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Occupation as a risk factor for knee disorders
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Occupation as a risk factor for knee disorders

by Lilli Kirkeskov Jensen, MD,1 Winnie Eenberg2

The objective of the present study was to review the literature on the risk of knee disorders in connection with kneeling or squatting work and heavy physical work. A systematic review of the literature revealed 19 controlled studies on this correlation: 16 on osteoarthrosis, 5 on bursitis, 3 on meniscal lesions, and 0 on chondromalacia. All the studies demonstrated a significantly increased prevalence of knee osteoarthrosis (all degrees) for subjects with kneeling or squatting work. The prevalence ratio in most of these studies was between 1.4 and 4. Four of eight studies demonstrated a significantly increased prevalence of knee osteoarthrosis in subjects with heavy physical work. The prevalence ratio in most of these studies was between 1.4 and 4.1. All the studies on bursitis showed an increased prevalence of bursitis in subjects with kneeling work. Occupational exposure could not be sufficiently documented as the cause of meniscal lesions and chondromalacia.

Key terms: bursitis, chondromalacia, epidemiology, heavy physical work, knee osteoarthrosis, kneeling and squatting work, meniscal lesions, review.

Thus far investigations of the correlation between occupational risk factors and the development of diseases and trouble in the musculoskeletal system have mainly been limited to the lower back, neck, shoulders, and arms (1, 2).

Many occupations involve exposure of the knee joints during work, but health problems arising from such work loads have not received much attention. On the average, 19% of a population of Danish employees complained of knee trouble within the preceding 12 months. The frequency varied highly between occupational groups and was especially high, 32%, for workers in the building trade (3). Osteoarthrosis of the knee has been radiologically demonstrated in 6% of an adult population aged between 35 and 74 years (4). The risk of developing knee osteoarthrosis depends on age, gender, weight, and sports activities together with exposure at work. The prevalence increases with age, from being negligible in subjects aged 25—34 years to 20—40% in subjects aged 75 years or more (4—8). The prevalence is higher for men than for women until the age of 45 years, whereafter it is higher for women (4).

Several investigations have shown a correlation between overweight and knee osteoarthrosis (4, 8—10). Sports may be a risk factor for the development of joint lesions, which are a well-known cause of osteoarthrosis (8, 11, 12). No certain correlation has been demonstrated between the various types of sport (eg, running, weight-lifting and football) and the development of osteoarthrosis in subjects without previous major joint lesions (8).

The objective of this investigation was to review the literature on knee disorders and kneeling, squatting, and heavy physical work. The review concerns osteoarthrosis of the knee, bursitis, meniscal lesions, and chondromalacia.

Materials and methods

The relevant studies were identified in a search of computer-based data bases: MEDLINE, NIOSHTIC (a data base from the National Institute for Occupational Safety and Health), CISdoc, Embase and HSEline (the International Labour Organisation Occupational Health data bases). The key terms used were knee, meniscus, osteoarthrosis, osteoarthritis, bursitis, chondromalacia, work, and occupation.

In addition, literature on work and knee disorders was provided via a data base at the library of the Factory Inspectorate (Direztoratet for Arbejdssilsynet) in Denmark.

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The material was evaluated on the basis of title and the reading of the abstracts. Studies were selected for a more-detailed review if they had a controlled design and they were carried out for one or several occupational groups; if they dealt with disorders of the knee (knee osteoarthrosis, bursitis, meniscal lesions or chondromalacia); if the study group had been exposed to kneeling, squatting, or heavy physical work (if the exposure was unclear from the title or the abstract, the works were procured and read); and if the works were published in English, German, or one of the Scandinavian languages. The references in the works procured were reviewed and selected with the same criteria.

The investigations were divided by the diagnoses as knee osteoarthrosis, bursitis, and meniscal lesion studies. We failed to find any relevant study on chondromalacia and occupation. Work involving a load on the knee was defined as kneeling or squatting work or heavy physical work. Studies in which the load was not detailed were classified according to experience, within occupational medicine, of whether the occupation was characterized by kneeling or squatting work or by heavy physical work. For some studies in which it was not stated, the prevalence ratio was calculated if the data were sufficient. For some studies we also calculated the P-value for the difference between the prevalences stated by using the Fisher exact test or the χ²-test.

With the key terms employed we obtained 585 references in NIOSHTIC, CISDoc, HSEline, EMbase and the data base of the Factory Inspectorate, and 314 references in MEDLINE. Among them 42 studies fulfilled our criteria for a review. The studies referred to another 10 not revealed by the search. Exclusion was made of 15 studies dealing exclusively with self-reported knee trouble (3, 13-26), four studies without a reference group (27-30), seven studies in which the design was not epidemiologic (8, 31-36), and one study dealing with an occupational group not exposed to knee load (37). Thus there remained 19 controlled studies with 25 references (4, 6, 9, 38-59). Several of the studies dealt with different types of knee disorders.

The methodological quality of each of the studies was systematically evaluated by methods adapted from Kristensen (60), Koes et al (61) and Sacks et al (62) and adjusted for the present review. The following five aspects of quality were evaluated for each study: (i) design and material (description of inclusion and exclusion criteria, size of the study group, description of participation rates, comparability of the study groups with respect to age, gender, height and weight, and healthy worker effect); (ii) potential confounding (age, gender, weight or body mass index, sport, traumas); (iii) measurement of outcome (clinical and paraclinical examination methods, blinded assessment); (iv) measurement of exposure (qualitative description, quantitative ergonomic observations); and (v) data presentation and statistical analysis. Each item was scored and the quality of the study was assessed by the sum of the scores, the maximum being 15 points, and subdivided into “poor” studies (1—5 points), “medium” quality studies (6—10 points), and “good” studies (11—15 points). Each study was evaluated independently by the authors. In case of disagreement on the final classification, a joint evaluation decided the classification.

**Table 1.** Methodological quality and results of the epidemiologic studies dealing with knee osteoarthrosis (all degrees), bursitis, and meniscal lesions. (Reference numbers in parentheses)

| Criteria | Poor (N) | Medium (N) | Good (N) |
|----------|----------|------------|----------|
| Knee osteoarthrosis | 1 (41) | 5 (39, 40, 42—44) | 3 (38, 45, 46) |
| Kneeling and squatting | — | 1 (47) | — |
| Heavy physical work | — | 2 (60—62) | 1 (53) |
| Bursitis | 1 (49) | — | 2 (47, 48) |
| Meniscal lesions | — | 2 (42, 54, 55) | 2 (38, 56, 57) |
| Positive | 1 (41) | 1 (58, 59) | — |
| Negative | — | 1 (38) | — |

* Positive = significant positive association between work and outcome; negative = no significant positive association between work and outcome.

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**Results**

Table 1 presents the evaluation of the studies. The main shortcomings were no description of participation rates, small sample sizes, uncontrolled potential confounding, outcome assessments not blinded, and poor exposure description.

**Osteoarthrosis of the knee**

Altogether we found 16 studies on a correlation between knee osteoarthrosis and occupation. Among them, 13 were cross-sectional, two were case-referent in nature, and one was a historical follow-up study. Nine concerned occupations with predominantly kneeling or squatting work, and seven concerned occupations with heavy physical work. One study dealt with both kneeling and heavy physical work.
Kneeling or squatting work

Eight studies demonstrated an increased prevalence of knee osteoarthrosis (all degrees), and one study showed an increased prevalence of radiologically determined knee osteoarthrosis among miners as compared with various reference groups without kneeling or squatting work.

Von Nauwald (41) compared 101 pipe fitters between 35 and 65 years of age and employed in the shipbuilding industry with a reference group of 74 subjects whose occupations did not involve kneeling. The participants were interviewed and physical and radiological examinations were performed. Knee osteoarthrosis was divided into three degrees of severity (grade 1—3) using unspecified criteria. Mild to severe knee osteoarthrosis (grade 1—3) was found in 78% of the pipe fitters and in 55% of the referents, and moderate to severe knee osteoarthrosis (grade 2—3) was determined for 32% of the pipe fitters and 8% of the referents.

Thun et al (42) carried out a questionnaire study on 112 floor and carpet layers, 42 terrazzo setters, and 243 millwrights and bricklayers. The groups were divided by three degrees of knee load, grade 1 being kneeling work with use of a “knee kicker,” a tool used to stretch the carpet for wall-to-wall installation (floor and carpet layers), grade 2 being kneeling work without using a knee kicker (terrazzo setters), and grade 3 being no kneeling work (millwright and bricklayers). One of the questions was “Have you ever had arthritis of the knee?” The prevalences were 14.3% for the floor and carpet layers, 25.7% for the terrazzo setters, and 12.9% for the millwrights and bricklayers.

Greinemann (43, 44) examined 500 miners 50 years of age who had been working for at least 25 years and 500 referents 50 years of age who had not been exposed to knee load either at work or in their leisure-time activities. Knee osteoarthrosis was radiologically determined for 13% of the miners and 1% of the referents.

Anderson & Felson (4) employed data from HANES I, an American population survey of 5193 subjects from 1971 to 1975. Subjects 35 to 64 years of age, totaling 4011 (of whom 1853 were men) were divided by occupation and classified according to occupation involving kneeling, squatting or crawling postures. The data on

Table 2. Osteoarthrosis of the knee (%) and occupations with kneeling and squatting work among men.*

| Author                  | Outcome | Participants (N) | Age (years) | Type of work | Exposure | Knee osteoarthrosis | Prevalence ratio | Significant (P < 0.05) |
|-------------------------|---------|------------------|-------------|--------------|----------|---------------------|------------------|---------------------|
| Kivimaki et al (38)     | X-ray   | 168              | 25—49       | Floor and carpet laying | Kneeling; carpet and floor layers | 58% | 2 | 1.4 | 1.0 | Yes | No |
| Enderlein & Kasch (45, 46) | X-ray and clinical | 173          | 18—65       | Painting     | 42% and painters 3% | 41 | 2 | 1.0 | 1.0 | No | No |
| Anderson & Felson (4)   | X-ray   | 1853             | 35—64       | Knee-bending work | Categories of occupations associated to no need for kneeling and kneeling needed | 3 (all) | 0.9 (35—44) | No | No | 0.8 (45—64) | No |
| Greinemann (43, 44)     | X-ray   | 500 in 50s       |             | Mining       | At least 25 years under ground compared with men without knee-bending work | 16 | 1 | 1.0 | 1.0 | Yes | Yes |
| Thun et al (42)         | Self-reported | 113          | 19—87       | Carpet and floor laying | Kneeling with use of knee kicker, kneeling and sedentary kneeling (employed 1—60 years) | 14 | 1 | 1.1 | No | Yes | 2.0 | Yes |
| Von Nauwald (41)        | X-ray   | 75 (35—63)       |             | Pipe fitting  | Kneeling with squatting, on the average 25 years | 76 | 32 | 1.4 | 4.0 | Yes | Yes |
| Kelgren & Lawrence (9)  | X-ray   | 75 (55—64)       |             | Mining       | Persons associated with the predominant occupation | 42 | 2 | 2.1 | Yes | Yes | 1.0 |
|                        | Sedentary work | 18          |             |             |                      | 20 | 1 | 1.0 |
|                        | Docking | 45              |             |             |                      | 24 | 4 | 1.4 |
|                        | Light manual work | 45         |             |             |                      | 17 | 1 | 1.0 |
|                        | Slightly work | 45          |             |             |                      | 17 | 1 | 1.0 |
| Kelgren & Lawrence (30) | X-ray   | 42 (40—50)       |             | Mining       | By occupation | 46 | 6 | 1.9 |
|                        | Office work | 45          |             |             |                      | 22 | 2 | 0.9 |
|                        | Office work | 45          |             |             |                      | 24 | 1 | 1.0 |

* In all the studies the design was cross-sectional.
† Severe knee osteoarthrosis grade 3—4 or grade 3.
‡ Knee osteoarthrosis, not knee osteoarthrosis grade 1—4.
§ Odds ratio used in the study (y = years).
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exposure were based on 400 occupational codes, of which 308 were represented in the study. The data correlated with X-ray findings in the knees evaluated according to the criteria of Kellgren & Lawrence (63). There was a significantly increased prevalence of knee osteoarthrosis for the men [odds ratio (OR) 2.45] and the women (OR 3.49) aged 55–64 years who used kneeling, squatting, and crawling work postures. For the age groups under 55 years there were no certain differences.

In a cross-sectional study of shipyard workers, Enderlein & Kasch (45, 46) examined 283 welders, 171 shipbuilders (stell millwrights), and 113 pipe fitters and a reference group of 168 persons aged 18 to 65 years. The material was grouped into subjects with and without previous knee trauma. Keratosis on the front of their knees was used as a measure of the degree of kneeling work. Among the pipe fitters, 10% had keratosis on the knees, as did 30% of the shipbuilders and 75% of the welders. No keratosis was found in the reference group. On the basis of the aggregated results from a physical and radiological examination, the degree of osteoarthritis was classified on a scale from 0 (no knee osteoarthrosis) to 3 (severe knee osteoarthrosis).

There was an increased prevalence of knee osteoarthrosis, grade 1–3, for the welders compared with the other groups. The prevalence of knee osteoarthritis increased with increasing intensity and duration of exposure. Subjects with previous knee disorders had a higher prevalence, and knee osteoarthritis occurred at an earlier age. The prevalences in Table 2 are given for the group without previous knee disorders only.

In a cross-sectional study, Kivimäki et al (38) examined 168 carpet and floor layers and 146 painters (reference group) aged 25–49 years using questionnaires and a physical and radiological examination. Work practices were studied using video recordings of both occupational groups. The carpet and floor layers worked in a kneeling posture with one or both knees on the floor for 42% of the time. The painters used kneeling or squatting postures for less than 5% of the observed work hours. There were no differences between the groups as to severe knee osteoarthritis according to the criteria of Kellgren & Lawrence (63), but there was a significantly increased prevalence of knee osteophytes among the carpet and floor layers as compared with the painters.

Heave physical work

Eight studies dealt with heavy physical work and knee osteoarthritis (Table 3). Four of these studies demonstrated an increased prevalence of knee osteoarthritis in subjects with heavy physical work.

Lawrence et al (47) examined 294 foundry workers active as such for at least 10 years and aged 35–74 years, and 287 age-matched referents from the general population. They found a prevalence of knee osteoarthrosis, grade 1–4, of 26% for the foundry workers and of 39% for the general population, the difference being significant.

Partridge & Duthie (48) interviewed 206 dockers with heavy physical work and 138 referents. A clinical examination was made of all the subjects, and it revealed knee osteoarthritis in 3.4% of the dockers and 2.2% of the referents.

The cross-sectional study by Wickström et al (6) comprised 252 active concrete reinforcement workers and 231 painters (reference group) aged 24–64 years. The participants were interviewed and underwent a physical and radiological examination. For the evaluation of the radiological findings, the material was divided into no, mild, moderate, and severe osteoarthritis on the basis of consensus between two radiologists. In Wickström et al’s study (6) the work practices of both groups were video-taped, and the results showed that the concrete reinforcement workers had more heavy lifts than the painters. The former group lifted loads weighing over 20 kg six times an hour, whereas the latter seldom lifted such loads. The painters worked in a squatting posture for 9% of the observed worktime and in a kneeling posture for 3% of the time, whereas the respective figures for the concrete reinforcement workers were 2% and 4%.

X-rays revealed osteophytes corresponding to the tibiofemoral joint in 18% of the concrete reinforcement workers and in 15% of the painters. Narrowing of the joint space was seen in 2% of both groups, and subchondral sclerosis was found in 2% of the concrete reinforcement workers and 1% of the painters. The prevalence of degenerative changes was 22% for the concrete reinforcement workers and 20% for the painters.

Lindberg & Montgomery (49) examined the prevalence of knee osteoarthritis in 332 men, mean age 66 years, with heavy physical work at a shipyard for more than 30 years. The “internal” reference group consisted of 179 office workers from the shipyard and 173 male teachers, the “external” reference group of 438 age-matched subjects from the general population. A knee X-ray was performed for the subjects in the study group and evaluated with regard to knee osteoarthritis using the criteria of Ahlbäck (64). Knee osteoarthritis was found in 3.9% of the shipyard workers, 1.4% of the “internal” reference group, and 1.6% of the “external” reference group. The difference was significant.

In the previously mentioned HANES I study by Anderson & Felson (4) the material was divided into subjects with and without heavy physical work. Among 4011 subjects between 35 and 64 years of age they found a significantly increased prevalence of knee osteoarthritis among women with heavy physical work in the age group 55–64 years (OR 3.1). The prevalence was likewise increased for the men with heavy physical work in
investigated 1307 men from the Stockholm area who were born between 1915 and 1934 or who were assigned an early retirement pension in 1979, 1980, 1981, and 1984 because of low-back trouble, shoulder and neck trouble, or hip or knee osteoarthrosis. It was not stated how the diagnoses were made. A comparison as to occupation and exposure was made between the 181 patients with knee osteoarthrosis and 298 men from the general population. On the basis of occupational codes four experts classified the degree of static and dynamic impact loads on the knees within the individual occupations and the material was divided into occupational groups with low, moderate, and high exposure.

In Vingård et al.'s studies (51, 52) a comparison of subjects with high and low exposure showed a relative risk of 14.3 for early retirement pension owing to knee osteoarthrosis. In the group consisting of painters and floor layers, a combination that was not justified in the study, the relative risk of being assigned an early retirement pension owing to knee osteoarthrosis was 23.1.

Vingård et al (53) also performed a register-based cohort study (historical follow-up study). The study population consisted of subjects from 13 of 24 counties in Sweden and was drawn from a nationwide register of hospitalized subjects. Among the criteria were that the subjects be born between 1905 and 1945, that they re-

### Table 3. Osteoarthrosis of the knee (%) and occupations with heavy physical work. All studies not deemed otherwise were cross-sectional.

| Author | Outcome | Participants (N) | Age (years) | Type of work | Exposure | Knee osteoarthrosis | Prevalence ratio |
|--------|---------|------------------|-------------|--------------|----------|-------------------|----------------|
| Vingård et al (53) | Knee diagnosis | 521 knee osteoarthrosis | 36-78 | High exposure work | High or low exposure to | 0.9 | 1.2 (1905-24) No |
| Vingård et al (51, 52) | Knee diagnosis | 181 knee osteoarthrosis | 45-60 | High exposure work | Low exposure work (blue-collar workers) | 2.2 | 1.4 (1905-45) Yes |
| Kohatsu & Schurman (50) | Knee grade 3-4 | 46 severe knee osteoarthrosis | 71 (mean) | Moderate to heavy work | Low exposure work | 2.3 | 14.3 Yes |
| Anderson & Felson (4) | Knee grade 2-4 | 1853 | 35-64 | Age-matched community referents | Self-reported light, moderate, heavy or very heavy work | 2.3-3.4 Yes |
| Lindberg & Montgomery (49) | X-ray severe | 352 | 66 (mean) | Shipyard work | Heavy work in a shipyard for more than 30 years | 2.9 | Yes |
| Wickström et al (6) | X-ray, all degrees | 252 | 20-64 | Reinforcement work | Lifting loads over 20 kg; six times an hour for reinforcement workers and seldom for painters; work experience 15 years (mean) | 2.2 | No |
| Partridge & Duffle (45) | Clinical | 206 | 25-64 | Docking | High physical effort; no physical effort | 3.4 | No |
| Lawrence et al (47) | X-ray grade 1-4 | 254 | 45-74 | Foundry work | Heavy work under hot conditions | 2.2 | 1.4 0.7 1.0 No |

### Notes
1. Osteoarthrosis of the knee grade 3-4 or grade 3
2. Design not cross-sectional.
3. Odds ratio or relative risk used in the study.
4. Reference group in the study.
5. Case-referent study.

The questionnaire study by Kohatsu & Schurman (50) comprised 138 patients who had undergone total knee arthroplasty owing to osteoarthrosis during the period 1977–1988. Among those who answered the questionnaire, a selection was made of patients over 55 years and 46 referents. The questions concerning work load and exposure was reported two to three times more often by the patients than by the referents.

Using a case-referent design, Vingård et al (51, 52) investigated 1307 men from the Stockholm area who were born between 1915 and 1934 or who were assigned an early retirement pension in 1979, 1980, 1981, and the age group 55—64 years (OR 1.88), but the difference was not significant. No correlation was found in the younger age groups.
mained in the same occupation through the period 1960 to 1970, and that they had been hospitalized for knee osteoarthrosis in the period 1981 to 1983. Exposure to dynamic and static impact loads on the knees were assessed for the individual occupations using the same methods as described for the author’s studies (51, 52). The material was divided into subjects with high, moderate, and low exposure. The groups with high and low exposure were compared, whereas that with moderate exposure was excluded from the analyses.

As compared with the low-exposure group, men in the high exposure group of Vingård et al’s study (53) had a risk ratio (RR) of 1.2 (men born between 1905 and 1924) and 1.4 (men born between 1925 and 1945) for knee osteoarthrosis. The difference was significant for the younger birth cohort. Male farmers, construction workers, and fire fighters had increased risks of hospital treatment due to osteoarthrosis of the knee (RR 2.5 — 3.8).

Bursitis

We found five controlled studies on a correlation between occupation and bursitis (table 4). Von Nauwald (41) performed a physical examination of 101 pipe fitters and 74 referents. Among the pipe fitters, bursitis was present in the right knee of 44% and in the left knee 36%. Bursitis was not found in any of the referents.

Partridge et al (54) interviewed 858 workers at six foundries and found 14 cases of prepatellar bursitis among 169 floor molders (8.3%), whose work involved kneeling, against five cases (0.7%) among the remaining foundry workers without kneeling postures.

In the studies by Thun et al (42) and Tanaka et al (55), comprising 112 carpet and floor layers, 42 terrazzo setters, and 243 millwrights and bricklayers (reference group), previous bursitis was reported by 20% of the millwrights and bricklayers involved neither kneeling nor the use of knee kickers.

In the questionnaire study by Kivimäki et al (38), of 168 floor and carpet layers and 146 painters, 19% of the floor and carpet layers reported that they had previously had prepatellar bursitis diagnosed by a physician, against 2% of the painters (reference group).

An ultrasonographic examination of a sample of the floor and carpet layers and of the painters in Kivimäki et al’s study (56, 57) revealed changes in the prepatellar, the superficial, and the infrapatellar bursa in 49% of the floor and carpet layers and in 7% of the painters (56, 57). Fluid accumulation was present in the prepatellar or the superficial bursa in 5.8% of the floor and carpet layers and in none of the painters. Only the 5.8% of the floor and carpet layers with signs of acute bursitis (verified by fluid accumulation) reported knee pain. Ultrasonographically demonstrated changes in the bursa did not correlate with previously reported bursitis.

Meniscal lesions

Our search for relevant literature revealed nine references on meniscal lesions and occupation (27, 30, 36, 38, 41, 43, 44, 58, 59). Only three studies, four references (38, 41, 58, 59) fulfilled our criteria of inclusion.

Sharrard & Liddell (58) and Sharrard (59) analyzed all meniscectomies performed on subjects aged 15 to 64 years at five hospitals around Sheffield in the United Kingdom during the period 1958 to 1960. The total number was 957, of which 605 (63%) had been performed on miners and 352 (37%) on workers other than miners. By way of comparison all the appendectomies performed during the same period were analyzed. The total number was 365 (34%) for the miners and 710 (66%) for the nonminers. Among the 605 miners who had undergone meniscectomy, 150 were interviewed to

Table 4. Bursitis of the knees (%) and occupation.

| Author           | Outcome       | Participants (N) | Age (years) | Type of work                     | Exposure                                                                 | Bursitis | Prevalence ratio | Significant (P < 0.05) |
|------------------|---------------|------------------|-------------|----------------------------------|--------------------------------------------------------------------------|----------|------------------|------------------------|
| Kivimäki et al   | Self-reported | 168              | 25—49       | Floor and carpet laying          | Kneeling: carpet and floorlayers                                         | 19.0     | 9.5              | Yes                    |
| (38)             |               |                  |             |                                  | Kneeling and squatting, no knee-bending work (employed in average 25 years) | 43.7 (I) | 35.6 (I)        | Yes                    |
| Kivimäki et al   | Self-reported | 146              |             | Painting                        | Kneeling: carpet and floorlayers                                          | 20.0     | 3.2              | Yes                    |
| (56)             |               |                  |             |                                  | Kneeling with use of knee kickers                                       | 11.2     | 1.8              | Yes                    |
| Mäikymäki et al  | Self-reported | 72               | 25—49       | Floor and carpet laying          | Kneeling: carpet and floorlayers                                          | 5.8      | —                | Yes                    |
| (57)             |               |                  |             |                                  | Kneeling, kneeling and seldom                                             | 6.2      | —                | Yes                    |
| Thun et al (42)  | Self-reported | 112              | 19—67       | Terrazzo setting                 | Kneeling: carpet and floorlayers                                          | 0        | —                | Yes                    |
| Tanaka et al (55)| Self-reported | 42               |             | Millwrighting and bricklaying    | Kneeling: carpet and floorlayers                                          | 0        | —                | Yes                    |
| Von Nauwald (41) | Self-reported | 101              | 35—63       | Pipe fitting                     | Kneeling: carpet and floorlayers                                          | 0.7      | 0.7              | Yes                    |
| Partridge et al  | Self-reported | 169              | 25—64       | Floor molding                    | Kneeling: carpet and floorlayers                                          | 8.3      | 11.9             | Yes                    |
| (54)             |               |                  |             | Other foundry working            | Kneeling: carpet and floorlayers                                          | —        | —                | Yes                    |
|                  |               |                  |             |                                  | Heavy lifting under hot temperature                                       | 0.7      | 0.7              | Yes                    |

* Reference group in the study.
obtain a description of their normal work posture. For 62% the daily work was predominantly done kneeling or crawling, 34% walked or stood, and 4% squatted. Among the subjects who normally worked in a kneeling, squatting or crawling position, 76% had gotten their meniscal lesion in this position. The symptoms generally occurred when the worker had to jump up from his knees and turn to one side, for instance, in order to avoid being hit by something falling from the ceiling. Among the subjects whose daily work was done in a walking or standing position, 92% had gotten their meniscal lesion in this position. The meniscal lesion had occurred in the squatting position in 9% of the 150 miners.

In his physical examination of 101 pipe fitters and 74 referents, Von Nauwald (41) found signs of right and left meniscal lesion in 11.8% and 6.9% of the pipe fitters, respectively. None of the referents showed any signs of meniscal lesion.

In their study on 168 carpet and floor layers and 146 painters, Kivimäki et al (38) found that 10% of the carpet and floor layers and 5% of the painters had had a meniscal lesion diagnosed by a physician. The difference was not statistically significant. In both groups 6% stated having undergone knee surgery.

Discussion

Methodological quality of the studies

Potentially relevant studies were searched for in international computer data bases, in the data base of the library of the Danish Factory Inspectorate, and from references in the literature procured for purposes of the present review. Computer-based searches alone yield less than two-thirds of the relevant studies identified from other studies (62). We reviewed several potentially relevant studies identified from sources other than the computer-based searches. In the final selection of studies, however, only four references had not been identified in these searches (44, 48, 51, 52).

Only studies published in English, German, or one of the Scandinavian languages were considered for inclusion. This limitation may have excluded some relevant studies. In the computer-based searches, however, very few references in other languages emerged.

It is generally accepted that negative studies are less likely to be published than positive ones. This publication bias, in our opinion, is more likely when a study is not well designed. Actually, all of the studies considered as being of “poor” quality in the present review reported positive associations. We assume that most well-designed hypothesis testing studies are published even if negative. If so, such studies should not only be considered as the more important owing to their superi-
Occupation as a risk factor for knee disorders

Three studies (6, 43—46) used the authors’ own classification with a description of the criteria. Vingård et al (51—53) employed the diagnosis at hospitalization or application for early retirement pension in the studies. The criteria of a diagnosis of knee osteoarthrosis were not reported, but it must be presumed that they included a radiological examination of the knees. In the study by Thun et al (42) the diagnosis was based on answers to a questionnaire.

The difference between the classification criteria possibly explains some of the large differences between the prevalences reported in the studies. Thus radiological knee osteoarthrosis (all degrees) was present in 20% of the painters aged 24—64 years (mean age 42 years) in the study by Wickström et al (6) whereas 41% of painters aged 25—49 years (mean age 39 years) had knee osteophytes in that by Kivimäki et al (38). A correlation between type of work and development of knee osteoarthrosis (all degrees) was demonstrated in all the studies and severe knee osteoarthrosis in three of six studies on kneeling and squatting work. A correlation was found in four of the eight studies on heavy physical work. Knee osteoarthrosis occurred predominantly after many years of exposure (more than 10 years) and in the age group >45—50 years.

The prevalence ratios for the development of radiological knee osteoarthrosis (all degrees) in occupations with kneeling or squatting work were between 1.4 and 4.1. As to heavy physical work, the prevalence ratio was between 1.4 and 3.4 in three studies; in one it was 14.3; and in four there was no significant correlation (prevalence ratio = 1.9, 1.6, 1.1, and 0.7).

The risk of knee osteoarthrosis increases with age from being negligible at the age of 25 years to between 20% and 40% at about 75 years of age (4, 8). In studies on knee osteoarthrosis, therefore, it is essential that the study population include subjects above 45—50 years of age. In the study by Kivimäki et al (38) the study group was relatively young, 25—49 years, and this low age may explain that the authors failed to demonstrate any correlation between severe knee osteoarthrosis and knee load.

The studies were divided into kneeling or squatting work and heavy physical work. The classification was made on the basis of an evaluation of the exposure reported in the studies and on the basis of our own evaluation of the occupation in question. In several of the occupations the exposure was mixed. Thus the work of floor layers involves heavy lifting and that of shipbuilders has varying degrees of kneeling and squatting work together with heavy lifts, depending on the occupational group (38, 45, 46).

Most of the studies gave a simplified description of the exposure (eg, by using occupational codes as a measure). Only two studies (6, 38) employed video recording of the work practices in the study and reference groups. In a case-referent study (50) the exposure was based on the individual subject’s assessment of the physical load. This procedure may give rise to information bias leading to overestimation of the risk.

The studies did not render it possible to describe a real dose-response correlation between the degree of exposure and the development of knee osteoarthrosis. In the study by Enderlein & Kasch (45, 46), there seemed, however, to be a higher frequency of knee osteoarthrosis, the greater the extent of kneeling work when judged from the number of subjects with keratosis on the knees. Some of the studies (6, 38) comprised only subjects who were active at the time of study. In all probability this design factor involves a selection bias with underestimated risk of knee osteoarthrosis in occupations exposing the knees.

Taking into consideration possible sources of error, a joint evaluation of the reviewed studies that were controlled affords reasonable grounds for the assertion that occupational exposure of the knee in the form of kneeling and squatting work or heavy physical work is a risk factor for developing knee osteoarthrosis.

It is obvious that occupational load on the knees can be compared with loads from sports activities. Many types of sport (eg, football, running, and jumping) can induce acute joint lesions, among them, lesions of the meniscus and the ligaments. Major joint lesions in connection with sports are a well documented cause of knee osteoarthrosis (8). On the other hand, it must be considered unclarified whether sports activities that expose the knees induce an increased risk of knee osteoarthrosis if there has been no previous acute major knee lesion. Many studies of this problem have been uncontrolled, with a short follow-up time or with a high proportion of subjects under 50 years of age. [See the review by Felson (8).]

In occupations exposing the knees there may also be an increased risk of acute knee lesions in connection with jumping from one level to another or walking on uneven ground. Only one study (45, 46) controlled for acute knee lesions. This study confirmed that previous acute knee trauma was a risk factor for knee osteoarthrosis, but it also showed an increased prevalence of knee osteoarthrosis among subjects with work involving knee load but without previous acute major knee trauma.

The pathogenesis of knee osteoarthrosis in relation to work loads on the knees has not been clarified. One hypothesis is that knee osteoarthrosis is caused by a reduction of the blood flow through the bone owing to increased intraarticular pressure (65). In the standing position, the weight on either knee corresponds to 40% of body weight. Biomechanical calculations have shown that the pressure on the knee joint is increased to two to four times the body weight during normal walking and to
six times during stair climbing (66–68). We have not been able to trace studies illustrating the intraarticular pressure during exposure to the knees in the form of kneeling and squatting work or heavy physical work. During kneeling approximately 70% of the body weight rests on a few cubic centimeters of the tibia and the patella (17). Obviously increased intraarticular pressure must be involved. Pressure will also be increased during heavy physical work.

Another hypothesis is that subchondral microfractures may induce osteoarthrosis (69). Such microfractures are considered to occur when physical load exceeds a critical level, the size of which is not known. Trained sportsmen have greater muscular strength and will generally limber up before starting real activity. This habit may result in sportsmen being less exposed to microfractures at a certain load as compared with the less trained worker who does not make any preparation before starting work. A possible difference in the risk of knee osteoarthrosis for sportsmen and workers with a comparable load on the knees may thus be explained by differences in physical condition and limber-up before the exposure. When workers and sportsmen are compared with regard to the risk of knee osteoarthrosis in relation to exposure, it should, however, be borne in mind that the exposures to the knees are so qualitatively different that there is probably no point in speaking about a directly comparable exposure.

Future investigations of the relation between occupational exposure and knee osteoarthrosis should especially focus on more precise measures of exposure. Since the period of latency for the development of knee osteoarthrosis is long, it is essential that the study group predominantly consists of subjects over 50 years of age, just as it is important to include subjects who have stopped work exposing the knees.

In addition, the pathogenesis of osteoarthrosis induced by work exposing the knees should be investigated.

**Bursitis**

The following bursae are located on the anterior part of the knee: (i) the prepatellar bursa, which is subcutaneous and located in front of the distal part of the patella, (ii) the subcutaneous infrapatellar bursa, located in front of the patellar ligament distal to the patella, and (iii) the deep infrapatellar bursa, located just behind the patellar ligament. Aseptic bursitis may develop in all three bursae. Bursitis has been described for workers with kneeling work and is often called "housemaid’s knee" or "carpet layer’s knee" (70).

All five studies revealed a higher prevalence of bursitis in occupational groups with kneeling work relative to groups without such work. An increased prevalence of bursitis was found for floor and carpet layers by three studies, in pipe fitters and terrazzo setters in one, and in floor molders in another.

One of the studies on carpet and floor layers employed video recording of the work practices, which showed that the workers were kneeling about 40% of the time (38). The proportion of kneeling work was not determined for any other occupational group.

The prevalence ratio for bursitis was between 3.2 and 9.5 for carpet and floor layers and between 1.8 and 11.9 for the other occupational groups with kneeling work. Thus a correlation between kneeling work and the development of pre- or infrapatellar bursitis is well documented.

Bursitis is presumably caused by an irritation of the bursa owing to direct pressure on it in the kneeling position. If knee protectors are used, the pressure will be distributed over a greater area of the knee (17). The direct load on the bursae will thereby be reduced with a consequently reduced risk of developing bursitis. Bursitis is a less serious disorder as compared with knee osteoarthrosis, and it will therefore be a less likely reason for leaving one’s trade to find other work.

**Meniscal lesions**

Meniscal lesions may limit flexion and extension of the knee joint and the knee may lock. The lesions are generally induced by forced rotation while the knee is semi-flexed or flexed (71). The lesions are very often a result of acute trauma (eg, during skiing). Lesions occur far more often in the medial than in the lateral meniscus, except in football players, for whom the two types occur equally often (71). Meniscal lesions have been reported to occur as a result of both acute trauma and kneeling or squatting work. In Germany, meniscal lesions in miners have been recognized as being work-related for more than 40 years (34, 43). In Denmark, meniscal lesions occurred during work in the squatting position in confined work spaces are recognized as an occupational disease (72).

Our search for literature revealed very few controlled studies that suggested a correlation between occupation and meniscal lesion. None of them controlled for the effect of sports activities, previous knee trauma, or trauma that occurred during work. Several of the uncontrolled studies were of an early date and predominantly concerned meniscal lesions in miners. It cannot be determined whether meniscal lesions are traumatic or a result of kneeling or squatting work during a long period. Sharrard and Sharrard (58) and Sharrard (59) reported, however, that most meniscal lesions were traumatic, being caused by a twist of the knee.

It can be concluded that the data are insufficient for evaluating a correlation between kneeling and squatting work and the development of meniscal lesion.

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