# Occupational Kneeling and Meniscal Tears: A Magnetic Resonance Imaging Study in Floor Layers

SØREN RYTTER, LILLI KIRKESKOV JENSEN, JENS PETER BONDE, ANNE GRETHE JURIK, and NIELS EGUND

***ABSTRACT.*** ***Objective.*** To evaluate the association between occupational kneeling and degenerative meniscal tears.

***Methods.*** Magnetic resonance imaging (MRI) of both knees was conducted in 92 male floor layers and 49 male graphic designers (referents), with a mean age of 55.6 years (range 42–70 yrs). The presence of grade 3 MRI signal intensities indicating degenerative tears of the anterior, middle, and posterior one-third of the lateral and medial menisci was assessed on 1.5-Tesla MRI scans. The odds ratio (OR) of meniscal tears was determined among floor layers compared to graphic designers. Using logistic regression, models were adjusted for age, body mass index, and knee-straining sports.

***Results.*** Degenerative tears were significantly more prevalent in the medial meniscus among floor layers than among graphic designers [OR 2.28, 95% confidence interval (CI) 1.10–4.98] and significantly more floor layers had medial tears in both knees (OR 3.46, 95% CI 1.41–8.48). Tears extending to the tibial aspect and localized in the middle and posterior one-third of the medial meniscus were most prevalent. Lateral meniscal tears were predominantly unilateral and the prevalence of lateral tears did not differ between the 2 study groups. Knee complaints occurred in about 50% of all floor layers, irrespective of the presence of meniscal tears.

***Conclusion.*** Occupational kneeling increases the risk of degenerative tears in the medial but not the lateral menisci in both knees. (First Release May 1 2009; J Rheumatol 2009;36:1512–9; doi:10.3899/jrheum.081150)

*Key Indexing Terms:*
MENISCAL TEARS — MAGNETIC RESONANCE IMAGING — KNEE — FLOOR LAYERS — KNEELING

Magnetic resonance imaging (MRI) is a safe and noninvasive method for the evaluation of internal knee pathologies. The diagnosis of meniscal tears constitutes a leading indication and MRI is commonly accepted as an accurate method for the evaluation of meniscal pathology[1-3]. Trauma-related meniscal injuries and abnormalities among asymptomatic populations have been examined in several previous MRI studies[4-11]. However, there has been a lack of studies evaluating the association between occupational loading and MRI-detected knee abnormalities. Based on MRI, a recent study examined the relation between occupational kneeling/squatting and cartilage morphology at the tibiofemoral (TF) and patellofemoral joints, but to our knowledge no previous MRI study has investigated the association between occupational kneeling and degenerative meniscal tears[12]. Clinical studies have indicated that occupational kneeling may be a risk factor in the formation of meniscal tears. An early study by Sharrard and Liddell showed an increased incidence of meniscus damage among miners and in a case-control study of hospital-treated meniscal injuries, and Baker, *et al* showed that degenerative lesions were increased almost 4-fold among workers with occupational kneeling[13-15]. However, in a postal survey among men from the same community, Baker, *et al* suggested that part of the risk association found in the case-control study may have been biased due to selective hospital referral of cases whose work involves occupational kneeling and in respect to differential recall of exposures to kneeling knee demands[16].

It has been estimated that floor layers on average spend half of their daily work time in kneeling work positions and there are few workers in the construction industry exposed to the same extent as floor layers[17,18]. Studies have shown that floor layers have an increased prevalence of knee complaints and radiographic knee osteoarthritis (OA)[17-21]. However, the high prevalence of knee complaints cannot be

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explained by knee OA alone and knee morbidity may therefore be attributable to pathologies other than OA.

Our study was designed to determine the prevalence of meniscal tears, and to evaluate the association between occupation and meniscal tears, among 2 trade groups with large exposure contrasts: floor layers highly exposed to kneeling work strains compared to a group of low-level exposed graphic designers.

## MATERIALS AND METHODS

*Study sample*. A Danish sample of 286 male floor layers and 370 male graphic designers was established from trade union rosters comprising members aged 36–70 years in 2004. The workers were recruited in Copenhagen (capital city) and Aarhus (second largest city), Denmark. Graphic designers were included as reference group. They worked mostly at visual display units and their work did not include any knee demands. Floor layers install linoleum, carpet, and vinyl floorings and their work tasks involve removal of old floorings, priming, grinding, filling, gluing, welding, and mounting skirting boards (plastic). The majority of Danish floor layers and graphic designers are members of a trade union and in Denmark these 2 trade groups are comparable regarding the level of education and socioeconomic status.

A self-administered questionnaire was sent to the study sample in 2005. Respondents constituted 253 (88%) floor layers and 290 (78%) graphic designers. The questionnaire included data on demographic and anthropometric characteristics (age, height, and weight), employment (trade seniority), knee complaints (during the past 12 mo), or knee injuries (fractures involving the knee joint, meniscal injuries, cruciate ligament ruptures) and knee-straining sports experience defined as ever participated in football, handball, badminton, tennis, volleyball, ice hockey, or weight lifting. Respondents were invited to participate in additional knee examinations. Written informed consent was obtained from 156 floor layers and 152 graphic designers. Among those a random sample of 92 (Copenhagen, n = 45; Aarhus, n = 47) floor layers and 49 graphic designers (Copenhagen) underwent an MRI examination of both knees. Insufficient MRI were obtained in 2 knees, the left knee in 1 floor layer and the right knee in 1 graphic designer. They both participated with 1 knee in the analyses. So there were 280 knees (floor layers, n = 183; graphic designers, n = 97) for the assessment by MRI. Examinations were conducted at 2 MRI centers in Aarhus (Center I) and Copenhagen (Center II) over a 1-year period (2005-2006).

Permission was obtained from the Central Danish Region Committee on Biomedical Research Ethics.

*MRI technique and evaluation of meniscal tears*. MRI at Center I was performed by a 1.5-Tesla scanner (SymphonyVision, Siemens Medical Systems, Erlangen, Germany) in 47 patients and at Center II by a 1.5-Tesla scanner (Infinion, Philips, Best, The Netherlands) in 94 patients. A dedicated quadrate transmit/receive knee coil was used in both MRI scanners. The MRI sequences were identical for both the right and left knee. The following MRI sequences were obtained at Center I: sagittal proton density fat-saturated turbo spin-echo (TR/TE, 3300/15 ms) and sagittal and coronal T2-weighted (4000/86 ms) fat-saturated turbo spin-echo; coronal T1-weighted (608/20 ms) spin-echo sequences and axial proton density fat-saturated turbo spin-echo (3450/15 ms). The section thickness was 4 mm with an intersection gap of 0.4 mm; field of view was 200 × 200 mm and matrix 512 in all sequences. At Center II the MRI sequences included sagittal proton density fat-saturated turbo spin-echo (TR/TE, 2500/18 ms) and sagittal and coronal T2-weighted (4000/85 ms) fat-saturated turbo spin-echo; coronal T1-weighted (400/13 ms) spin-echo and axial proton density fat-saturated turbo spin-echo (2880/17 ms). The section thickness was 4 mm with an intersection gap of 0.4 mm; field of view was 150 × 150 mm and matrix 512 in all sequences.

A musculoskeletal radiologist with substantial MRI experience evaluated each of the 280 MRI examinations. The observer was blinded to any medical history of knee disorders among participants. Due to differences in the appearance of MRI from the 2 centers, blinding of occupational affiliation was incomplete regarding participants from Center I, who were all floor layers. Blinding of occupational affiliation was complete concerning all participants from Center II.

The medial and lateral meniscus of each knee was evaluated separately for abnormalities in the anterior, middle, and posterior one-third of the meniscus or as combinations with abnormalities in 2 or all 3 portions. A distinction was made between abnormalities in the central 4/5 (white zone) and the peripheral 1/5 (red zone) of the meniscus (Figure 1)[22].

In each plane and in each part of a meniscus the observer indicated whether intrameniscal MRI signal had contact with the articular surface[23,24]. A distinction was made between definite and possible intrameniscal signal intensity (SI) communicating with the meniscal surface; definite intrameniscal SI (grade 3) was considered in contact with the surface if it occurred on 2 contiguous images in either the sagittal or coronal planes, or on at least 1 image in both the sagittal and coronal planes[25]. A meniscus was considered to have SI in possible contact with the surface (equivocal grade 3) if only 1 image in the sagittal or coronal plane demonstrated surface contact irrespective of the number of equivocal SI contacts with the articular surface on additional images. The observer noted whether definite and possible SI in contact with or approaching the surface involved the femoral or tibial aspect or both, and if the meniscus showed morphologic and multiple abnormalities, e.g., defects of the free edge, thinning, and/or generally changed SI extending to the surface (Figures 1 and 2).

Knees with severe OA in the medial or lateral TF compartments or both were registered. The classification criteria of severe OA included diffuse full-thickness cartilage loss on opposing femoral and/or tibial condyles with or without subarticular bone attrition and bone marrow edema[26].

*Statistical analyses*. Using logistic regression, we compared intrameniscal grade 3 SI among floor layers and graphic designers by computing the odds ratio (OR) with 95% confidence intervals (CI) adjusted for age, body mass index (BMI), and knee-straining sports. In side-specific sensitivity analyses, the OR of intrameniscal grade 3 SI between the 2 trade groups were estimated after the exclusion of participants reporting knee injuries or with current MRI findings of TF OA or cruciate ligament lesions. Categorizing trade seniority into 4 strata (≤ 20, 21–30, 31–35, and ≥ 36 yrs) we additionally examined the association between trade seniority and grade 3 SI in adjusted test for trend analyses and evaluated possible age-modifying effects in stratified analyses. The prevalence of knee complaints (during the past 12 mo) was assessed among subjects with and without meniscal tears.

The reliability of MRI-assessed grade 3 SI in the medial meniscus was estimated in 110 MRI examinations of 55 participants. Examinations were evaluated, blinded, by a second experienced musculoskeletal radiologist and reevaluated by the first observer. The reliability analyses revealed high kappa scores both for the primary observer [$\kappa = 0.87$, standard deviation (SD) 0.01] and between the 2 observers ($\kappa = 0.84$, SD 0.01)[27].

Statistical analyses were performed using Stata (version 8.0, StataCorp LP, College Station, TX, USA).

## RESULTS

Characteristics of the 2 study groups are given in Table 1. The age of participants ranged from 42 to 70 years. Mean age and trade seniority was higher among graphic designers compared to floor layers, but the 2 groups were comparable regarding BMI and the proportion of knee complaints. The proportion of lifetime participation in any knee-straining sports and previous major knee injuries was higher among graphic designers than among floor layers.

Among 141 participants, 94 (66.7%) were classified as having a medial or lateral intrameniscal MRI SI contacting

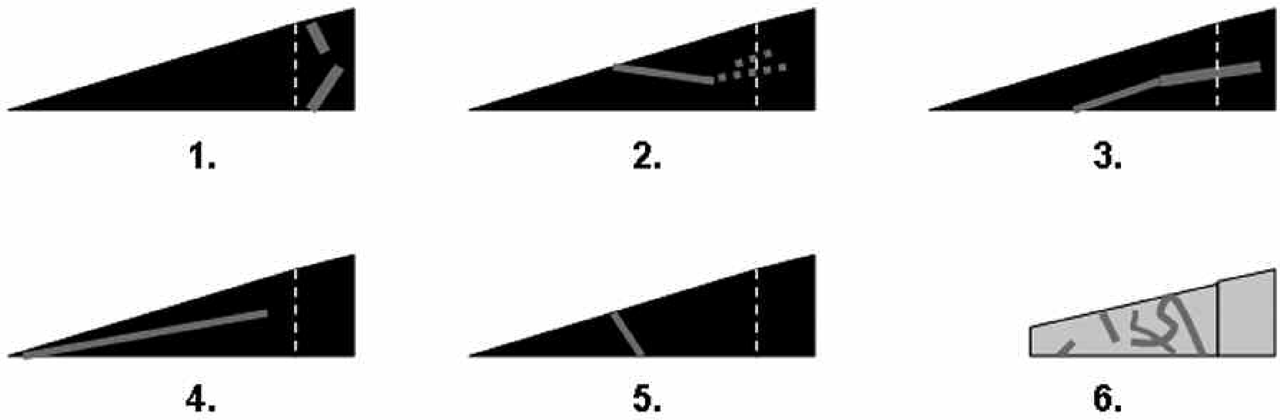


*Figure 1.* Classification of the anatomical sites and types of MRI signal intensity (SI) extending to the surface of the meniscus: 1. Abnormalities confined to the peripheral 1/5 of the meniscus with SI involving the femoral or tibial surface or both. 2. SI in contact with femoral surface. 3. SI in contact with tibial surface. 4. SI extending to apex. 5. SI extending to both femoral and tibial surface. 6. Comminuted intrameniscal SI extending to both surfaces and/or defects of the meniscus.

the articular surface (grade 3) in at least 1 knee. A grade 3 SI in both the medial and lateral meniscus (unilateral or bilateral) was evident in 17 participants (12.8%). Grade 3 SI were more prevalent in the medial than in the lateral meniscus. Comparing the 2 occupations there was a significantly higher prevalence of medial meniscal lesions among floor layers compared to graphic designers. Moreover, significantly more floor layers than graphic designers had grade 3 SI bilaterally in the medial meniscus. Grade 3 SI in the lateral meniscus were predominantly unilateral and there were no significant differences in the prevalence of lateral meniscal lesions between the 2 study groups. Additionally, there were no significant differences in the distribution of unilateral grade 3 SI in the medial meniscus between the right and left knee, either within or between the occupational groups. Unilateral grade 3 SI in the lateral meniscus showed a 10 to 1 distribution between the left and right knee among floor layers and a 1 to 2 distribution among graphic designers, although the number of cases was small (Table 2a).

Table 2b gives the distribution of grade 3 SI in the medial meniscus by type and location (Figures 1 and 2). The posterior third of the meniscus had the highest prevalence of abnormalities, followed by the middle and anterior thirds. Type 3 lesions contacting the tibial surface of the medial meniscus were the most prevalent type, and were more prevalent among floor layers compared to graphic designers both in the posterior third (20.7% vs 9.5%) and in the middle third (7.7% vs 2.0%) of the meniscus. The prevalence of horizontal lesions (type 4) and lesions in the red zone (type 1) was also higher among floor layers. Type 2 and type 5 lesions were few. Among floor layers (n = 77) and graphic designers (n = 26) with definite grade 3 SI in the posterior third of the medial meniscus, 47 (61.0%) floor layers and 14 (53.8%) graphic designers also had a concurrent grade 3 SI in the middle third of the medial meniscus.

Age-stratified analyses did not indicate confounding or modifying effects of age (Table 3). Additionally, no significant association was found between trade seniority and grade 3 SI in the medial meniscus in trend test analyses adjusted for age, BMI, and knee-straining sports, either among floor layers (OR 0.82, 95% CI 0.49–1.36) or among graphic designers (OR 1.06, 95% CI 0.49–2.33).

MRI evaluations revealed 16 participants (floor layers, n = 10; graphic designers, n = 6) with severe TF OA, and 2 cases (1 floor layer and 1 graphic designer) with anterior cruciate ligament (ACL) lesions. Among the remaining participants, the initial survey revealed 4 floor layers and 9 graphic designers with previous knee injuries. Excluding these subgroups of floor layers (n = 15) and graphic designers (n = 16) from the analysis did not alter the results. Grade 3 SI in the medial meniscus was still more prevalent among floor layers compared to graphic designers (OR 2.32, 95% CI 1.00–5.35).

The prevalence of knee complaints in floor layers was 48.4% among those with a meniscal tear and 53.6% among those without a tear (p = 0.65); the corresponding prevalences in graphic designers were 46.7% and 52.6% (p = 0.68). Knee complaints were evident in 45 of 94 (47.9%) individuals with a meniscal tear.

Restricting analyses of medial grade 3 SI to floor layers (n = 45) and graphic designers (n = 49) from Center II, all blinded in regard to occupational affiliation to the observers, showed the same trend (OR 1.88, 95% CI 0.78–4.50) compared to analyses of the whole study group (Table 2a).

## DISCUSSION

We found a significantly higher prevalence of degenerative tears (grade 3 SI) in the medial meniscus among floor layers compared to graphic designers and significantly more floor layers had a bilateral distribution of medial tears. Studies have shown that the prevalence of degenerative meniscal changes increases with age, and studies indicate that menis-

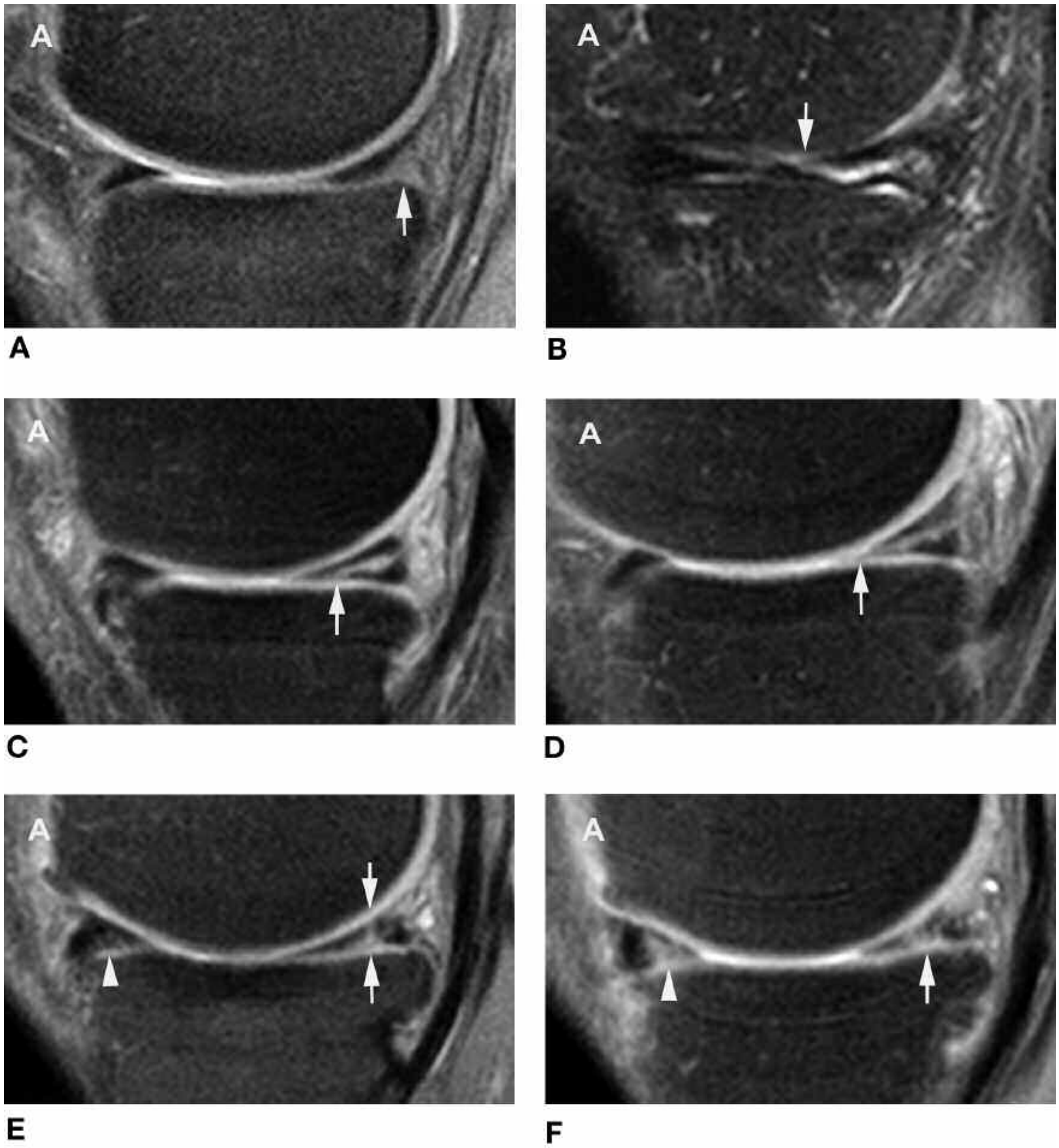


*Figure 2*. Sagittal MRI of the anterior (A) and posterior one-third of the menisci from floor layers with type 1 to 6 signal intensities (SI) contacting 1 or both articular surfaces. Intermediate-weighted (TR/TE, 3300/15 ms), fat saturated, turbo spin-echo sequences in panels a, c, d, and e; and in T2-weighted (TR/TE, 4000/86 ms) fat saturated turbo spin-echo sequence in panel b. (a) Type 1, broad intermediate SI in peripheral 1/5 of posterior third in contact with tibial surface (arrow). (b) Type 2, high SI contacting femoral surface (arrow). (c) Type 3, intermediate SI contacting tibial surface (arrow). (d) Type 4, band-like intermediate SI extending to apex of posterior third (arrow). (e) Type 5, intrameniscal intermediate SI contacting both femoral and tibial surfaces (arrows); one definite and 2 possible SI in contact with tibial surface of anterior third (arrowhead). (f) Type 6, comminuted lesions in contact with both surfaces of anterior (arrowhead) and posterior third (arrow).

cal degeneration may progress and predispose to traumatic or spontaneous meniscal tears[8-10,28,29]. Current results did not indicate an association between trade seniority and degenerative tears among either floor layers or graphic designers, but the power of the study to detect effects of seniority may be low, because age and trade seniority are strongly correlated (r = 0.6). However, internal knee stress is high during kneeling work, and an age-related, degenerative, vulnerable meniscus could easily be torn during such work demands. Moreover, getting from kneeling to the standing position many times a day may theoretically predispose to knee twists and subclinical meniscal tears. Accumulated exposures to kneeling work tasks may predispose to the development of degenerative meniscal tears

*Table 1.* Characteristics of the study participants, floor layers (n = 92) and graphic designers (n = 49).

| | Floor Layers | | Graphic Designers | |
|---|---|---|---|---|
| Age, yrs (mean, SD) | 54.5 | 7.2 | 57.7 | 5.6 |
| BMI, kg/m$^2$ (mean, SD) | 26.2 | 3.4 | 26.6 | 4.8 |
| Seniority†, yrs (mean, SD) | 29.6 | 9.8 | 35.9 | 6.5 |
| ≤ 20, n (%) | 20 | 21.8 | 1 | 2.1 |
| 21–30, n (%) | 27 | 29.3 | 10 | 20.4 |
| 31–35, n (%) | 22 | 23.9 | 10 | 20.4 |
| ≥ 36, n (%) | 23 | 25.0 | 28 | 57.1 |
| Knee complaints††, n (%) | 46 | 50.0 | 24 | 48.9 |
| Knee-straining sports*, n (%) | 46 | 50.0 | 36 | 73.5 |
| Previous injury**, n (%) | 5 | 5.4 | 10 | 20.4 |
| Tibiofemoral osteoarthritis#, n (%) | 10 | 10.9 | 6 | 12.2 |

BMI: body mass index. † Duration of employment in the trade. †† Ache, pain, or nuisance during the past 12 mo. * Football, handball, badminton, tennis, volleyball, ice hockey, and weight lifting. ** Fractures of the knee joint, meniscal injuries, cruciate ligament ruptures. # MRI-assessed diffuse full-thickness cartilage loss on opposing femoral and/or tibial condyles with or without subarticular bone attrition and bone marrow edema.

through multiple micro-trauma or cumulative mechanical strain. It could also be, however, that kneeling is an important determinant in the progression from meniscal degeneration to tears among aging workers. Our study cannot distinguish these possibilities. In any case, these contemplations could explain the increased prevalence of degenerative tears observed among floor layers.

The posterior third of the meniscus was more often involved than the middle and the anterior third, and the medial meniscus more often than the lateral. These findings are in accord with previous studies[2-3,9]. During knee flexion there is a load imbalance between medial and lateral TF contact forces, created by an adduction moment in the knees[30]. In a study on cadaver knees, Thambyah, *et al* showed that contact stresses increased significantly during deep knee flexion (120°) and that medial peak pressures were up to 70% greater than pressures in the lateral TF compartment[31]. Meniscal movements during loaded knee flexion have also been studied in human *in vitro* cadaver models and in MRI *in vivo* examinations[32-34]. Results showed that the lateral

*Table 2A.* Risk of meniscal tears (grade 3 MRI SI) among 92 floor layers compared to 49 graphic designers.

| | Floor Layers | | Graphic Designers | | | |
|---|---|---|---|---|---|---|
| | n | % | n | % | OR* | 95% CI |
| Medial meniscus | 62 | 67.4 | 26 | 53.1 | 2.28 | 1.10–4.98 |
| Unilateral† | 15 | 24.2 | 11 | 42.3 | 0.95 | 0.33–2.67 |
| Right Knee | 8 | 53.3 | 4 | 36.4 | | |
| Left knee | 7 | 46.7 | 7 | 63.6 | | |
| Bilateral†† | 47 | 75.8 | 15 | 57.7 | 3.46 | 1.41–8.48 |
| Lateral meniscus | 12 | 13.0 | 11 | 22.4 | 0.75 | 0.29–1.98 |
| Unilateral† | 11 | 91.7 | 9 | 81.8 | 0.78 | 0.28–2.17 |
| Right knee | 1 | 9.1 | 6 | 66.7 | | |
| Left knee | 10 | 90.9 | 3 | 33.3 | | |
| Bilateral†† | 1 | 8.3 | 2 | 18.2 | 0.50 | 0.04–6.51 |

* Adjusted for age, body mass index, and knee-straining sports. † Meniscal tear in 1 knee. †† Meniscal tears in both knees.

*Table 2B.* Proportion of grade 3 MRI SI in the medial meniscus by type and location in 183 knees* of 92 floor layers and 97 knees* of 49 graphic designers.

| | Posterior Third | | | | Middle Third | | | | Anterior Third | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Floor Layers | | Graphic Designers | | Floor Layers | | Graphic Designers | | Floor Layers | | Graphic Designers | |
| Types (n, %) | | | | | | | | | | | | |
| Normal | 95 | 51.9 | 60 | 63.2 | 130 | 71.0 | 78 | 80.5 | 168 | 91.8 | 93 | 96.0 |
| Type 1 | 11 | 6.0 | 2 | 2.1 | 10 | 5.5 | 1 | 1.0 | 0 | — | 0 | — |
| Type 2 | 2 | 1.1 | 1 | 1.0 | 0 | — | 0 | — | 1 | 0.5 | 0 | — |
| Type 3 | 38 | 20.7 | 9 | 9.5 | 14 | 7.7 | 2 | 2.0 | 1 | 0.5 | 1 | 1.0 |
| Type 4 | 12 | 6.6 | 2 | 2.1 | 5 | 2.7 | 2 | 2.0 | 1 | 0.5 | 1 | 1.0 |
| Type 5 | 2 | 1.1 | 2 | 2.1 | 3 | 1.7 | 0 | — | 1 | 0.5 | 1 | 1.0 |
| Type 6 | 12 | 6.6 | 10 | 10.5 | 20 | 10.9 | 9 | 9.3 | 8 | 4.5 | 1 | 1.0 |
| Equivocal† | 11 | 6.0 | 9 | 9.5 | 1 | 0.5 | 5 | 5.2 | 3 | 1.7 | 0 | — |
| Total | 183 | 100 | 95†† | 100 | 183 | 100 | 97 | 100 | 183 | 100 | 97 | 100 |

* Insufficient examination of 1 knee. † Possible and/or visible in only 1 section. †† The posterior horn of the medial meniscus (bilateral) not accessible in 1 examination.

*Table 3*. Medial meniscus tears (grade 3 MRI SI) among 92 floor layers compared to 49 graphic designers stratified into age groups.

| | Floor Layers Total Meniscal Tear | | Graphic Designers Total Meniscal Tear | | |
|---|---|---|---|---|---|
| Age, yrs | N | n (%) | N | n (%) | OR* (95% CI) |
| ≤ 49 | 24 | 16 (66.7) | 4 | 2 (50.0) | 2.0 (0.1–34.3) |
| 50–59 | 45 | 29 (64.4) | 28 | 13 (46.4) | 2.7 (0.9–8.2) |
| ≥ 60 | 23 | 17 (73.9) | 17 | 11 (64.7) | 2.5 (0.4–17.0) |

* Adjusted for body mass index, trade seniority, and knee-straining sports.

meniscus moved more than the medial, and the anterior horn more than the posterior during knee flexion. The posterior horn of the medial meniscus has a marked soft-tissue attachment restricting movements. This could put a greater load on the posterior part of the meniscus and make it more vulnerable[34]. High medial contact forces and the relative immobility of the posterior part of the medial meniscus combined with its larger size could explain our results of an unbalanced distribution of degenerative tears between the medial and lateral meniscus, and the anterior and posterior parts.

The meniscus is responsible for shock absorption, load transmission, joint stability, and lubrication of the cartilage in the knee joint[35]. Meniscal and/or ACL injuries may induce malalignment of knee dynamics and initiate or extend degenerative joint changes[36]. Knee OA starts with degenerative cartilage changes, and prevalence of OA also increases with age. Degenerative meniscal tears and OA often coexist, but interactions between the 2 pathological conditions are not well understood[11]. Progression of knee OA may increase with concomitant meniscal tears, but knee OA may also increase the progression of degenerative meniscal changes. However, sensitivity analyses excluding participants with reports of previous knee injuries and participants with current MRI findings of TF OA did not alter results. Degenerative meniscal tears were still more prevalent among floor layers compared to graphic designers.

We found a high prevalence of knee complaints in both study groups, and knee complaints occurred in about 50% of all participants irrespective of the presence of meniscal tear. This is in accord with previous studies where a high prevalence of meniscal tears among asymptomatic individuals has been observed. Englund, *et al* found a 35% prevalence of meniscal damage (tears or destruction) in a study sample with a mean age of 62 years, and 61% were in subjects without knee pain[6]. Boden, *et al* reported a 36% prevalence of meniscal tears among asymptomatic individuals older than 45 years, whereas Jerosch, *et al* found a prevalence of up to 40% among asymptomatic subjects older than 50 years[7,8]. A high baseline prevalence of degenerative tears has also been supported by cadaveric and specimen studies. In an autopsy series, Noble and Hamblen found degenerative horizontal tears in 60% of cadavers with an average age of 65 years[29]. Thus, meniscal tears may to some extent explain previous reports of significantly increased prevalences of knee complaints among floor layers[17-21].

Abnormalities of the meniscus are commonly evaluated on MRI using the grading system reported by Lotysch, *et al*[23]. This grading system was first evaluated by Stoller, *et al* by the use of close MRI and histological correlation[24]. They defined grade 1 and grade 2 as intrameniscal MRI SI alterations that did not extend to an articular surface of the menisci, whereas grade 3 was defined as intrameniscal SI contacting the articular surface of the meniscus. Using arthroscopy as the reference standard, the diagnostic performance of MRI of the meniscus was assessed in a meta-analysis[1]. A pooled weighted sensitivity of 93% and a specificity of 88% were calculated for diagnosing medial tears, and for lateral tears, 79% and 93%, respectively. However, study design characteristics and the experience of the radiologists are factors that may improve the accuracy of interpretation of intrameniscal SI on MRI[1,37,38]. In our study, we used MRI sequences in both the sagittal and coronal planes with short TE that is most sensitive for the visualization of intrameniscal abnormalities. In addition, the assessments of MRI were conducted on high definition screens by radiologists highly experienced in musculoskeletal MRI. The distinction between possible/equivocal and definite SI extending to the surface of the meniscus appears to be of crucial importance for accurate interpretation of intrameniscal SI as tears. De Smet, *et al* demonstrated that more than 90% of menisci with grade 3 SI contacting the surface on more than 1 image had tears at arthroscopy. In comparison, tears at arthroscopy were observed in fewer than 55% of patients if grade 3 SI was seen on only 1 MRI[25].

Our results should be interpreted with caution. We obtained a high questionnaire response rate, but among respondents invited to participate in additional examinations, only 62% of the floor layers and 52% of graphic designers participated. Results could be biased if the decision to participate were differentially influenced by previous or current knee complaints. First, analysis of those who participated in the medical examinations and those who declined revealed a higher participation rate among graphic designers with knee complaints [relative risk (RR) 2.7, 95% CI 1.7–4.3] than among floor layers with knee complaints

(RR 1.2, 95% CI 0.9–1.6). Part of the explanation could be that graphic designers with knee complaints are more motivated to participate in a medical knee examination than graphic designers without complaints, whereas floor layers who depend on well-functioning and healthy knees may participate, having knee complaints or not. It is therefore most likely that selection bias has influenced risk estimates towards the null. There were no significant differences regarding the distribution of age, BMI, trade seniority, and knee-straining sports between participants and nonparticipants. Second, differential selection of individuals towards different occupations depending on their health status may be inevitable concerning occupations with high physical demands. We acknowledge that a healthy-worker selection may have influenced results either in terms of primary selection of more healthy individuals into the trade or in terms of longer survival in the trade of more healthy individuals. However, if it is assumed that the healthiest individuals are selected into occupations with the most strain, we would expect bias towards the null, with an underestimation of the investigated association. Yet results still revealed a high prevalence of meniscal tears among floor layers. Sensitivity analyses among the subgroup from Center II, all blinded in regard to occupational affiliation to the observer, did not alter the observed trend, and the influence of bias owing to incomplete blinding regarding occupational affiliation among participants from Center I is therefore considered negligible.

Results revealed a significantly higher prevalence of bilateral degenerative tears in the medial meniscus among floor layers highly exposed to kneeling work demands compared to a group of low-level exposed graphic designers. Findings indicate that occupational kneeling increases the risk of degenerative tears in the medial, but not the lateral, menisci in both knees.

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## REFERENCES

1. Oei EH, Nikken JJ, Verstijnen AC, Ginai AZ, Myriam Hunink MG. MR imaging of the menisci and cruciate ligaments: a systematic review. Radiology 2003;226:837-48.
2. Crues JV III, Mink J, Levy TL, Lotysch M, Stoller DW. Meniscal tears of the knee: accuracy of MR imaging. Radiology 1987;164:445-8.
3. Bachmann GF, Basad E, Rauber K, Damian MS, Rau WS. Degenerative joint disease on MRI and physical activity: a clinical study of the knee joint in 320 patients. Eur Radiol 1999;9:145-52.
4. Mandelbaum BR, Finerman GA, Reicher MA, et al. Magnetic resonance imaging as a tool for evaluation of traumatic knee injuries. Anatomical and pathoanatomical correlations. Am J Sports Med 1986;14:361-7.
5. Reicher MA, Hartzmann S, Bassett LW, Mandelbaum B, Duckwiler G, Gold RH. MR imaging of the knee. Part I. Traumatic disorders. Radiology 1987;162:547-51.
6. Englund M, Guermazi A, Gale D, et al. Incidental meniscal findings on knee MRI in middle-aged and elderly persons. N Engl J Med 2008;359:1108-15.
7. Boden SD, Davis DO, Dina TS, et al. A prospective and blinded investigation of magnetic resonance imaging of the knee. Abnormal findings in asymptomatic subjects. Clin Orthop 1992;282:177-85.
8. Jerosch J, Castro WH, Asheuer J. Age-related magnetic resonance imaging morphology of the menisci in asymptomatic individuals. Arch Orthop Trauma Surg 1996;115:199-202.
9. Kornick J, Trefelner E, McCarthy S, Lange R, Lynch K, Jokl P. Meniscal abnormalities in the asymptomatic population at MR imaging. Radiology 1990;177:463-5.
10. Negendank WG, Fernandez-Madrid FR, Heilbrun LK, Teitge RA. Magnetic resonance imaging of meniscal degeneration in asymptomatic knees. J Orthop Res 1990;8:311-20.
11. Fukuta S, Masaki K, Korai F. Prevalence of abnormal findings in magnetic resonance imaging of asymptomatic knees. J Orthop Sci 2002;7:287-91.
12. Amin S, Goggins J, Niu J, et al. Occupation-related squatting, kneeling, and heavy lifting and the knee joint: a magnetic resonance imaging-based study in men. J Rheumatol 2008;35:1645-9.
13. Sharrard WJ, Liddell FD. Injuries to the semilunar cartilages of the knee in miners. Br J Ind Med 1962;19:195-202.
14. Baker P, Coggon D, Reading I, Barrett D, McLaren M, Cooper C. Sports injury, occupational physical activity, joint laxity, and meniscal damage. J Rheumatol 2002;29:557-63.
15. McMillan G, Nichols L. Osteoarthritis and meniscus disorders of the knee as occupational diseases of miners. Occup Environ Med 2005;62:567-75.
16. Baker P, Reading I, Cooper C, Coggon D. Knee disorders in the general population and their relation to occupation. Occup Environ Med 2003;60:794-7.
17. Kivimaki J, Riihimäki H, Hänninen K. Knee disorders in carpet and floor layers and painters. Scand J Work Environ Health 1992;18:310-6.
18. Jensen LK, Mikkelsen S, Loft IP, Eenberg W. Work-related knee disorders in floor layers and carpenters. J Occup Environ Med 2000;42:835-42.
19. Jensen LK, Mikkelsen S, Loft IP, Eenberg W. Radiographic knee osteoarthritis in floor layers and carpenters. Scand J Work Environ Health 2000;26:257-62.
20. Thun M, Tanaka S, Smith AB, et al. Morbidity from repetitive knee trauma in carpet and floor layers. Br J Ind Med 1987;44:611-20.
21. Rytter S, Jensen LK, Bonde JP. Knee complaints and consequences on work status; a 10-year follow-up survey among floor layers and graphic designers. BMC Musculoskel Disord 2007;8:93.
22. Hauger O, Frank LR, Boutin RD, et al. Characterization of the “red zone” of knee meniscus: MR imaging and histologic correlation. Radiology 2000;217:193-200.
23. Lotysch M, Mink J, Crues JV III, Schwartz SA. Magnetic resonance imaging in the detection of meniscal injuries. Magn Reson Imaging 1986;4:185.
24. Stoller DW, Martin C, Crues JV III, Kaplan L, Mink JH. Meniscal tears: pathologic correlation with MR imaging. Radiology 1987;163:731-5.
25. De Smet AA, Norris MA, Yandow DR, Quintana FA, Graf BK, Keene JS. MR diagnosis of meniscal tears of the knee: importance of high signal in the meniscus that extends to the surface. AJR Am J Roentgenol 1993;161:101-7.
26. Peterfy CG, Guermazi A, Zaim S, et al. Whole-organ magnetic resonance imaging score (WORMS) of the knee in osteoarthritis. Osteoarthritis Cartilage 2004;12:177-90.
27. Landis JR, Koch GG. The measurement of observer agreement for

categorical data. Biometrics 1977;33:159-74.
28. Hodler J, Haghighi P, Pathria MN, Trudell D, Resnick D. Meniscal changes in the elderly: correlation of MR imaging and histologic findings. Radiology 1992;184:221-5.
29. Noble J, Hamblen DL. The pathology of the degenerative meniscus lesion. J Bone Joint Surg Br 1975;57:180-6.
30. Andriacchi TP. Dynamics of knee malalignment. Orthop Clin North Am 1994;25:395-403.
31. Thambyah A, Goh JC, De SD. Contact stresses in the knee joint in deep flexion. Med Eng Phys 2005;27:329-35.
32. Tienen TG, Buma P, Scholten JG, van Kampen A, Veth RP, Verdonschot N. Displacement of the medial meniscus within the passive motion characteristics of the human knee joint: an RSA study in human cadaver knees. Knee Surg Sports Traumatol Arthrosc 2005;13:287-92.
33. Yao J, Lancianese SL, Hovinga KR, Lee J, Lerner AL. Magnetic resonance image analysis of meniscal translation and tibio-menisco-femoral contact in deep knee flexion. J Orthop Res 2008;26:673-84.
34. Vedi V, Williams A, Tennant SJ, Spouse E, Hunt DM, Gedroyc WM. Meniscal movement. An in-vivo study using dynamic MRI. J Bone Joint Surg Br 1999;81:37-41.
35. Sweigart MA, Athanasiou KA. Toward tissue engineering of the knee meniscus. Tissue Eng 2001;7:111-29.
36. Andriacchi TP, Mündermann A. The role of ambulatory mechanics in the initiation and progression of knee osteoarthritis. Curr Opin Rheumatol 2006;18:514-8.
37. White LM, Schweitzer ME, Deely DM, Morrison WB. The effect of training and experience on the magnetic resonance imaging interpretation of meniscal tears. Arthroscopy 1997;13:224-8.
38. Roos JE, Chilla B, Zanetti M, et al. MRI of meniscal lesions: soft-copy (PACS) and hard-copy evaluation versus reviewer experience. AJR Am J Roentgenol 2006;186:786-90.