain. Psychosocial elements of work were more involved in the persistence of the symptoms in the knee.

Key words: Epidemiology, Physical work load, Overweight, Sports.

Introduction

Knee pain is a common musculoskeletal symptom among working-age people. The prevalence of knee pain varies from 10 to 60%, depending on age, occupation and the definition of knee pain[1–4], yet only few epidemiological studies exist on knee pain and its risk factors. In the majority of earlier studies the standard outcome has been radiographically evaluated osteoarthritis (OA), possibly due to the advantage of an objective definition of the disease. Knee pain, however, often occurs without OA; of those 1004 subjects, who reported having knee pain in a study of Hannan and others, only 15% had radiographic stage 2–4 changes of OA[5]. Knee OA is a highly age-related phenomenon[6–8]; the prevalence of OA increases with age being negligible in those aged 25–35 years and reaching 20–40% in those aged 75 and older. Knee pain, however, does not occur only in older age; in a Finnish study of 967 schoolchildren, 19% of those aged 14–15 years reported having chronic knee pain[9].

Hence, pain in the knee occurs often because of other reasons than OA and consequently, the risk factors may also differ. There is even some evidence that the risk factors for reported knee pain among persons with radiographic knee OA are more similar to the factors for knee pain among persons without OA than to the risk factors for radiographic knee OA *per se*[10].

The knowledge of the risk factors for knee pain, particularly with respect to occupational physical loading and physical exercise, is still limited, mainly due to a very small number of prospective studies. In a cross-sectional study on NHANES I data among subjects between 25 and 74 years of age, the prevalence of knee symptoms (pain, swelling, morning stiffness) increased with age and was slightly higher for women[5]. Other studies have also shown that the prevalence of knee pain is higher for women[11].

Lower education has been shown to be associated with knee pain in some studies[1,12] but not in others[10]. In a study on 55-year-old Swedish residents, knee pain was more frequent among those with moderate work load compared with those with light or heavy work[1]. In another study, those with physically demanding work, such as carpenters, miners and construction workers had a higher prevalence of knee pain compared to those with physically less demanding work[3].

The objective of this prospective study was to examine the effects of work-related and individual factors as well as physical activity and sports on the incidence and persistence of knee pain among a working population.

Subjects and methods

STUDY POPULATION

In 1992, 7000 employees of a large forest industry company in Finland received a questionnaire on

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Table I
Potential predictors of knee pain

Individual factors:
Sex (male/female)
Age (years, classified into four categories: <35, 35–44, 45–54, ≥55)
Body mass index (weight/height^2, classified into four categories: <23.0, 23.0–25.9, 26.0–28.9, ≥29.0)
Mental stress (classified into four categories: not at all, only little, to some extent, rather much or much)
Smoking (non-, ex-, current smoker)
Previous knee injury (none/yes)
Work-related factors:
Working in kneeling or squatting position (hours/day, four categories: not at all, <1/2, 1/2–1, >1)
Working in sitting position (hours/day, three categories: <2, 2–4, >4)
Working with the trunk forward flexed in standing or kneeling position (hours/day, four categories: <1/2, 1/2–1, 1–2, >2)
Amount of twisting movements of the trunk during a workday (classified into three categories: not at all or only little, moderately, much)
Physical strenuousness of work (classified into three categories: not at all or rather light, somewhat strenuous, rather or very strenuous)
Overload at work (difficulty at work, hurry at work, scoring of both from 1 to 5, sum score variable, classified into three categories: not at all, little, definite)
Risk of accident at work due to tripping, slipping, climbing stairs etc. (classified into three categories: small, moderate, great)
Daily lifting of loads (the average frequency (f) of handling 6–15 kg, 16–25 kg and >25 kg loads daily.
Index: $1\times f_{(6-15\ kg)}+2\times f_{(16-25\ kg)}+3\times f_{(>25\ kg)}$, classified into four categories: 0–10, 10–30, 31–150, >150)
Operating a motor vehicle (hours/day, four categories: 0, <2, 2–4, >4)
Job satisfaction (classified into three categories: rather or very satisfied, not satisfied but not dissatisfied either, rather or very dissatisfied)
Frequency of physical exercise (times/week, classified into three categories: ≤1, 2–3, >4)
Sports activity (sum score variable, classified into three categories: ≤52, 53–156, ≥157)
Different types of sports (the average frequency of sports during 12 months, index, classified into three categories: not at all or only little, moderately, actively)
Jogging, orienteering, competition walking (index value 0–11=not at all or only little, 12–71=moderately, ≥72=actively)
Walking (0–47, 48–143, ≥144)
Bicycling (0–11, 12–143, ≥144)
Cross-country skiing, biathlon, skating (0–7, 8–39, ≥40)
Swimming, water polo (0–11, 12–47, ≥48)
Trekking, hunting (0–7, 8–39, ≥40)
Dancing (0–5, 6–23, ≥24)
Keep-fit weight lifting, competition weight lifting, bodybuilding (0–11, 12–95, ≥96)
Gymnastics, aerobic dance (0–11, 12–71, ≥72)
Downhill skiing (0–3, 4–15, ≥16)
Tennis, squash, badminton (0–5, 6–35, ≥36)
Basketball, European football (soccer), floorball (0–7, 8–23, ≥24)
Ice hockey, bandy (0–7, 8–29, ≥30)
Volleyball (0–11, 12–51, ≥52)
Other modes

musculoskeletal pain and potential risk factors. After two reminders, 75% (N=5250) responded to the questionnaire. A few subjects with rheumatoid arthritis and with part-time work were excluded, leaving 5180 subjects in the study population. Follow-up questionnaires were sent in 1993, 1994 and 1995 to those who had responded to the previous questionnaire and the response rates were 83%, 77%, and 90%, respectively. The corresponding numbers of subjects were 4283, 3312 and 2984. This one-year follow-up study is based on data for the time period 1994 to 1995. The year 1994 was chosen as baseline because in that year the questionnaire contained for the first time detailed questions about different sports.

QUESTIONNAIRE

The questionnaires (a modified version of the Nordic Questionnaire)[13] contained the following question about knee pain: 'Estimate the total number of days you have had knee pain during the preceding 12 months?' Questions were also asked about symptoms in other body regions. The baseline questionnaire in 1994 inquired if the respondents had ever experienced a severe knee injury (such as bone fracture, meniscal injury, severe distortion) which had led them to consult a medical practitioner. The baseline questionnaire also contained several questions about possible risk factors, such as individual factors, physical loading factors, work characteristics and physical exercise. These factors have been presented in Table I. Of the individual factors, age, sex, height and weight, and smoking status were queried. Mental stress was qualified with a validated question[14]: 'Mental stress means the situation when a person feels tense, restless, nervous or anxious, or is unable to sleep at night because his mind is troubled all the time. Do you feel that kind of stress these days?' Working in kneeling or squatting position, in sitting position, or with the trunk forward flexed in kneeling or standing position was investigated with questions regarding the duration (hours/day) of such positions. Questions about the amount of twisting movements of the trunk during a work day, daily lifting of loads and the duration of operating a

motor vehicle were also asked. The questionnaire contained questions about work characteristics (such as risk of accident, difficulty and hurry at work, physical strenuousness of work) and job satisfaction. Questions were asked about physical exercise in general (times a week on average during the preceding 12 months, at least 20 minutes per session, for example bicycling, swimming. etc.). Also, the questionnaire contained a table of 15 different types of sports. The respondents answered how many times per month and how many months during the preceding 12 months they had practised these sports[15].

OUTCOMES

The outcome variables were incident knee pain and persistent severe knee pain. In the questionnaires, the question about knee pain had five categories (0 days, 1–7 days, 8–30 days, >30 days but not daily, daily). The first two categories were combined, since some days with pain do not necessarily indicate a significant underlying disorder. Also, the last two categories were combined due to a small number of subjects with daily pain.

In the incidence analyses those 2122 workers who had no significant knee pain (0–7 days) during the 12 months preceding the baseline questionnaire in 1994 formed the healthy study cohort. Incident cases were those who in the follow-up questionnaire in 1995 reported knee pain (more than 7 days) during the preceding 12 months. Those who had no knee pain in both 1994 and 1995 formed the healthy comparison group.

In the persistence analyses those 333 workers who had knee pain more than 30 days (defined as severe pain) during the 12 months preceding the baseline questionnaire formed the study cohort. Persistent cases were those who reported severe pain both in 1994 and in 1995 questionnaires. They were compared with those who had severe knee pain in 1994 but no severe pain in 1995.

PREDICTORS

The potential explanatory variables were chosen from the baseline questionnaire in 1994. These variables with detailed description of the categories have been listed in Table I. For some workload factors, categories showing equal effect estimates were combined into broader categories. Also, some categories with small counts were combined. Continuous variables (age, body mass index, and lifting of loads) were categorized so that the cutpoints were selected on the basis of previous studies and literature as well as hypotheses. Partly, the selection was data-oriented on the basis of the distribution of exposures in the study population.

We formed indices for the 15 different types of sports; an index represents the number of times a sport was practised per year. The indices were classified into three categories (not at all or only little, moderately, actively) and the cutpoints of the categories were chosen for each type of sport individually[15]. For example, a person who practised actively keep-fit weight lifting must have had a minimum index value of 96 [practicing this activity at least twice a week (=8 times/month) around the year (8 times/month × 12 months=96)] (Table I).

DATA ANALYSIS

Each of the possible risk factors listed in Table I was placed one-by-one in the logistic regression models. The models also included age and sex as potential confounders. All the variables with statistical significance at 5% level in the age- and sex-adjusted models were chosen to the final multivariable model. For incident knee pain, the final multivariable model included age, sex, body mass index, smoking, previous knee injury, working with the trunk forward flexed in standing or kneeling position, lifting index, and physical strenuousness of work. For persistent pain, the final multivariable model included age, sex, twisting movements of the trunk during a work day, and job satisfaction.

In addition to these main analyses, we investigated the effects of the predictors on incident knee pain in a subcohort of those respondents who were free of knee pain already in 1992 and 1993. Also, the possible interactions between different predictors (such as between sex and other individual factors or work load factors, age and other individual factors or work load factors, body mass index and work load factors, or previous injury and sports) were studied. Pain in other body regions was related to knee pain, but since it had no confounding effect it was not included in our analyses. Neither was the information about the duration in occupation included in the analyses due to a strong correlation with age. All statistical analyses were performed using the GENMOD procedure in the SAS 6.12 software package.

Results

Of those 3312 employees who completed and returned the questionnaire in 1994, 28% were white-collar workers (foremen, management, office clerks and technical designers) and 72% were blue-collar workers (paper machine process and forest workers). The mean age of the white-collar workers was 45.3 (S.D. 9.2) years and 53% of those were men. For the blue-collar workers, the mean age was 45.3 (S.D. 9.1) years and 82% were men.

The number of the respondents in 1994 represents 47% of the original cohort (N=7000) to whom the first questionnaire in 1992 was sent. Selection between the respondents and non-respondents due to the outcome or exposures did not occur though. The occurrence of knee pain in the previous year (in 1993, 1994 and 1995 questionnaires) was similar among the respondents and those who dropped out after 1992. Regulations of confidentiality precluded us from collecting data on non-respondents to the first questionnaire in 1992. The younger subjects replied slightly less frequently than the older and the men less frequently than the women, but the differences were small.

INCIDENCE OF KNEE PAIN

Of those 2122 workers who had no knee pain at baseline, 214 (10%) developed knee pain during the one-year follow-up time (Table II). The subcohort having no knee pain for 3 consecutive years before the follow-up (years 1992–1994) consisted of 1656 workers and 7% of these workers developed knee pain during the follow-up. The results of the preliminary and multivariable logistic regression models are presented in Table III.

RISK FACTORS FOR INCIDENT KNEE PAIN

Individual factors

As presented in Table III, the risk of incident knee pain increased with age, although this increase was not statistically significant in the multivariable model. The women had

Table II
Knee pain at baseline (in 1994) and in the follow-up (in 1995) among forest industry workers

	1995								
	Healthy		Mild pain (8–30 days)		Severe pain (>30 days)		All		
1994	No.	%	No.	%	No.	%	No.	%	%
Healthy	1908	90	139	7	75	3	2122	100	(77)
Mild pain (8–30 days)	129	41	114	36	73	23	316	100	(11)
Severe pain (>30 days)	61	18	52	16	220	66	333	100	(12)
All	2098	(75)	305	(11)	368	(13)	2771*		(100)

*213 subjects of the total of 2984 had missing values in either year 1994 or 1995 question on knee pain.

a higher risk than did the men. Body mass index of 26 kg/m^2 or more increased the risk of incident pain. Also, ex- and current smokers had an elevated risk of incident knee pain.

Previous knee injury

Of those 2122 workers who had no knee pain at baseline, 249 (11%) reported having ever experienced a previous severe knee injury. Injury had happened on the average 14 years before the baseline. For those who had had a previous knee injury, the risk of incident knee pain was almost three-fold compared with the risk of those who had never experienced a knee injury. Among those 1656, who were free of knee pain at least 3 consecutive years before the follow-up, 153 (9%) had reported a previous knee injury. Injury was also an independent risk factor for incident knee pain in this subcohort.

Work-related factors

In the sex- and age-adjusted models, working with the trunk forward flexed in kneeling or standing position, daily lifting of loads, and physically strenuous work increased the risk of incident knee pain significantly. In the multivariable model, these factors increased the risk of incident pain slightly, although non-significantly.

Physical exercise

The amount of general physical exercise nor the practicing of different sports was related to the one-year incidence of knee pain.

No significant interactions between different predictors and the outcome were detected.

PERSISTENCE OF SEVERE KNEE PAIN AND RISK FACTORS

The one-year persistence of severe knee pain was 66% (Table II). Age increased the risk of persistent severe knee pain. Women and men had an equal risk. Job dissatisfaction and twisting movements of the trunk were associated with an increased risk of persistent severe knee pain. Neither the amount of general physical exercise nor the practicing of different sports was related to the one-year persistence of knee pain.

No significant interactions between different predictors and the outcome were detected.

Discussion

Among Finnish people aged 19–67 years working in various tasks in the forest industry, knee pain seems to occur as often as other musculoskeletal symptoms, such as shoulder pain or radiating low back (sciatic) pain[15–17]. However, compared to symptoms in the shoulder or low back, knee pain is a more persistent type of pain; of those who had severe knee pain at baseline, 66% had severe pain during the follow-up. The percentages for persistent shoulder and sciatic pain were 55 and 53, respectively[16,17]. This difference is plausible if considered from the aspect of the underlying pathology; a common cause for knee pain is OA, defined as a disease affecting joint cartilage and subchondral bone, leading to loss of cartilage and, when extensive, to visible radiographic changes[7]. Such degenerative changes are irreversible.

Degeneration, however, explains only a part of the occurrence of symptoms. According to Felson and his co-workers, only 30–40% of those with radiographic changes have symptoms in the knee[18]. And vice versa, knee pain very often occurs without any signs of radiographic changes[2,8], due to early symptoms of OA but also because of other conditions such as bursitis, tendinitis, meniscal lesions and chondromalacia.

Many earlier studies have shown that the prevalence of OA increases with age[6–8]. Also, the prevalence has been consistently higher in women than in men, particularly among the elderly[6,19]. In our study, age appeared to be an important risk factor for incident knee pain but particularly for persistent knee pain. Women also had a higher risk of incident pain. However, when the baseline study population was restricted to those who had been healthy (no knee pain) at least for three consecutive years before the incident pain, the difference between the genders decreased. This suggests that women may have more often recurrent type of knee pain.

Occupational loading has been linked to knee OA in several papers[20–23]. Stereotyped repetitive use of the knee joint, heavy external loading, awkward working positions, and injuries are those potential risk factors which can be related to many physical work tasks. In the literature, a positive relationship exists between work, which involves knee bending and squatting, and knee OA[2,24,25]. In our study, the most knee-specific variable, i.e. working in kneeling or squatting position, unexpectedly did not appear to be a significant predictor of incident knee pain (OR 1.3, 95% CI 0.7–2.3, highest vs lowest exposure). Instead, another work-related physical loading factor, working with the trunk forward flexed in kneeling or standing position, slightly

Table III
Factors predicting the incidence of knee pain

Explanatory variables	Prevalence of explanatory variables (number of subjects)		Model adjusted for sex and age*		Multivariable model			Subcohort†, multivariable model		
	%	(*N*)	OR	95% CI	OR	95% CI	*P*-value	OR	95% CI	*P*-value
Individual factors										
Sex							0.0324			0.5767
male	72	1535	1.0		1.0			1.0		
female	28	586	0.9	0.7–1.3	1.6	1.0–2.4		1.2	0.7–2.0	
Age (years)							0.2370			0.2695
<35	17	360	1.0		1.0			1.0		
35–44	32	681	1.3	0.8–2.1	1.1	0.6–1.9		1.1	0.6–2.2	
45–54	26	772	1.9	1.2–3.0	1.5	0.9–2.5		1.5	0.8–2.9	
≥55	15	309	2.3	1.4–3.9	1.6	0.8–3.3		2.0	0.9–4.9	
Body mass index (kg/m^2)							0.0216			0.0147
<23.0	24	489	1.0		1.0			1.0		
23.0–25.9	37	779	1.2	0.8–1.9	1.2	0.7–2.0		0.7	0.4–1.4	
26.0–28.9	27	557	1.8	1.2–2.9	1.9	1.2–3.2		1.7	0.9–3.2	
≥29.0	12	255	1.8	1.1–3.1	1.8	1.0–3.3		1.3	0.6–2.8	
Smoking							0.0124			0.0058
non-smoker	47	996	1.0		1.0			1.0		
ex-smoker	29	610	1.6	1.1–2.2	1.8	1.2–2.7		2.2	1.4–3.6	
current smoker	24	499	1.2	0.8–1.8	1.3	0.9–2.0		1.3	0.7–2.3	
Previous knee injury							0.0001			0.0036
none	89	1873	1.0		1.0			1.0		
yes	11	241	2.4	1.7–3.5	2.7	1.8–4.1		2.4	1.4–4.3	
Work-related factors										
Working with the trunk forward flexed in standing or kneeling position (h/day)							0.0733			0.1894
<1/2	43	812	1.0		1.0			1.0		
1/2–1	25	471	1.7	1.2–2.4	1.6	1.0–2.4		1.2	0.7–2.1	
1–2	13	252	0.9	0.5–1.5	0.9	0.5–1.6		0.9	0.4–1.9	
>2	19	363	1.7	1.1–2.6	1.4	0.8–2.5		1.9	1.0–3.8	
Lifting index‡							0.2873			0.2994
0–10	67	1232	1.0		1.0			1.0		
11–30	15	276	1.4	0.9–2.2	1.0	0.6–1.6		1.2	0.6–2.4	
31–150	10	185	2.0	1.3–3.2	1.5	0.9–2.6		1.7	0.8–3.4	
>150	8	140	1.2	0.6–2.2	0.8	0.4–1.8		0.8	0.3–2.1	
Physical strenuousness of work							0.3743			0.9015
not at all or rather light	51	952	1.0		1.0			1.0		
somewhat strenuous	29	552	1.5	1.0–2.1	1.2	0.8–1.9		1.0	0.6–1.7	
rather or very strenuous	20	374	1.6	1.1–2.4	1.5	0.8–2.6		1.1	0.5–2.4	

Logistic regression model (OR=odds ratio, CI=confidence interval).
*Sex adjusted for age, and age adjusted for sex.
†Subcohort of those workers who had no knee pain in 1992–1994.
‡The average frequency (f) of handling 6–15 kg, 16–25 kg and >25 kg loads daily. Index: $1\times f_{(6-15\ kg)}+2\times f_{(16-25\ kg)}+3\times f_{(>25\ kg)}$.

increased the risk of incident knee pain. In the subcohort analysis, the increase in the risk was almost two-fold when the duration of working in such position exceeded 2 h a day. Due to a relatively small size of the subcohort, this effect was not statistically significant, however. In addition to a direct knee-straining effect, this risk factor may also reflect the general physical loading at work.

Frequent lifting of heavy loads has biomechanical grounds to be a potential risk factor for knee disorders. Earlier studies have shown a positive association between lifting and knee osteoarthritis[23,26,27]. A slightly increased risk of incident knee pain, although not significant, was seen in our study. Physically strenuous work also non-significantly increased the risk in the multivariable model. Obviously those with knee-straining work often have also heavy physical work and this correlation reduced the effects of these variables when adjusted for each other. Nevertheless, our results support the assumption by Jensen *et al*. that knee-straining work positions rather than overall physical work load seem to be the more important risk factors[8].

Some previous studies have demonstrated a protective effect of smoking on knee OA[2,28]. In our study, no such protective effect was detected but instead we found an increased risk of incident knee pain among former smokers compared to non- or current smokers. Similar results have been presented in a cross-sectional study by Davis and others where former smokers were more likely to report knee pain. This association was, however, only seen among women[10]. It is difficult to find reasonable explanations for the results seen in our study as well as those in previously mentioned studies. It has been hypothesized that one of the many constituents of cigarette smoke could act to prevent cartilage destruction[18].

Table IV
Factors predicting the persistence of severe knee pain

Explanatory variables	Prevalence of explanatory variables (number of subjects)		Model adjusted for sex and age*		Multivariable model		
	%	(*N*)	OR	95% CI	OR	95% CI	*P*-value
Individual factors							
Sex							0.8988
male	73	244	1.0		1.0		
female	27	989	0.9	0.5–1.5	1.0	0.6–1.9	
Age (years)							0.0378
<35	7	22	1.0		1.0		
35–44	17	58	1.7	0.6–4.6	2.1	0.7–6.1	
45–54	52	174	2.7	1.1–6.6	3.7	1.4–9.8	
>55	24	79	3.0	1.1–7.8	2.8	0.9–8.6	
Work-related factors							
Twisting movements of the trunk during a work day							0.0018
not at all or only little	4	12	1.0		1.0		
moderately	70	200	3.6	1.1–11.9	3.2	0.9–11.0	
much	26	72	1.5	0.4–5.3	1.2	0.3–4.4	
Job satisfaction							0.0304
rather or very satisfied	65	192	1.0		1.0		
not satisfied but not dissatisfied either	25	75	0.6	0.4–1.1	0.7	0.4–1.2	
rather or very dissatisfied	10	29	2.2	0.8–5.8	2.8	1.0–7.8	

Logistic regression model (OR=odds ratio, CI=confidence interval).
*Sex adjusted for age, and age adjusted for sex.

The association between overweight and knee OA has been shown in several population-based studies[19,24,29]. The results from prospective studies have strengthened the evidence of the role of overweight as a causative factor[18,30]. The results from our prospective study are in agreement with the literature; those workers with body mass index of 26 kg/m^2 or more had an increased risk of incident knee pain. Overweight is assumed to cause OA by increasing the mechanical stress on the weight-bearing joints. Although this mechanism is highly plausible regarding the development of knee pain, other explanations such as metabolic elements may also exist[30]. Overweight may contribute to symptoms of other underlying disorders than OA of the knee. Overweight may also be an indicator of other factors, such as lack of physical fitness.

In our study, neither the amount of general physical exercise nor the practicing of different sports was related to the one-year incidence or persistence of knee pain. The number of participants in some sports was rather small, but even combining some sports with the same type of loading did not bring out any new effects. The follow-up time may have been too short for detecting long-term effects of sports on the knee. Physical activity has been shown to be a risk factor for the incidence of radiographically evaluated OA in the knee[18,31,32]. However, ex-athletes with osteoarthritic changes have similar rates of symptom reporting than non-athletes, due to higher pain thresholds[33]. Good muscle strength in lower extremities presumably protects the knee joint to some extent, but achieving such strength requires intensive physical activity, which itself increases the risk of acute and overuse injuries. Particularly sports with high levels of impact or torsional loading on the knee involve a significant injury risk.

Prior severe knee injury was the strongest predictor of the incidence of knee pain. The injury had happened on the average 14 years before the baseline. Those who practised team and ball sports reported more prior injuries, but no significant interaction was found between these variables and the outcome. Injury is a common cause for knee complaints; in addition to the pain related to the acute trauma, severe knee injury may cause problems even after a long asymptomatic period by inducing the development of OA[7]. Injury, however, explained only a part of the occurrence of knee pain in this study since no more than 19% of those who developed knee pain during the follow-up reported having ever experienced a severe knee injury. Naturally, when recalling lifetime events, the possibility of recall error is considerable[34].

Most of the questions concerning work load have been validated[35] and the correlations between self-assessed and observed estimations were relatively high especially among those workers who were free of musculoskeletal pain. In epidemiological studies on occupational physical loading and musculoskeletal pain, a notable information bias may occur if the current symptoms affect the estimation of past exposure. This bias was avoided in the incidence study with the prospective study design where the baseline study cohort was symptom-free. However, because of the intermittent and episodic nature of musculoskeletal symptoms, some of the incident cases may have experienced recurrent knee pain (recurrence from 1992 or 1993 or earlier years) and the risk factors for recurrent pain may differ from those for incident pain. Therefore, in addition to the main analyses, we restricted the study population to those who had been healthy at least for three consecutive years (since 1992) and investigated the effects of the risk factors in this subcohort. With this procedure we were able to diminish the confounding effect of recent previous pain. As shown in Table III, the effects of the risk factors remained largely similar. This analysis gives support to the fact that these predictors may be true risk factors for the first occurrence of knee pain.

In the analyses of persistent pain, the aim was to assess those risk factors, which had a prognostic value on persistent pain symptoms. Naturally, recall bias may be present when workers with severe pain estimate their exposure, particularly occupational loading. Selection due to healthy worker effect may have also biased the results to some extent. Such selection occurs when those with severe musculoskeletal symptoms are not hired into physically demanding work tasks, or when those workers who develop symptoms during physical work change to work with lower exposure or leave the labor market entirely, and those with better health status and physical fitness remain at work. Healthy worker effect may cause an underestimation in the results related to occupational loading in particular.

When interpreting the results of this or other similar studies, assumptions of a direct causality between the detected risk factor and the outcome should be made with caution. Other explanations may exist as well. For instance, some factors such as obesity may be indicators of other factors, such as lack of physical fitness. Some people may also be more prone to perceive and report exposures such as physical workloads as well as their symptoms. This may lead to spurious associations.

The outcome of this one-year follow-up study was self-reported knee pain but the risk factors for this symptom were highly similar to the risk factors for radiographic knee OA reported in other papers. Age, previous knee injuries, smoking, overweight, and knee-straining work were those risk factors, which contributed to the incidence of knee pain. Psychosocial elements of work seemed to be more involved in the persistence of knee symptoms. Knee disorders, especially painful OA, cause substantial disability and functional impairment and hence it is important to try to prevent the onset of knee pain but also the disability resulting from knee disorders. It is possible only by recognizing and affecting those factors, which have predictive value in the onset and prognosis of the disorder.

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References

1. Bergenudd H, Nilsson B, Lindgarde F. Knee pain in middle age and its relationship to occupational work load and psychosocial factors. Clin Orthop 1989;245:210–5.
2. Kivimäki J, Riihimäki H, Hänninen K. Knee disorders in carpet and floor layers and painters. Scand J Work Environ Health 1992;18:310–6.
3. O'Reilly SC, Muir KR, Doherty M. Occupation and knee pain: a community study. Osteoarthritis Cart 2000;8:78–81.
4. Peat G, McCarney R, Croft P. Knee pain and osteoarthritis in older adults: a review of community burden and current use of primary health care. Ann Rheum Dis 2001;60:91–7.
5. Hannan MT, Felson DT, Pincus T. Analysis of the discordance between radiographic changes and knee pain in osteoarthritis of the knee. J Rheumatol 2000;27:1513–7.
6. Felson DT, Naimark A, Anderson J, Kazis L, Castelli W, Meenan RF. The prevalence of knee osteoarthritis in the elderly. The Framingham Osteoarthritis Study. Arthritis Rheum 1987;30:914–8.
7. Felson DT. Epidemiology of hip and knee osteoarthritis. Epidemiol Rev 1988;10:1–28.
8. Jensen LK, Mikkelsen S, Loft IP, Eenberg W, Bergmann I, Logager V. Radiographic knee osteoarthritis in floorlayers and carpenters. Scand J Work Environ Health 2000;26:257–62.
9. Vähäsarja V. Prevalence of chronic knee pain in children and adolescents in northern Finland. Acta Paediatr 1995;84:803–5.
10. Davis MA, Ettinger WH, Neuhaus JM, Barclay JD, Segal MR. Correlates of knee pain among US adults with and without radiographic knee osteoarthritis. J Rheumatol 1992;19:1943–9.
11. Andersen RE, Crespo CJ, Ling SM, Bathon JM, Bartlett SJ. Prevalence of significant knee pain among older Americans: results from the Third National Health and Nutrition Examination Survey. J Am Geriatr Soc 1999;47:1435–8.
12. Hannan MT, Anderson JJ, Pincus T, Felson DT. Educational attainment and osteoarthritis: differential associations with radiographic changes and symptom reporting. J Clin Epidemiol 1992;45(2):139–47.
13. Kuorinka I, Jonsson B, Kilbom Å, Vinterberg H, Biering-Sørensen F, Andersson G, *et al*. Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. Applied Ergonomics 1987;18:233–7.
14. Elo A-L, Leppänen A, Jahkola A. Voidaanko stressiä tutkia pätevästi yhdellä kysymyksellä? (Can a single item give valid information about perceived stress?). Työ ja Ihminen 1999;13:2309 (in Finnish with English summary).
15. Miranda H, Viikari-Juntura E, Martikainen R, Takala E-P, Riihimäki H. Physical exercise and musculoskeletal pain among forest industry workers. Scan J Med Sci Sports 2001;11:239–46.
16. Miranda H, Viikari-Juntura E, Martikainen R, Takala E-P, Riihimäki H. prospective study of work-related factors and physical exercise as predictors for shoulder pain. Occup Environ Med 2001;58:528–34.
17. Miranda H, Viikari-Juntura E, Martikainen R, Takala E-P, Riihimäki H. Individual factors, occupational loading and physical exercise as predictors for sciatic pain. Spine (in press).
18. Felson DT, Zhang Y, Hannan MT, Naimark A, Weissman B, Aliabadi P, *et al*. Risk factors for incident radiographic knee osteoarthritis in the elderly: the Framingham Study. Arthritis Rheum 1997;40:728–33.
19. Heliövaara M, Mäkelä M, Sievers K. Tuki- ja liikuntaelinten sairaudet Suomessa. [Musculoskeletal diseases in Finland.]. Helsinki: Social Insurance Institution 1993: publication AL: 35.
20. Jensen LK, Eenberg W. Occupation as a risk factor for knee disorders. Scand J Work Environ Health 1996;22:165–75.
21. Maetzel A, Mäkelä M, Hawker G, Bombardier C. Osteoarthritis of the hip and knee and mechanical occupational exposure—a systematic overview of the evidence. J Rheumatol 1997;24:1599–607.
22. Riihimäki H, Viikari-Juntura E. Back and limb disorders. In: McDonald C, Ed. Epidemiology of Work Related Diseases, 2nd edn. London: BMJ Publishing Group 1999.

23. Sandmark H, Hogstedt C, Vingard E. Primary osteoarthrosis of the knee in men and women as a result of lifelong physical load from work. Scand J Work Environ Health 2000;26:20–5.
24. Anderson JJ, Felson DT. Factors associated with osteoarthritis of the knee in the first national Health and Nutrition Examination Survey (HANES I). Evidence for an association with overweight, race, and physical demands of work. Am J Epidemiol 1988; 128:179–89.
25. Felson DT, Hannan MT, Naimark A, Berkeley J, Gordon G, Wilson PW, *et al*. Occupational physical demands, knee bending, and knee osteoarthritis: results from the Framingham Study. J Rheumatol 1991;18:1587–92.
26. Coggon D, Croft P, Kellingray S, Barrett D, McLaren M, Cooper C. Occupational physical activities and osteoarthritis of the knee. Arthritis Rheum 2000;43:1443–9.
27. Lau EC, Cooper C, Lam D, Chan VN, Tsang KK, Sham A. Factors associated with osteoarthritis of the hip and knee in Hong Kong Chinese: obesity, joint injury, and occupational activities. Am J Epidemiol 2000;152:855–62.
28. Felson DT, Anderson JJ, Naimark A, Hannan MT, Kannel WB, Meenan RF. Does smoking protect against osteoarthritis? Arthritis Rheum 1989;32: 166–72.
29. Oliveria SA, Felson DT, Cirillo PA, Reed JI, Walker AM. Body weight, body mass index, and incident symptomatic osteoarthritis of the hand, hip, and knee. Epidemiology 1999;10:161–6.
30. Gelber AC, Hochberg MC, Mead LA, Wang NY, Wigley FM, Klag MJ. Body mass index in young men and the risk of subsequent knee and hip osteoarthritis. Am J Med 1999;107:542–8.
31. McAlindon TE, Wilson PW, Aliabadi P, Weissman B, Felson DT. Level of physical activity and the risk of radiographic and symptomatic knee osteoarthritis in the elderly: the Framingham study. Am J Med 1999;106:151–7.
32. Cooper C, Snow S, McAlindon TE, Kellingray S, Stuart B, Coggon D, *et al*. Risk factors for the incidence and progression of radiographic knee osteoarthritis. Arthritis Rheum 2000;43:995–1000.
33. Spector TD, Harris PA, Hart DJ, Cicuttini FM, Nandra D, Etherington J, *et al*. Risk of osteoarthritis associated with long-term weight-bearing sports: a radiologic survey of the hips and knees in female ex-athletes and population controls. Arthritis Rheum 1996;39:988–95.
34. Zwerling C, Sprince NL, Wallace RB, Davis CS, Whitten PS, Heeringa SG. Effect of recall period on the reporting of occupational injuries among older workers in the Health and Retirement Study. Am J Ind Med 1995;28:583–90.
35. Viikari-Juntura E, Rauas S, Martikainen R, Kuosma E, Riihimäki H, Takala E-P, *et al*. Validity of self-reported physical work load in epidemiologic studies on musculoskeletal disorders. Scand J Work Environ Health 1996;22:251–9.