



Supplement

Scand J Work Environ Health 2005;31(2):68-74

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Key terms: [carpenter](#); [dose-response relationship](#); [floor layer](#); [knee complaint](#); [knee osteoarthritis](#); [knee osteoarthrosis](#); [knee strain](#); [knee stress](#); [knee-straining work activity](#); [kneeling](#); [radiography](#); [self-assessment](#); [self-report](#); [self-reported knee disorder](#); [squatting](#)

This article in PubMed: www.ncbi.nlm.nih.gov/pubmed/16363449



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Knee-straining work activities, self-reported knee disorders and radiographically determined knee osteoarthritis

by Lilli Kirkeskov Jensen, MD¹

Kirkeskov Jensen L. Knee-straining work activities, self-reported knee disorders and radiographically determined knee osteoarthritis. *Scand J Work Environ Health* 2005;31 suppl 2:68–74.

Objectives Earlier studies indicate an increased risk of knee disorders in trades with knee-straining work positions, but no dose–response correlation has yet been documented. This study examined whether self-reported knee complaints and radiologically diagnosed knee osteoarthritis are dose-related to kneeling and squatting work positions.

Methods Worktasks for floor layers and carpenters were video-recorded, and the time spent in knee-straining work positions was quantified. A questionnaire study included 133 floor layers, 506 carpenters, and 327 compositors, all without earlier acute knee trauma. Radiological examinations were carried out on a stratified sample (N=150) from the questionnaire study. The individual exposure was calculated from the amount of knee strain quantified in the video-recorded worktasks, the self-reported time spent in the worktask, and the number of years in the trade. Statistical analyses were carried out with a binary logistic regression model, adjusting for age, body mass index, smoking, and knee-straining sports activities.

Results The odds ratios for self-reported knee complaints and radiographically determined knee osteoarthritis were increased in relation to the degree of knee-straining work demands for workers with low-to-moderate, high, and very high exposure to knee-straining work demands in a comparison with the reference group, without knee-stressing work activities.

Conclusions The results indicate that there is a dose–response correlation between knee-straining work activities and the development of self-reported knee complaints and radiologically diagnosed knee osteoarthritis.

Key terms knee strain; knee stress; kneeling; squatting; knee complaints; knee osteoarthritis; knee osteoarthrosis; dose–response relationship; floor layers; carpenters.

The risk of developing knee osteoarthritis depends on age, gender, weight, earlier severe acute knee traumas, and sports activities, together with exposure at work (1). Previous studies indicate an increased frequency of self-reported knee disorders, bursitis diagnosed clinically and with ultrasound, and radiologically diagnosed knee osteoarthritis among workers performing work involving kneeling work positions (2–6). Many occupations, especially on construction sites, involve exposure of the knee joints during work (2). However, earlier studies do not make it possible to describe a real dose–response correlation between the degree of exposure and the development of knee disorders, including knee osteoarthritis.

The purpose of this study was to examine whether self-reported knee complaints and radiologically diagnosed knee osteoarthritis are dose-related to work in

knee-stressing work positions such as kneeling and squatting.

Study population and methods

General description of the work circumstances in the three trades

Floor and carpet layers. Floor and carpet layers (hereafter referred to collectively as floor layers) install linoleum, carpet, and vinyl floorings. Their worktasks include the removal of old flooring, grinding, filling, installing underlay, measuring and cutting materials, gluing, welding, and installing skirting board (plastic). Only a few floor layers in Denmark install parquet flooring or other flooring made by laying wood on joists. The

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floor layers in this study did not usually use knee kickers, they altered their worktasks, and none solely installed carpets.

Carpenters. The worktasks of the carpenters included installing plasterboard, doors, windows, rafters and lathing for roofs, parquet flooring on joists, skirting boards made out of wood, gypsum for walls and ceilings, and insulation materials. Joiners, who were not included in this study, have traditionally installed kitchen equipment and wardrobes.

Compositors. The compositors in this study handled the layout of text and advertisements and made up pages before newspapers, weekly papers, books, and other publications were printed. They used visual display units, mostly while sitting. Their work did not include physically demanding or knee-straining work positions.

Interview and videotaping of knee-straining work positions

Telephone interviews of a random sample of 79 carpenters and 47 floor layers were used to record the distribution of different worktasks among floor layers and carpenters. The most frequent worktasks thus found were recorded on videotape. Each of the worktasks was studied for 3–30 minutes for one to six workers. A total of 39 carpenters and 33 floor layers were videotaped for a total of 798 minutes for the carpenters and 620 minutes for the floor layers. For floor layers, 13 worktasks were recorded (installing underlay, linoleum, carpet, rubber, tiles and vinyl; installing stairs and skirting board; filling; moving old floorings; measuring and cutting; welding; and grinding); and for carpenters it was nine worktasks (installing plaster boards, doors, rafters and lathing, parquet floors, windows, skirting board, gypsum on ceiling, kitchen and wardrobe; and insulation). Two persons quantified the worktasks, and the time spent in knee-straining work positions with a stopwatch during the playback of the videotape. The agreement between the two investigators' measurements was studied from 13 pairs of measurements. The repeatability of the observations varied by a mean of 2 percentage points (floor layers) and 3 percentage points (carpenters) between the two observers. The knee-straining activities were calculated as the observed time spent in a knee-straining position for a specific task as a percentage of the total videotaped worktime spent on the task in question.

Knee-straining work was defined as (i) kneeling completely on the left, right, or both knees, (ii) squatting, and (iii) kneeling partly on the left, right, or both knees while using the knees as support and balance. This

latter work position was only used for carpenters installing roofs with a gradient of >45 degrees.

Questionnaire and radiological study

In Denmark more than 95% of skilled carpenters, floor layers, and compositors are members of a trade union. Membership lists from the trade unions were used to create the cohort. Male workers who were members of the trade 10 years before the study was carried out, and not more than 70 years of age at the time of the investigation, were included. Altogether, 190 floor layers, 798 carpenters, and 500 compositors were selected for the study. The questionnaire response rates were 85%, 79%, and 78% for the floor layers, carpenters, and compositors, respectively. The workers in the study group were asked to complete a questionnaire on previous employment, medical disorders, knee accidents, participation in sports, smoking, height, and weight. The participants were asked to register different worktasks as a percentage of the total worktime in the trade. They were also asked if they had had musculoskeletal complaints during the past 12 months and during the past 7 days and to quantify the duration during the past 12 months (1–7 days, 7–30 days, >30 days or daily) according to the Nordic Musculoskeletal Questionnaire (7). Workers who, in the questionnaire, reported a previous acute knee trauma (fractures involving the knee joint, meniscus lesions, rupture of tendons or ligaments) were excluded from the study population. The final study material consisted of 133 floor layers, 506 carpenters, and 327 compositors (members and former members of the trade unions). The study material and a description of the questionnaire respondents by age, weight, BMI (body mass index = weight/height²), smoking habits, knee-straining sports, and the percentage of those currently working in the trade are presented by trade and by exposure in tables 1 and 2.

Radiological examinations were carried out on a stratified sample of 150 participants (50 floor layers, 51 carpenters, and 49 compositors) from the questionnaire study, as shown in table 1. X-rays of the anterior–posterior position of the knees were taken while the participants were lying down. The X-rays were assessed independently by two medical specialists in radiology without knowledge of the participant's trade, age, or reported knee complaints. In cases of any disagreement on the grade, a final joint assessment was made. The assessment was carried out according to the criteria defined by Kellgren & Lawrence (8, 9), who categorized knee osteoarthritis by severity in grades from 0 to 4.

The agreement between the assessments of knee osteoarthritis by the two radiologists showed a kappa coefficient of 0.52 (95%CI 0.43–0.61) when all of the

Table 1. Study population and final study sample for the questionnaire and radiological study by knee complaints and trade and degree of exposure.

	Study population (N)	Questionnaire respondents		Previous acute knee trauma		Final study sample ^a		Sample for the radiological study	
		N	% ^b	N	% ^b	N	% ^b	N	% ^b
Occupation									
Floor layers									
Knee complaints during past 12 months		88	55	17	61	71	53	32	64
Total	190	161	.	28	17 ^c	133	.	50	.
Carpenters									
Knee complaints during past 12 months		304	48	89	72	215	43	36	71
Total	798	629	.	123	20 ^c	506	.	51	.
Compositors									
Knee complaints during past 12 months		86	22	38	60	48	15	30	61
Total	500	389	.	63	16 ^c	327	.	49	.
Total	1488	1179	79 ^d	214	18 ^c	966	82 ^c	150	16 ^c
Exposure									
No									
Knee complaints during past 12 months	–	86	22	38	60	48	15	30	61
Total	–	389	.	63	16 ^c	326	.	49	.
Low-moderate									
Knee complaints during past 12 months	–	298	50	87	73	210	44	35	70
Total	–	602	.	119	20 ^c	482	.	50	.
High									
Knee complaints during past 12 months	–	47	45	13	68	34	40	12	67
Total	–	105	.	19	18 ^c	86	.	18	.
Very high									
Knee complaints during past 12 months	–	46	58	6	50	40	60	21	64
Total	–	79	.	12	15 ^c	67	.	33	.
Total	–	1175	.	213	18 ^c	961	65 ^c	150	16 ^c

^a Excluding workers with previous acute knee traumas (fractures, meniscus lesions, ligament, and tendon ruptures).

^b Percentage of total.

^c Percentage of questionnaire respondents.

^d Percentage of study population.

Table 2. Description of the questionnaire respondents by age, weight, body mass index, current smoking, knee-straining sports, and work in the trade (N=966), by trade and exposure group.

Study population	Age		Body mass index (kg/m ²)		Current smokers (%)	Knee-straining sports (%)	Currently at work in the trade (%)
	Mean	Range	Mean	Range			
Trade							
Floor layers (N=133)	47	26–72	25	18–40	57	55	56
Carpenters (N=506)	45	28–70	26	19–36	41	61	67
Compositors (N=327)	52	29–70	25	17–37	54	61	43
Exposure to knee-stressing work activities							
Number (N=327)	52	29–70	25	17–37	53	61	43
Low-moderate (N=482)	43	26–70	26	19–40	42	63	69
High (N=86)	53	31–70	26	18–36	52	49	58
Very high (N=67)	55	40–72	26	20–36	47	53	57

grades were considered and 0.61 when the grades were dichotomized as 0–1 and 2–4.

Analysis

Construction of the exposure index. Video-recorded time in knee-stressing work positions was calculated for the carpenters for the following job tasks: installing roofs (rafters and lathing), parquet flooring, gypsum for ceilings, plasterboard, and other worktasks (doors, windows, kitchen and wardrobes, skirting board, and insulation), as shown in table 3. For the floor layers, the video-recorded time in different worktasks was calculated for the installation of linoleum, carpets, and vinyl and “other worktasks” (moving old material, measuring and cutting, stairs, underlay, welding, grinding, filling) as shown in table 3.

By using the video-recorded knee-strain (v_i) in work-task i ; the self-reported time spent working in the work-task (t_i), and the self-reported years in the trade (Y), we

calculated an index for a knee-strain “exposure index” $\Sigma (v_i \times t_i \times Y)$.

The exposure index for knee-straining work activities was divided into the four categories of “no exposure” (= 0), “low-to-moderate exposure” (1–8), “high exposure” (9–14), and “very high exposure” (≥ 15). According to this method, a worker who had worked in knee-straining activities all day (100%) for 15 years would have an index of 15, and a worker who had worked in knee-straining activities for half of the day (50%) for 30 years would also have an index of 15.

Statistical analysis. Merging grades 0 and 1 and grades 2 through 4 dichotomized the grades of knee osteoarthritis.

Odds ratios for the dependent variables “knee complaints during the last 12 months”, “knee complaints ≥ 30 days during the last 12 months”, “knee complaints during the last 7 days”, and a knee osteoarthritis grade of 2–4 were calculated in logistic regression models. Knee complaints for ≥ 30 days during the last 12 months was defined as the most severe knee complaints and only these results are given in this paper.

The following covariates were included in the initial model: knee-straining activity explained by the exposure index, age, BMI, and knee-straining sports activities. The continuous variables were categorized according to age (<45, 45–60, and >60 years), BMI (<25, 25–27, and >27 kg/m²), and smoking (present versus never or previous smoker). The following sports activities were considered to be possibly knee-straining: badminton, basketball, parachuting, football, handball, ice hockey, rugby, skiing, tennis, volleyball, and weight lifting.

Results

Degree of knee-stressing work and self-reported knee complaints

The estimated percentage of time in knee-straining work positions was 56% for the floor layers and 26% for the carpenters.

The exposure index varied between the three trades. Floor layers had an average exposure index of 14.9 (range 1.1–27.2), carpenters had an average exposure index of 5.1 (range 0.1–14.2), and the compositors comprised the category of 0, as shown in table 3.

The odds ratios (OR) and 95% confidence intervals (95% CI) for knee complaints for ≥ 30 days during the past 12 months were OR 2.81 (95% CI 1.1–4.4), OR 3.95 (95% CI 2.2–7.3), OR 6.85 (95% CI 3.6–13.0) for low-to-moderate, high, and very high exposure, respectively, when compared with no exposure. The differences between the exposure groups were still present after

Table 3. Video-recorded knee-straining work activities by trade and exposure index.

Occupation	Video-recorded knee-straining work activities (%)	Knee exposure (index) ^a	
		Mean	Range
Floor layers			
Linoleum installation	55	14.9	1.1–27.2
Carpets installation	56	.	..
Vinyl installation	92	.	..
Other worktasks	62	.	..
Carpenters			
Roofs installation	30	5.1	0.1–14.2
Parquet flooring installation	41	.	..
Gypsum installation for ceilings	0	.	..
Plasterboard installation	8	.	..
Other worktasks	25	.	..
Compositors	0	.	0

^a The index was calculated as Σv_i (video-recorded knee strain in the worktask i) $\times t_i$ (self-reported time spent in the worktask) $\times Y$ (years in the trade).

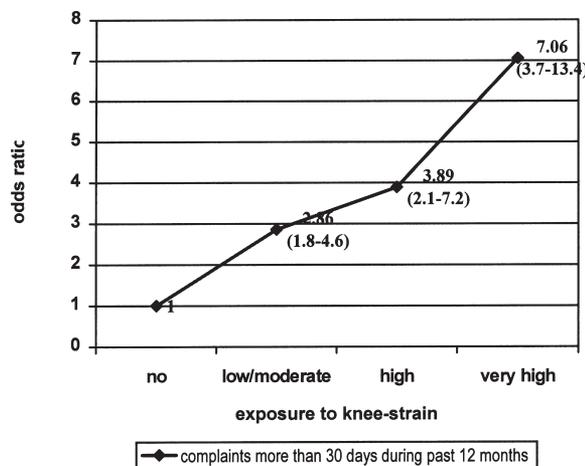


Figure 1. Dose–response relationship for kneeling and squatting work positions according to self-reported knee complaints for more than 30 days during the past 12 months—adjusted odds ratio (OR) and 95% confidence intervals (95% CI) (N=966). (exposure: “no”=0; low/moderate=1–8; high=9–14; very high ≥ 15).

adjustment for age, BMI, smoking habits, and knee-straining sports activities, as shown in figure 1.

A comparison of each of the four groups showed differences between each level of exposure with an odds ratio of >1 as calculated by the logistic regression adjusted for age, BMI, smoking habits, and knee-straining sports activities as follows: OR 1.47 (95% 0.9–2.4) for low-to-moderate versus high; OR 2.4 (95% 1.4–4.2) for low-to-moderate versus very high, and OR 2.1 (95% 0.99–4.4) for high versus very high. Only the comparison of low-to-moderate versus very high exposure showed significant differences.

The results for knee complaints during the previous 12 months and during the previous 7 days were similar

to those for complaints for >30 days during the last 12 months (results not shown).

Degree of knee-stressing work and radiographically diagnosed knee osteoarthritis

The results comparing radiographically diagnosed knee osteoarthritis grade 2–4 with the degree of kneeling work activities showed increased odds ratios in relation to the degree of kneeling work positions. In a comparison with no exposure, the odds ratios were OR 1.39 (95% 0.3–3.6) for low-to-moderate exposure, OR 3.07 (95% 0.6–16.8) for high exposure, and OR 4.47 (1.1–18.9) for very high exposure. The odds ratios after adjustment for age, BMI, smoking habits, and knee-straining sports activities are shown in figure 2. Only the comparison between the no-exposure group and the group with very high exposure showed significant differences.

The comparison of each of the four groups showed differences between each level of exposure with odds ratios of >1 (calculated by the logistic regression adjusted for age, BMI, smoking habits, and knee-straining sports activities) as follows: OR 1.33 (95% 0.2–8.4) for low-to-moderate versus high, OR 1.4 (95% 0.3–6.8) for low-to-moderate versus very high, and OR 1.3 (95% 0.2–7.2) for high versus very high. However, none of these values showed significant differences.

Discussion

The odds ratios increased with the degree of kneeling work positions. There were significant differences between the control group and all of the exposure groups

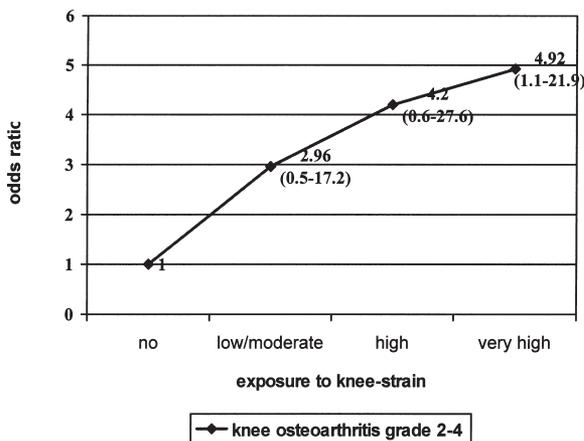


Figure 2. Dose–response relationship for kneeling and squatting work positions according to radiologically diagnosed knee osteoarthritis grade 2–4—adjusted odds ratio (OR) and 95% confidence intervals. (N=150). (exposure: “no”=0; low/moderate=1–8; high=9–14; very high ≥15).

and also between the different exposure groups. These results indicate a dose–response relationship for self-reported knee complaints. The odds ratio for the entire explaining variable was 3 for the low-to-moderate exposure group, 4 for the high exposure group, and 7 for the very high exposure group in the comparison with the controls without exposure to knee-straining work positions.

Only for workers with very high exposure were there significant differences in relation to knee osteoarthritis, but there was also a tendency towards a dose–response relationship for knee osteoarthritis, shown by the odds ratios of >1 when each of the exposure groups was compared with the control group. The small number of workers who were radiologically investigated (N=150) may play a role in the missing significance between the exposure groups.

In general, the floor layers had more knee-straining activities than the carpenters. The compositors had no knee-straining activities at all. The total exposure for knee-straining work varied between the trades, but it also varied greatly between workers within the same trade (range 1.1–27.2 for floor layers and 0.1–14.2 for carpenters). Instead of using trade as the covariate variable in the analyses, an exposure index was chosen, which, to a higher degree, could explain the individual knee-straining work demands.

In this study self-reported time in different worktasks was used for the final calculation of the knee-stressing work situations. Since self-reported data were used, there can be a risk of information bias in the study (eg, the carpenters or floor layers with knee complaints may have reported more knee-stressing worktasks than the workers without knee complaints). Through the use of self-reported time in different worktasks instead of the self-reported percentage of time in knee-stressing worktasks, an effort has been made to minimize the risk of this category of information bias.

Earlier studies have, in general, compared the complaints between trades, which may lead to misclassification and thereby to an underestimation of the risk (8, 10). The exposure has been studied from video-recordings of floor layers in comparison with painters (5), and for concrete-reinforcement workers in comparison with painters (11), but without any calculation of the knee-strain for the individual workers being made. Ekström et al (2) used trained work inspectors for ranking trades within the construction site. The range for knee-strain in the specific trade was estimated from 1 (highest exposure) to 19 (no exposure). Carpet and floor layers were ranked as “1” and carpenters as “6” in comparison with white-collar workers, who were ranked as “19”. Some studies have classified the trades with or without exposure to kneeling or squatting (12, 13) or in high and low exposure groups (14). It is assumed that,

with the use of an exposure index, as in this study, the risk for misclassification would be reduced.

In previous studies, floor layers were found to have more knee complaints than workers with less knee-stressing work activities (2, 5, 15). Carpenters have also been found to have more knee complaints than white-collar workers, but to have prevalences similar to those of other construction workers (16). Studies of other trades with knee-stressing work activities have also demonstrated an increased prevalence of knee complaints among pipe fitters, welders, plate makers, and shipbuilders (10, 17, 18). These studies did not make it possible to describe a dose-response correlation between the degree of exposure and the development of self-reported knee complaints.

Earlier studies support the results from this study that knee-stressing worktasks may be a risk factor for knee osteoarthritis (3, 5, 8, 12–14, 19). In previous studies it was not possible to describe a real dose-response correlation between the degree of exposure and the development of knee osteoarthritis. In the study by Enderlein & Kasch (3), there seemed, however, to be a higher frequency of knee osteoarthritis with a greater extent of kneeling work, judged by the number of persons with keratosis on the knees. Sandmark et al (14) calculated an odds ratio of 2.1 (95% CI 1.4–3.3) for knee osteoarthritis among workers with high exposure to kneeling work demands, compared with an odds ratio 1.4 for medium-exposed workers.

Workers with knee-straining worktasks often have heavy physical work, and *visa versa*. Some studies indicate that heavy physical work is a risk factor for knee osteoarthritis (20–22), but they do not separate the possible effects of heavy physical work from the effects of knee-straining work positions. The carpenters and floor layers who participated in this study had, in general, the same amount of heavy lifting (approximately 1–3 tonnes a day). It is, therefore, difficult to distinguish the effect of lifting from the effect of kneeling and squatting. An increased frequency of knee osteoarthritis was found among floor layers but not among carpenters (4), and the two trades are considered to be fairly similar with respect to physical load and lifting. The floor layers had more knee-straining work positions than carpenters. The most likely explanation, that there is a combined effect of kneeling and lifting but with the knee-straining work positions being the most important risk factor, is supported by a study by Sahlström & Montgomery (23).

Workers with substantial knee problems may leave trades with high physical demands on the knees in higher proportions than if the physical demands were low. In this study, workers who had left their trade during the previous 10 years were included to minimize the healthy-worker effect.

The radiographs in this study were made while the participants were lying down. When a comparison is made with radiographs made in a standing position, this approach may have led to an underestimation of the prevalence of knee osteoarthritis in this study. Underestimation may also have resulted from not having assessed patellofemoral osteoarthritis (24, 25).

Severe acute knee trauma has been reported as a contributory factor to the development of knee osteoarthritis. Workers with earlier severe acute knee traumas were therefore excluded from this study.

It has been shown in several studies that the risk for developing knee osteoarthritis increases with age (1, 26, 27) and BMI (12, 28, 29). In some studies, sports participation has been reported to be a contributory factor to the development of knee osteoarthritis, especially if they have induced major joint lesions. It has also been connected with elite sports activities such as in football, handball, and running (30–32). In earlier studies, smoking has been found to be negatively associated with knee osteoarthritis (5, 29, 33). In this study, the logistic regression analyses were therefore adjusted for age, BMI, sports activities, and smoking.

In conclusion, the results of this study suggest that, for trades that include knee-stressing work activities such as kneeling and squatting, there is a positive dose-response relationship between exposure to knee-stressing work activities and the number of workers who have self-reported knee complaints. Already at low-to-moderate exposure, there is a two-to-threelfold risk of developing more severe knee complaints (>30 days during the previous 12 months).

Furthermore, there seems to be a positive dose-response relationship between exposure to knee-stressing work activities and the development of knee osteoarthritis. Knee osteoarthritis is found mainly among workers with a considerable amount of time spent in knee-stressing work positions.

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