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# MR Imaging of Degenerative Cartilage Lesions of the Knee Joint in Floor Layers and Graphic Designers

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## Abstract

**Introduction:** Kneeling work leads to an additional risk of developing knee osteoarthritis (OA). Previous studies have primarily been based on radiography, but radiography is limited by its inability to visualize articular cartilage, in which the earliest signs of OA occur. The objective of this explorative study, based on available data, was to examine the prevalence of magnetic resonance imaging (MRI)-detected knee cartilage lesions in male floor layers exposed to kneeling work, as compared to non-exposed male graphic designers.

**Methods:** MRI of the knees was conducted in 92 floor layers and 49 graphic designers, with a mean age of 55.6 years (42-70 years). MRI-detected cartilage lesions were graded according to a nine-point lesion scale using a modified Whole Organ Resonance Score (WORMS) system. Severe knee cartilage lesions were defined as a maximal lesion score ≥ 3 in 1) the medial tibiofemoral posterior area, the most strained area during kneeling and 2) the total knee. Presence of lesions was compared in floor layers and graphic designers after adjusting for age, BMI, seniority, knee injuries, and sports activity in logistic regression analyses for correlated data, and investigated as a risk factor for self-reported knee complaints in ordinary logistic regression analyses.

**Results:** The prevalence of MRI-detected knee cartilage lesions did not differ between the two occupations in the tibiofemoral medial posterior area of the knee ($p \geq 0.50$), or in the total knee ($p \geq 0.29$). For the two study groups combined, age showed a five-fold increase in the odds of cartilage lesions per 10 years' difference in age, and presence of cartilage lesions was associated with a 2.5-fold increase in the odds of self-reported knee complaints.

**Conclusions:** In contrast to our expectations, MRI-detectable knee cartilage lesions were not more prevalent among workers with knee-demanding work. This calls for further research that can clarify the mechanisms that causes knee OA in occupations with knee-demanding work.

## Keywords

MR imaging, Cartilage lesions, Knee, Occupational, Epidemiology

## Introduction

Floor layers have a high prevalence of knee complaints and results from a previous study have shown that self-reported knee complaints are a risk factor for premature work termination from a knee demanding trade [1]. In earlier studies, we have shown a higher risk of radiological knee osteoarthritis (OA) in male floor layers as compared to a control group [2,3] and have also shown that floor layers have an increased risk of developing meniscal and cystic lesions in the posterior part of the knee joint [4,5]. However, the high prevalence of self-reported knee complaints may not be explained by the previous findings of radiological knee OA and meniscal tears alone, but could be attributable to other knee pathologies such as lesions in the cartilage [6]. Magnetic resonance imaging (MRI) has proved to be superior in showing cartilage lesions compared to other imaging techniques [7]. The purpose of this study, therefore, was to examine if there was a higher prevalence of MRI-detected degenerative cartilage lesions of the knee joint in male floor layers with a substantial amount of kneeling work activities as compared to a group of male graphic designers without any occupational kneeling work activities. Furthermore, knowledge about mechanisms concerning the development of occupational knee OA has been sparse. It has been argued that OA is initiated when healthy cartilage is exposed to traumatic or chronic conditions that shift loads to regions of cartilage that are not conditioned to chronic repetitive loading [8]. Biomechanical studies have shown that tibiofemoral (TF) contact forces increases significantly during deep knee flexion, especially forces acting in the posterior part of the knee joint [9]. Additionally, TF contact surfaces are displaced posteriorly during knee flexion. Given that knee contact forces increases as the contact area decreases during deep knee flexion, this could be a contributing factor in the formation of degenerative cartilage lesions in workers with kneeling work activities, such as floor layers. We therefore investigated whether cartilage lesions in the medial TF posterior area of the knee joint were more prevalent among floor layers than graphic designers. Finally, we hypothesized that cartilage lesions were associated with a higher probability of self-reported knee complaints.

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## Methods

### Study sample

A source population of 286 male floor layers and 370 male graphic designers was established in 1994, based on membership lists from the two corresponding Danish trade unions. The study included members aged 36-70 years in 2004, still employed or who had left the trade, and who were living in the geographical area of Copenhagen (Denmark's capital city) or Aarhus (Denmark's second largest city). Graphic designers, all from Copenhagen, were included as a group of non-exposed employees. There are approximately a thousand floor layers in Denmark, but there are more than 50,000 employees in the construction industry who frequently engage in kneeling or squatting work activities. Floor layers spend half of their work time in kneeling work positions (i.e., kneeling, crawling, and squatting), and it has been found that the external pressure on the knee was highest while kneeling was combined with moving from side to side or crawling [10-12]. The primary work tasks for graphic designers involved layout of texts and advertisements using visual display units, and their work did not involve kneeling work activities, heavy lifting, or stair climbing. The levels of education of the Danish floor layers and graphic designers were comparable.

Questionnaires were mailed to the source population in year 2004-2005. The response rates were 89% and 78% among floor layers and graphic designers, respectively. The questionnaire included information on age, height, weight, number of years in the profession, knee complaints (ache or pain), knee injuries, and sports activity. Questionnaire respondents were invited to participate in a clinical, a radiographic, and an MRI investigation. Informed consent to participate was given by 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) had MRI examinations of the knees (n = 280; insufficient MRI were obtained in 2 knees, the left knee in one floor layer and the right knee in one graphic designer) [13]. Examinations were conducted at two MR Centers in Aarhus and Copenhagen over a 1-year period (2005-2006). Permission for the study and data collection was obtained from the Central Danish Regional Committee on Biomedical Research Ethics.

### Magnetic resonance imaging

MR imaging in Aarhus was performed by a 1.5-Tesla scanner (Symphony Vision, Siemens Medical Systems, Erlangen, Germany), and in Copenhagen by a 1.5-Tesla scanner (Infinion, Philips, Best, The Netherlands). The following MRI sequences were obtained in Aarhus: 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. In Copenhagen 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 radiologist with substantial MRI experience assessed each of the 280 MRI examinations while blinded to the medical history of knee disorders among participants. Due to differences in the appearance of MRI from the two centers, blinding of occupational affiliation regarding participants from Aarhus was incomplete, all participants were floor layers. Blinding of occupational affiliation concerning all participants from Copenhagen was complete.

Cartilage lesions were scored using a modified Whole Organ Magnetic Resonance Score (WORMS) system in the total knee, and by compartment [14]. The articular surface of each knee joint was subdivided into 59 regions, with 30 different regions in the femoral compartment, 18 regions in the tibial compartment, and 11 regions in the patellar compartment [15]. Cartilage signal and morphology for each region were graded according to a nine-point lesion scale: 0 = normal, 1 = normal thickness with signal changes, 2 = partial thickness focal lesions < 1 cm and fissures, 3 = full thickness focal lesions < 1 cm and fissures, 4 = diffuse partial thickness loss < 50% of the area, 5 = diffuse partial thickness loss > 50% of the area, 6 = diffuse total thickness loss < 50% of the area, 7 = diffuse total thickness loss > 50% of the area, 8 = bone attrition. Two overall outcomes based on the 59 regions were applied; 1) the maximal lesion score within the medial TF posterior area, as this area is the most strained during kneeling work activities [3,9], and 2) the maximal lesion score in any area of the knee.

### Statistical analysis

The observed prevalence of MRI-detected knee cartilage lesions in the medial TF posterior area, as well as the observed prevalence of MRI-detected knee cartilage lesions in the total knee on the individual subject level were compared for floor layers and graphic designers using Fisher's exact test. Furthermore, the prevalence of MRI-detected knee cartilage lesion defined as a maximum lesion score of ≥ 3 in the total knee was compared in floor layers and graphic designers in logistic regression analyses adjusted for different sets of covariates: (1) age, (2) age and body mass index (BMI), (3) age, BMI, and seniority as floor layer, and (4) age, BMI, seniority as floor layer, earlier knee injuries (yes/no), and knee straining sports activity (yes/no). The quantitative variables, age, BMI, and seniority as a floor layer, were entered as linear variables; for details on the modeling, please see supplementary material. Earlier knee injuries comprised rupture of ligaments, meniscal tears operations, and fractures including the knee joint. Sports activity was considered as potentially knee straining if it was one of the following: football, handball, badminton, tennis, volleyball, ice hockey, weight lifting, or skiing. Earlier knee injuries and knee straining sports were included jointly to indicate the level of exposure to acute strain of the knee. The logistic regression analyses of MRI-detected knee cartilage lesions in the total knee used the knees as the observation units. We used a random subject effect to account for the correlation between the two knees of each single subject. MRI-detected knee cartilage lesions in the total knee were also investigated as a risk factor for self-reported knee complaints within the previous 12 months in ordinary logistic regression analyses using the individual subjects as the observation units and knee complaints as the outcome. The same sets of covariates as in the above described analyses, including occupation, were considered as potential risk factors for self-reported knee complaints, without as well as with the additional risk factor, MRI-detected knee cartilage lesions in the total knee for either knee (maximum lesion score ≥ 3 versus maximum lesion score ≤ 2), to investigate whether the potential effect on knee complaints of any of the covariates was partially or totally mediated through the MRI-detected knee cartilage lesions.

All p-values and 95% confidence intervals were based on Wald's test statistics on the log scale for the odds ratio. The analyses were performed using SAS®, version 9.3 for the Windows platform. The unadjusted analyses were performed using the Freq procedure. The logistic regression analyses of MR-detected knee cartilage lesions in the total knee were performed using the Glimmix procedure with the option Method = Quad. The logistic regression analyses of self-reported knee complaints within the previous 12 months were performed using the Genmod procedure.

## Results

Participants' ages ranged from 42 to 70 years with a higher mean age among graphic designers (57.7 years) as compared to floor layers (54.5 years, $p < 0.05$). Duration of employment in the trade was high among both study groups, but graphic designers (35.9 years) had a higher trade seniority on average than floor layers (29.6 years, $p < 0.05$). The two study groups were comparable regarding BMI: graphic designers had a mean of 26.6 kg/m$^2$, floor layers a mean of 26.2 kg/m$^2$ ($p = 0.53$) [4,5].

**Table 1:** Prevalence of MRI-detected cartilage lesions in the medial tibiofemoral posterior area of the knee among 92 male Danish floor layers and 49 male Danish graphic designers.

| Lesions of the medial posterior area | Either knee | | | | | | | Left knee | | | | | | | Right knee | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Occupation | | | | | Total | | Occupation | | | | | Total | | Occupation | | | | | Total | |
| | Floor layers | | Graphic designers | | Fisher's exact | | | Floor layers | | Graphic designers | | Fisher's exact[1] | | | Floor layers | | Graphic designers | | Fisher's exact[1] | | |
| | N | % | N | % | P | N | % | N | % | N | % | P | | | N | % | N | % | P | N | % |
| Max lesion score in the area | | | | | 0.98 | | | | | | | 0.50 | | | | | | | 0.94 | | |
| 0 | 81 | 88.0 | 43 | 87.8 | | 124 | 87.9 | 82 | 89.1 | 45 | 91.8 | | 127 | 90.1 | 84 | 91.3 | 43 | 87.8 | | 127 | 90.1 |
| 4 | 3 | 3.3 | 2 | 4.1 | | 5 | 3.5 | 4 | 4.3 | 1 | 2.0 | | 5 | 3.5 | 2 | 2.2 | 2 | 4.1 | | 4 | 2.8 |
| 5 | 3 | 3.3 | 2 | 4.1 | | 5 | 3.5 | 1 | 1.1 | 2 | 4.1 | | 3 | 2.1 | 2 | 2.2 | 1 | 2.0 | | 3 | 2.1 |
| 6 | 1 | 1.1 | 1 | 2.0 | | 2 | 1.4 | 1 | 1.1 | 1 | 2.0 | | 2 | 1.4 | 1 | 1.1 | 1 | 2.0 | | 2 | 1.4 |
| 7 | 4 | 4.3 | 1 | 2.0 | | 5 | 3.5 | 3 | 3.3 | | | | 3 | 2.1 | 3 | 3.3 | 1 | 2.0 | | 4 | 2.8 |
| Missing | | | | | | | | 1 | 1.1 | | | | 1 | 0.7 | | | 1 | 2.0 | | 1 | 0.7 |
| | | | | | | | | | | | | | | | | | | | | | |
| Max score ≥ 3 | | | | | 1.00 | | | | | | | 1.00 | | | | | | | 0.76 | | |
| Yes | 11 | 12.0 | 6 | 12.2 | | 17 | 12.1 | 9 | 9.8 | 4 | 8.2 | | 13 | 9.2 | 8 | 8.7 | 5 | 10.2 | | 13 | 9.2 |
| No | 81 | 88.0 | 43 | 87.8 | | 124 | 87.9 | 82 | 89.1 | 45 | 91.8 | | 127 | 90.1 | 84 | 91.3 | 43 | 87.8 | | 127 | 90.1 |
| Missing | | | | | | | | 1 | 1.1 | | | | 1 | 0.7 | | | 1 | 2.0 | | 1 | 0.7 |
| Total | 92 | 100 | 49 | 100 | | 141 | 100 | 92 | 100 | 49 | 100 | | 141 | 100 | 92 | 100 | 49 | 100 | | 141 | 100 |

[1]Fisher's exact test of the association between occupation and severe cartilage lesions among observations with non-missing cartilage lesions.

**Table 2:** Prevalence of MRI-detected cartilage lesions in the total knee among 92 male Danish floor layers and 49 male Danish graphic designers.

| Lesions of the knee | Either knee | | | | | | | Left knee | | | | | | | Right knee | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Occupation | | | | | Total | | Occupation | | | | | Total | | Occupation | | | | | Total | |
| | Floor layers | | Graphic designers | | Fisher's exact | | | Floor layers | | Graphic designers | | Fisher's exact[1] | | | Floor layers | | Graphic designers | | Fisher's exact[1] | | |
| | N | % | N | % | P | N | % | N | % | N | % | P | | | N | % | N | % | P | N | % |
| Max lesion score of the knee | | | | | 0.64 | | | | | | | 0.81 | | | | | | | 0.30 | | |
| 0 | 37 | 40.2 | 16 | 32.7 | | 53 | 37.6 | 46 | 50.0 | 21 | 42.9 | | 67 | 47.5 | 50 | 54.3 | 22 | 44.9 | | 72 | 51.1 |
| 1 | | | | | | | | | | | | | | | 1 | 1.1 | | | | 1 | 0.7 |
| 2 | 9 | 9.8 | 4 | 8.2 | | 13 | 9.2 | 11 | 12.0 | 6 | 12.2 | | 17 | 12.1 | 4 | 4.3 | 2 | 4.1 | | 6 | 4.3 |
| 3 | 6 | 6.5 | 3 | 6.1 | | 9 | 6.4 | 6 | 6.5 | 4 | 8.2 | | 10 | 7.1 | 6 | 6.5 | 4 | 8.2 | | 10 | 7.1 |
| 4 | 9 | 9.8 | 4 | 8.2 | | 13 | 9.2 | 3 | 3.3 | 4 | 8.2 | | 7 | 5.0 | 8 | 8.7 | 1 | 2.0 | | 9 | 6.4 |
| 5 | 10 | 10.9 | 4 | 8.2 | | 14 | 9.9 | 9 | 9.8 | 3 | 6.1 | | 12 | 8.5 | 6 | 6.5 | 3 | 6.1 | | 9 | 6.4 |
| 6 | 6 | 6.5 | 9 | 18.4 | | 15 | 10.6 | 7 | 7.6 | 6 | 12.2 | | 13 | 9.2 | 5 | 5.4 | 9 | 18.4 | | 14 | 9.9 |
| 7 | 13 | 14.1 | 8 | 16.3 | | 21 | 14.9 | 8 | 8.7 | 5 | 10.2 | | 13 | 9.2 | 11 | 12.0 | 6 | 12.2 | | 17 | 12.1 |
| 8 | 2 | 2.2 | 1 | 2.0 | | 3 | 2.1 | 1 | 1.1 | | | | 1 | 0.7 | 1 | 1.1 | 1 | 2.0 | | 2 | 1.4 |
| Missing | | | | | | | | 1 | 1.1 | | | | 1 | 0.7 | | | 1 | 2.0 | | 1 | 0.7 |
| | | | | | | | | | | | | | | | | | | | | | |
| Max score ≥ 3 | | | | | 0.38 | | | | | | | 0.47 | | | | | | | 0.29 | | |
| Yes | 46 | 50.0 | 29 | 59.2 | | 75 | 53.2 | 34 | 37.0 | 22 | 44.9 | | 56 | 39.7 | 37 | 40.2 | 24 | 49.0 | | 61 | 43.3 |
| No | 46 | 50.0 | 20 | 40.8 | | 66 | 46.8 | 57 | 62.0 | 27 | 55.1 | | 84 | 59.6 | 55 | 59.8 | 24 | 49.0 | | 79 | 56.0 |
| Missing | | | | | | | | 1 | 1.1 | | | | 1 | 0.7 | | | 1 | 2.0 | | 1 | 0.7 |
| Total | 92 | 100 | 49 | 100 | | 141 | 100 | 92 | 100 | 49 | 100 | | 141 | 100 | 92 | 100 | 49 | 100 | | 141 | 100 |

[1]Fisher's exact test of the association between occupation and severe knee cartilage lesions among observations with non-missing cartilage lesions.

**Table 3:** Association between potential risk factors and MRI-detected knee cartilage lesions in the total knee among 92 male Danish floor layers and 49 male Danish graphic designers.

| | Model 1 (mutually adjusted) | | | Model 2 (mutually adjusted) | | | Model 3 (mutually adjusted) | | | Model 4 (mutually adjusted) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Exposure Variable | Odds Ratio | 95% CI[1] | P | Odds Ratio | 95% CI[1] | P | Odds Ratio | 95% CI[1] | P | Odds Ratio | 95% CI[1] | P |
| Occupation | | | | | | | | | | | | |
| *Floor layer* | 0.85 | (0.24; 2.93) | 0.79 | 0.87 | (0.25; 3.02) | 0.83 | 0.88[2] | (0.26; 3.04) | 0.84 | 0.93[2] | (0.25; 3.48) | 0.91 |
| *Graphic designer* | 1 | - | | 1 | - | | 1 | - | | 1 | - | |
| Age *(per 10 years)* | 5.50 | (1.97; 15.3) | 0.0013 | 5.12 | (1.86; 14.1) | 0.0017 | 4.86 | (1.64; 14.4) | 0.0046 | 4.91 | (1.65; 14.6) | 0.0045 |
| BMI *(per 5 kg/m²)* | | | | 1.70 | (0.78; 3.69) | 0.18 | 1.71 | (0.79; 3.70) | 0.17 | 1.70 | (0.78; 3.69) | 0.18 |
| Floor layer seniority *(per 10 years)* | | | | | | | 1.11 | (0.49; 2.48) | 0.81 | 1.11 | (0.49; 2.49) | 0.80 |
| Earlier knee injuries | | | | | | | | | | | | |
| *Yes* | | | | | | | | | | 1.02 | (0.15; 7.07) | 0.98 |
| *No* | | | | | | | | | | 1 | - | |
| Participates in knee straining sports | | | | | | | | | | | | |
| *Yes* | | | | | | | | | | 1.20 | (0.36; 4.06) | 0.77 |
| *No* | | | | | | | | | | 1 | - | |

[1]CI: confidence interval.

[2]Estimated odds ratio of floor layers of 32-years' seniority compared to graphic designers.

The prevalence of MRI-detected knee cartilage lesions in the medial TF posterior area did not differ between the two occupations (Table 1; all $p \geq 0.50$) neither did the prevalence of MRI-detected knee cartilage lesions in the total knee as measured by the maximum lesions in any area of the knee (Table 2; all $p \geq 0.29$). Because of the low number of observed MRI-detected knee cartilage lesions in the medial TF posterior area (13 in the left knee and 13 in the right knee, affecting 17 men in total, see Table 1), only the MRI-detected knee cartilage lesions in the total knee were considered in the logistic regression analyses. The analyses showed no statistically significant effect of occupation after adjustment, but with wide confidence limits including odds ratios from around 0.25 to 3. The only covariate of statistical significance for the MRI-detected knee cartilage lesions in the total knee was age, showing a five-fold increase in the odds of MRI-detected knee cartilage lesions per 10 years' difference in age, but the confidence limits for the estimated effects of the other potential risk factors were wide (Table 3).

There was a clear association between MRI-detected knee cartilage lesions and self-reported knee complaints within the previous year ($p = 0.028$, Table 4). For self-reported knee complaints within the previous year, there was no sign of an increase in the odds with age, but there was an increase with BMI: around 60 percent per 5 kg/m$^2$ difference in BMI (Table 5). There was a strong association between MRI-detected knee cartilage lesions and self-reported knee complaints within the previous year, corresponding to a 2.4 to 2.5-fold increase in the odds of self-reported knee complaints for men *with* as compared to men *without* MRI-detected knee cartilage lesions (Table 6). The estimated associations with the other potential risk factors did not change, indicating that MRI-detected knee cartilage lesions were an independent risk factor for self-reported knee complaints.

**Table 4:** Association between MRI-detected cartilage lesions in the total knee and self-reported knee complaints within the last year among 92 male Danish floor layers and 49 male Danish graphic designers.

| | Max MRI-detected cartilage lesion score ≥ 3 | | | | Fisher's exact test | | |
|---|---|---|---|---|---|---|---|
| | Yes | | No | | | All | |
| | N | % | N | % | P | N | % |
| Self-reported knee complaints | | | | | 0.028 | | |
| *Yes* | 44 | 58.7 | 26 | 39.4 | | 70 | 49.6 |
| *No* | 31 | 41.3 | 40 | 60.6 | | 71 | 50.4 |

## Discussion

### Overall summary

In this study we could not show an association between occupations *with* and *without* kneeling work activities and MRI-detected cartilage lesions in the medial TF posterior area or in the total knee, respectively. Our hypotheses of a higher prevalence of

**Table 5:** Association between potential risk factors and self-reported knee complaints within the previous 12 months among 92 male Danish floor layers and 49 male Danish graphic designers.

| | Model 1 (mutually adjusted) | | | Model 2 (mutually adjusted) | | | Model 3 (mutually adjusted) | | | Model 4 (mutually adjusted) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Exposure Variable | Odds Ratio | 95% CI[1] | P | Odds Ratio | 95% CI[1] | P | Odds Ratio | 95% CI[1] | P | Odds Ratio | 95% CI[1] | P |
| Occupation | | | | | | | | | | | | |
| *Floor layer* | 0.99 | (0.49; 2.02) | 0.98 | 1.01 | (0.49; 2.08) | 0.98 | 0.97[2] | (0.47; 2.02) | 0.94 | 0.99[2] | (0.46; 2.16) | 0.99 |
| *Graphic designer* | 1 | - | | 1 | - | | 1 | - | | 1 | - | |
| Age *(per 10 years)* | 0.85 | (0.51; 1.40) | 0.52 | 0.80 | (0.48; 1.33) | 0.39 | 1.02 | (0.57; 1.82) | 0.95 | 1.01 | (0.57; 1.81) | 0.97 |
| BMI *(per 5 kg/m$^2$)* | | | | 1.60 | (1.01; 2.51) | 0.044 | 1.57 | (0.99; 2.48) | 0.053 | 1.57 | (0.99; 2.48) | 0.054 |
| Floor layer seniority *(per 10 years)* | | | | | | | 0.63 | (0.38; 1.04) | 0.070 | 0.63 | (0.38; 1.04) | 0.071 |
| Earlier knee injuries | | | | | | | | | | | | |
| *Yes* | | | | | | | | | | 1.57 | (0.50; 4.94) | 0.44 |
| *No* | | | | | | | | | | 1 | - | |
| Participates in knee straining sports | | | | | | | | | | | | |
| *Yes* | | | | | | | | | | 0.83 | (0.41; 1.70) | 0.61 |
| *No* | | | | | | | | | | 1 | - | |

[1]CI: confidence interval.

[2]Estimated odds ratio of floor layers of 32-years' seniority compared to graphic designers.

**Table 6:** Risk (odds ratio) between potential risk factors for MRI-detected knee cartilage lesions and self-reported knee complaints within the previous 12 months among 92 male Danish floor layers and 49 male Danish graphic designers.

| | Model 1 (mutually adjusted) | | | Model 2 (mutually adjusted) | | | Model 3 (mutually adjusted) | | | Model 4 (mutually adjusted) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Exposure Variable | Odds Ratio | 95% CI[1] | P | Odds Ratio | 95% CI[1] | P | Odds Ratio | 95% CI[1] | P | Odds Ratio | 95% CI[1] | P |
| MRI-detected severe knee cartilage lesions in either knee | | | | | | | | | | | | |
| *Yes* | 2.49 | (1.22; 5.08) | 0.0119 | 2.42 | (1.18; 4.96) | 0.0163 | 2.43 | (1.17; 5.04) | 0.0170 | 2.44 | (1.17; 5.08) | 0.0170 |
| *No* | 1 | - | | 1 | - | | 1 | - | | 1 | - | |
| Occupation | | | | | | | | | | | | |
| *Floor layer* | 1.02 | (0.49; 2.11) | 0.96 | 1.03 | (0.49; 2.17) | 0.93 | 1.00[2] | (0.47; 2.12) | 0.99 | 1.00[2] | (0.45; 2.23) | 0.99 |
| *Graphic designer* | 1 | - | | 1 | - | | 1 | - | | 1 | - | |
| Age *(per 10 years)* | 0.71 | (0.42; 1.21) | 0.21 | 0.68 | (0.39; 1.16) | 0.16 | 0.86 | (0.47; 1.58) | 0.63 | 0.85 | (0.46; 1.56) | 0.60 |
| BMI *(per 5 kg/m$^2$)* | | | | 1.56 | (0.98; 2.49) | 0.062 | 1.54 | (0.96; 2.47) | 0.075 | 1.54 | (0.96; 2.46) | 0.075 |
| Floor layer seniority *(per 10 years)* | | | | | | | 0.63 | (0.37; 1.05) | 0.073 | 0.63 | (0.37; 1.05) | 0.074 |
| Earlier knee injuries | | | | | | | | | | | | |
| *Yes* | | | | | | | | | | 1.50 | (0.47; 4.76) | 0.49 |
| *No* | | | | | | | | | | 1 | - | |
| Participates in knee straining sports | | | | | | | | | | | | |
| *Yes* | | | | | | | | | | 0.79 | (0.38; 1.65) | 0.54 |
| *No* | | | | | | | | | | 1 | - | |

[1]CI: confidence interval.

[2]Estimated odds ratio of floor layers of 32-years' seniority compared to graphic designers.

cartilage lesions in floor layers as compared to graphic designers, and a higher prevalence of lesions located in the medial TF posterior area in floor layers, were not supported. MRI-detected knee cartilage lesions were statistically significant associated with self-reported knee complaints. The hypothesis of an association between self-reported knee complaints and findings of degenerative cartilage changes was therefore supported in this study.

### Relation to other studies

Previous studies have found an association between occupational kneeling work activities (i.e., squatting, kneeling, heavy lifting, and stair climbing) and increasing age, as well as increasing BMI and radiographic knee OA [16-22]. However, the present study examining the association between degenerative cartilage lesions assessed by MRI and potential risk factors did not find statistically significant associations with occupation or BMI, but the confidence limits for the potential effects were wide. Only age was statistically significant associated with MRI-detectable knee cartilage lesions. Two previous studies have used MRI to evaluate cartilage knee lesions in relation to different kneeling activities (i.e., squatting, kneeling, heavy lifting, and stair climbing) among men. Amin, et al. examined the relation between occupational exposures to frequent squatting/kneeling and/or heavy lifting with cartilage morphology, at the TF and patellofemoral (PF) joints in 192 men (mean age 69 years) with symptomatic knee OA. They found that occupational exposures to frequent squatting/kneeling and heavy lifting increased the risk for knee cartilage degeneration in the PF joint. There were too few men in the study who reported occupational exposures to squatting or kneeling without heavy lifting for adequate evaluation of the relation with cartilage degeneration, and there was insufficient information on the duration of exposures to the occupational activities [23]. The other study examined the association of baseline frequent knee bending activities with the prevalence and progression of cartilage abnormalities over 3 years in 115 subjects (55 males, 60 females). They showed that frequent knee bending activities were associated with an increased risk of presence and progression of knee cartilage lesions in the PF compartment in asymptomatic middle-aged subjects. This study included middle-aged subjects with a mean age of 50.8 years and did not correlate the development of morphological abnormalities with the development of symptoms [24].

In accordance with the results of the present study, Baum, et al. found a relationship between knee cartilage lesions and knee pain [25]. They demonstrated that cartilage lesions in subjects without radiographic OA, but with OA risk factors, were significantly more common in those with knee pain, as compared to those without knee pain. Both our study and the study by Baum, et al. found an association between knee pain/complaints and observed degenerative cartilage knee lesions. Since articular cartilage is without nociceptors, cartilage lesions cannot directly generate pain. The source of nociceptive stimuli may therefore arise from other periarticular structures that are richly innervated, e.g., the subchondral bone and bone marrow, periosteum, synovium, ligaments and the joint capsule [6,26]. Loss of articular cartilage in OA reduces its capacity to absorb impact stresses, which places a greater load on the underlying subchondral bone and periosteum [25]. Increased trabecular bone pressure, local ischemia, and inflammation are all possible stimuli that can cause pain in the knee [26,27]. Therefore, observed knee cartilage lesions may be a proxy for other damage's in the knee, which can cause pain. Earlier studies of floor layers found a higher prevalence of knee OA among floor layers (14%) as compared to graphic designers or compositors (6%). The differences increased for workers aged 50 years or more [2]. In a new investigation of the same cohort we also found a higher prevalence of knee OA (OR = 3.6, 95%CI 1.1-12.0) and of MRI verified meniscal lesions (OR = 2.28, 95%CI 1.10 - 4.98) among floor layers as compared to graphic designers [3,4]. These disorders alone cannot explain the much higher prevalence of knee complaints observed among floor layers (38% as compared to 15% among graphic designers) [28]. The present study indicates that MRI-detectable knee cartilage lesions may contribute to the explanation for knee pain, but since we found no difference between floor layers and graphic designers regarding MRI-detectable cartilage lesions and knee complaints, we cannot conclude whether these lesions contributes to the explanation of why floor layers in particular have knee pain and develop OA.

### Strengths and limitations

The strength of this study is the large number of MRI scans in workers from two trades. Previous studies in this area have primarily been based on radiography, but conventional radiography is limited by its inability to directly visualize articular cartilage, in which the earliest signs of OA occur. As a non-invasive technique with no ionizing radiation exposure, MRI has become an important modality for the assessment of pathological changes in knee cartilage [6,7]. As our understanding of the association between knee cartilage lesions and knee pain symptoms is sparse especially concerning factors which might lead to a shift from an asymptomatic to a symptomatic state such MRI information may be an important tool for research within this field.

However, this study also had limitations. Graphic designers had a greater tendency than floor layers to participate if knee symptoms were present [4]. Results could therefore be biased if the decision to participate in the study was differentially influenced by previous or current knee complaints. This may have led to an underestimation of the difference in the level of knee complaints between the two study groups and thus, explain the missing differences between occupation and knee complaints in our study. Differential selection of workers toward different occupations depending on their health status may be expected in occupations with high physical demands. A healthy-worker selection may therefore have influenced results either in terms of primary selection of the healthier workers into the trade, or in terms of longer continuance in the trade for the healthier workers. Such selection mechanisms would typically result in an underestimation of the investigated association and differences in outcomes between the two trade groups in this study might therefore be seen as a conservative estimate of the true difference. We tried to reduce such possible selection bias by including workers who had ceased the occupation. Our study lacks an evaluation of inter- and intra-observer reproducibility, as all the MR images were evaluated by one radiologist. This may affect how many persons are described with cartilage lesions, but it is not likely to have an impact on the difference between the trade groups, since the radiologist was blinded to occupational affiliation for the participants from Copenhagen, and a sensitivity analysis restricted to participants from Copenhagen gave similar results. In addition, excellent inter- and intra-observer reproducibility in the assessment of cartilage abnormalities has been reported in earlier studies [24,29,30]. As shown by the wide confidence limits for the differences between the two occupational groups, the power of the study was limited. Finally, due to the non-randomized, cross-sectional study design, we cannot make any causal inferences from our findings.

Overall, this study did not demonstrate a higher prevalence of cartilage lesions in the knees among workers with a high degree of kneeling work activities. There was an association between MRI-demonstrated knee cartilage lesions and self-reported knee-complaints. Thus, in spite of the observed association between knee complaints and MRI-detectable knee cartilage lesions, the lack of a difference between the two occupations may be explained by either that knee cartilage lesions are truly not associated with occupational exposure to kneeling work, or that self-selection into our study based on knee complaints may have distorted the observed association.

## Conclusions

This study did not show an association between MRI-detected knee cartilage lesions and occupations *with* and *without* kneeling work activities. This calls for further research that can clarify the mechanisms that cause self-reported knee complaints in occupations with knee-demanding work.

## Competing Interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

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