Occupation-Related Squatting, Kneeling, and Heavy Lifting and the Knee Joint: A Magnetic Resonance Imaging-Based Study in Men

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ABSTRACT. ***Objective.*** We examined the relation between occupational exposures to frequent squatting/kneeling and/or heavy lifting with cartilage morphology, based on magnetic resonance imaging (MRI), at the tibiofemoral and patellofemoral joints in men and determined which compartments are most affected.

Methods. We evaluated 192 men with symptomatic knee osteoarthritis (OA). The more symptomatic knee was imaged using MRI. Cartilage was scored using the Whole Organ MRI Score semiquantitative method at the medial and lateral tibiofemoral joint and patellofemoral joint. Occupational exposures to frequent squatting, kneeling, and/or heavy lifting were assessed using a validated questionnaire.

Results. Among the 192 men [mean (± standard deviation) age 69 ± 9 yrs, body mass index (BMI) 30.8 ± 4.7 kg/m^2], those reporting occupational exposure to squatting/kneeling alone, heavy lifting alone, both squatting/kneeling and heavy lifting, or none of these activities numbered 7, 40, 47, and 98, respectively. Compared with men with no occupational exposure to these activities, and following adjustment for age, BMI, and history of knee injury or surgery, we found that men reporting occupational exposures to both squatting/kneeling and heavy lifting had a modest increased risk for worse cartilage morphology scores at the patellofemoral joint [odds ratio (OR) 1.8, 95% confidence interval (CI) 1.1 to 3.2] and medial tibiofemoral joint (OR 1.6, 95% CI 0.9, 3.0), although the latter did not reach statistical significance.

Conclusion. Men with frequent occupational squatting/kneeling and heavy lifting have a greater likelihood for worse cartilage morphology scores at the patellofemoral joint. These findings add support to the important role of biomechanical loading on the pathogenesis of knee OA, particularly patellofemoral OA. (First Release July 1 2008; J Rheumatol 2008;35:1645–9)

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Excessive loading across the knee joint is considered an important risk factor in the pathogenesis of knee osteoarthritis (OA)[1,2]. It is well recognized that certain activities impart greater loads across the knee than others, especially when the knee is flexed beyond 90 degrees, and therefore, may be more injurious to cartilage[3-5]. Indeed, several studies have reported that squatting or kneeling activities are particularly associated with an increased risk of knee OA[6-17]. Further, according to published studies, occupations requiring a combination of heavy lifting along with squatting or kneeling pose an especially high rate of knee OA[7,8,10,16]. It is increasingly recognized that for the same given activity, such as squatting, the tibiofemoral and patellofemoral joints are exposed to different loads and contact stress[3-5]. Nevertheless, the compartment in the knee most affected by cartilage degeneration from exposure to occupational activities involving squatting/kneeling, and/or heavy lifting, is not known. Previous studies or reviews reporting a relation between occupational exposure to squatting or kneeling, with or without heavy lifting, and knee OA have been based on radiographs[6-13,15-17], which are insensitive to early changes in cartilage morphology[18], and are not suited to identify the location where cartilage is most affected, particularly cartilage abnormalities at the posterior tibiofemoral

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compartment[18]. Magnetic resonance imaging (MRI) based studies can directly visualize cartilage in all compartments of the knee. Understanding how occupational exposures to squatting/kneeling and/or heavy lifting may affect cartilage in different compartments of the knee joint may provide further insights into the role of biomechanical loading in the pathogenesis of knee OA.

In a cohort of individuals with symptomatic knee OA who had MRI evaluations of their more symptomatic knee, we studied the association between cartilage morphology at the knee and past occupations that involved frequent squatting/kneeling and/or heavy lifting. The goal was to identify whether past occupational exposure to frequent squatting/kneeling and/or heavy lifting was associated with an increased likelihood of cartilage degeneration, based on MRI, at the tibiofemoral and/or patellofemoral joint, and also to determine the location within each compartment or joint where cartilage degeneration was most frequently observed.

MATERIALS AND METHODS

Study participants. Study subjects were participants in a natural history study of symptomatic knee OA (Boston Osteoarthritis of the Knee Study) whose recruitment has been described in detail[19,20]. Potential participants had to have answered yes to the following 2 questions: "Do you have pain, aching or stiffness in one or both knees on most days" and "Has a doctor ever told you that you have knee arthritis?". A subsequent interview was conducted to exclude other forms of arthritis. Eligible participants all had to have an osteophyte present on radiographs of their symptomatic knee, and be able to walk, with or without the aid of a cane. There were 324 subjects (201 men and 123 women) who were enrolled in the natural history study and all participants met American College of Rheumatology criteria for symptomatic knee OA[21].

We focused our study on the men recruited, as too few women reported exposures during past employment to the activities of interest. The majority of men in the study received their care through the Veterans Administration (VA) Boston Healthcare System and had been recruited from their clinics, while the rest were recruited from the community[19,20].

The minimum age of entry for men was 45 years. They were weighed, with shoes off, on a balance beam scale, and height was measured. Participants had imaging studies of knees performed, including MRI, and completed questionnaire data as part of the study protocol. The institutional review boards of Boston University Medical Center and the VA Boston Healthcare System approved the study and written informed consent was obtained from all study participants. For the purposes of this particular analysis, we used the first knee MRI imaging available from participants to examine the relation between cartilage morphology on MRI with past occupational exposures to frequent squatting/kneeling and/or heavy lifting.

Assessment of occupational exposure to squatting/kneeling and heavy lifting. Using a validated questionnaire on past employment activity[8], we asked subjects, "for the job or occupation you did for the longest time, did you do the following nearly every day?" and asked subjects to mark the particular activities they did in their occupation. Among the activities queried were bending for 2 h or more, walking for 2 h or more over level ground, kneeling for 30 min or more, squatting for 30 min or more, climbing a total of 5 or more flights of stairs, lifting or moving objects weighing 25 lbs, driving for 4 h or more, or none of the above. We focused on squatting, kneeling, and heavy lifting, as previous studies have shown positive relations between these occupational exposures and radiographic knee OA[7,8,10,16]. We categorized participants into 4 groups according to whether they reported occupational exposure to (1) frequent squatting or kneeling, but not heavy lifting; (2) frequent heavy lifting, but not squatting or kneeling; (3) frequent squatting or kneeling as well as heavy lifting; or (4) none of these activities.

MRI evaluation of knee articular cartilage. Participants without contraindications underwent MRI of the more symptomatic knee. MRI were acquired on a Signa 1.5-Tesla MRI system (GE Medical Systems, Milwaukee, WI, USA) using a phased-array knee coil. An anchoring device for the ankle and knee was used to ensure uniformity of positioning between patients. The imaging protocol included sagittal spin-echo proton density and T2-weighted images, as well as coronal and axial spin-echo, fat-saturated, proton-density, and T2-weighted images (repetition time 2200 ms; time to echo 20/80 ms) with a slice thickness of 3 mm, a 1-mm interslice gap, 1 excitation, a field of view of 11-12 cm, and a matrix of 256 × 192 pixels.

Cartilage morphology scoring. Cartilage morphology at the tibiofemoral and patellofemoral joint was assessed using the Whole Organ MRI Score (WORMS) semiquantitative method for knee OA[22]. Three trained readers scored all MRI, as described[18], and were blind to occupational status of subjects. The majority of subjects' MRI (86%) were read by a musculoskeletal radiologist and a musculoskeletal researcher, from the Osteoporosis and Arthritis Research Group of the University of California, San Francisco, reading together[18]. Cartilage morphology was scored at all 5 regions of each compartment (medial and lateral) of the tibiofemoral joint (central and posterior femur; anterior, central, and posterior tibia) and at all 4 regions of the patellofemoral joint (the medial and lateral compartments of the patella and anterior femur surfaces). Cartilage morphology was scored using a 0–6 scale: 0 = normal thickness and signal; 1 = normal thickness but increased signal on T2-weighted images; 2 = solitary focal defect < 1 cm in greatest width; 3 = areas of partial-thickness defects (< 75% of the region) with areas of preserved thickness; 4 = diffuse partial-thickness loss of cartilage (≥ 75% of the region); 5 = areas of full-thickness loss (< 75% of the region) with areas of partial thickness loss; 6 = diffuse full-thickness loss (≥ 75% of the region)[22]. Intraclass correlation coefficients (ICC) on agreement for cartilage readings ranged from 0.72 to 0.97 for readers[18].

As described, we collapsed the original WORMS cartilage scores, which were read on a 0–6 scale, to a 0–4 scale for the purposes of analyses[18]. This was done as grade 1 represents a change in signal in cartilage of otherwise normal morphology, grades 2 and 3 represent similar types of abnormality of the cartilage, and scores of grade 1 and 2 were extremely infrequent among the MRI read in our study population. The original WORMS scores of 0 and 1 were therefore collapsed to 0, the original scores of 2 and 3 were collapsed to 1, and the original scores of 4, 5, and 6 were considered 2, 3, and 4, respectively, in the new scale.

Statistical analysis. The men were categorized into 1 of 4 groups, according to their reported occupational exposure to squatting/kneeling, heavy lifting, both, or none of these activities. We then examined the relation between the exposure to these different occupational activities and cartilage morphology within the tibiofemoral and patellofemoral joints. The medial and lateral compartments of the tibiofemoral joint were analyzed separately. Cartilage morphology (0–4) was analyzed as a dichotomous variable (≥ 2 vs 0–1) using a logistic regression model. A generalized estimating equation correction was applied to regression models to account for the association of cartilage morphology scores between regions within a knee compartment or joint. For both the tibiofemoral and patellofemoral joint, we also examined whether certain regions within a compartment or joint were more likely to be affected for a given activity. All analyses were adjusted for age, body mass index (BMI), and history of knee injury or knee surgery, if it involved the knee that underwent MRI. Statistical analyses were performed using SAS software (SAS Institute, Cary, NC, USA; release 8.2).

RESULTS

Among the 201 men with knee OA recruited, 196 had no contraindications to MRI, of whom 192 had MRI that were readable for cartilage morphology. The mean age (± SD) of these 192 men was 69 ± 9 years and the average BMI was 30.8 ± 4.7 kg/m^2.

The number of men reporting past occupational exposure to squatting/kneeling alone, heavy lifting alone, both squatting/kneeling and heavy lifting, or none of these activities numbered 7, 40, 47, and 98, respectively. As there were too few men who reported having had jobs that required only squatting or kneeling to draw any robust conclusions regarding this particular exposure, we present our results excluding these 7 men, although their inclusion did not change results or our overall findings for the other occupational exposures of interest. Characteristics of men categorized by their past occupational exposure to frequent heavy lifting alone, frequent squatting/kneeling and heavy lifting, or neither of these activities are shown in Table 1.

The percentage of knees with cartilage morphology scores ≥ 2 in any region for a given compartment or joint, along with the percentage of regions within a compartment or joint with cartilage morphology scores ≥ 2 are presented in Table 2. When compared to men who did not report exposure in their occupations to either frequent squatting/kneeling and/or heavy lifting, men who reported both frequent squatting/kneeling and heavy lifting had an increased risk for worse cartilage morphology scores at the patellofemoral joint [odds ratio (OR) 1.8, 95% confidence interval (CI) 1.1, 3.2]. There was also a modest increased risk noted at the medial tibiofemoral compartment (OR 1.6, 95% CI 0.9, 3.0), although it did not reach statistical significance. Although the number of men in our study with cartilage morphology scores ≥ 2 isolated to the patellofemoral joint was small (n = 18), in additional exploratory analyses we still observed a strong and significant association between isolated patellofemoral disease and occupational exposure to both squatting/lifting and heavy lifting (data not shown). We were not able to identify a significant increase in risk for worse cartilage morphology scores with heavy lifting alone, in either the medial or lateral tibiofemoral joint, or patellofemoral joint (Table 2).

Table 1. Characteristics of men with knee osteoarthritis by occupational exposure.

	Occupational Exposures		
	Heavy Lifting	Squatting/Kneeling and Heavy Lifting	Neither
n	40	47	98
Age, yrs (mean ± SD)	69 ± 9	64 ± 9	70 ± 9
Body Mass Index, kg/m^2 (mean ± SD)	30.5 ± 4.9	31.2 ± 4.3	31.0 ± 4.9
% prior injury (to imaged knee)*	44	47	33
% prior knee surgery (to imaged knee)*	33	36	31

* Based on self-report. SD: Standard deviation.

We explored whether the posterior surface of the femur or central weight-bearing regions of the tibia and femur were more likely to show differences in cartilage morphology among groups, especially in men who were involved in past occupational activities requiring both squatting/kneeling and heavy lifting, but found no significant differences. In contrast, when we compared the cartilage morphology scores at the anterior femur or patellar surface, the 2 surfaces of the patellofemoral joint, we found among men exposed to both squatting/kneeling and heavy lifting that the odds for cartilage morphology scores ≥ 2 were higher at the patellar surface (OR 3.0, 95% CI 1.5, 6.0).

DISCUSSION

We present unique findings, based on MRI, regarding the effects of occupational exposure to frequent squatting/kneeling and heavy lifting on cartilage in the knee, and suggest that such exposures, as part of employment, increase the risk of cartilage degeneration particularly at the patellofemoral joint.

Our findings add further support to the biomechanical role of loading on the pathogenesis of knee OA and are consistent with those predicted by gait studies, which have suggested a marked increase in contact stress and loading across the knee during flexion beyond 90 degrees. Tibiofemoral contact stress increases by approximately 50% from walking to going up and down stairs, while patellofemoral contact stress during this same action generally doubles and reaches far higher absolute levels than estimated contact stress across the tibiofemoral joint[3]. Activities requiring more flexion than required by stair-climbing appear to impart greater loads across the knee joint. Dahlkvist and colleagues reported that knee forces during squatting were much higher at the patellofemoral joint than at the tibiofemoral joint[4]. A study incorporating kinetic and kinematic evaluation of deep knee flexion, such as squatting or kneeling, noted that net sagittal moments were 2–3 times higher during these activities than they were during walking[5]. These high sagittal moments would be expected to increase loads across the patellofemoral joint. While repeated squatting and kneeling may well have consequences for the tibiofemoral joint, these studies suggest that the part of the knee most likely to be exposed to the highest load during such activities is the patellofemoral joint. Any increased knee load conferred by squatting or kneeling is further magnified when heavy items are carried. Not only is loading across the joint increased with heavy lifting, but patellofemoral joint contact area increases with flexion and is greater with loading compared to unloading[23]. Our study results suggest that increased loading across the knee joint, such as during activities involving squatting/kneeling and heavy lifting, may have important longterm effects on carti-

Table 2. Risk for worse cartilage morphology scores at the medial and lateral tibiofemoral joint and the patellofemoral joint in men with knee osteoarthritis by occupational exposure.

	Occupational Exposures		
	Heavy Lifting	Squatting/Kneeling and Heavy Lifting	Neither
Medial tibiofemoral joint			
% knees with cartilage morphology scores ≥ 2 in any region*	64	67	67
% regions with cartilage morphology scores ≥ 2*	49	50	44
Crude odds ratio (95% CI)	1.2 (0.6, 2.3)	1.2 (0.7, 2.2)	Referent
Adjusted odds ratio (95% CI)†	1.4 (0.7, 2.6)	1.6 (0.9, 3.0)	Referent
Lateral tibiofemoral joint			
% knees with cartilage morphology scores ≥ 2 in any region*	33	30	31
% regions with cartilage morphology scores ≥ 2*	16	11	14
Crude odds ratio (95% CI)	1.2 (0.5, 2.8)	0.8 (0.4, 1.7)	Referent
Adjusted odds ratio (95% CI)†	1.2 (0.5, 2.7)	0.8 (0.4, 1.8)	Referent
Patellofemoral joint			
% knees with cartilage morphology scores ≥ 2 in any region*	60	72	47
% regions with cartilage morphology scores ≥ 2*	32	34	24
Crude odds ratio (95% CI)	1.5 (0.8, 2.6)	1.6 (1.0, 2.7)	Referent
Adjusted odds ratio (95% CI)†	1.5 (0.8, 2.7)	1.8 (1.1, 3.2)	Referent

* Equivalent to original Whole Organ MRI Score ≥ 4. † Adjusted for age, body mass index, and history of injury or surgery to the imaged knee.

lage at the patellofemoral joint, in particular. Our findings also suggest that the cartilage along the patellar surface, which may be exposed to greater shear stresses than the femoral surface during squatting[24], appears to be particularly vulnerable.

Our study has limitations. We do not have an assessment of recreational or non-employment exposure to squatting/kneeling or heavy lifting. However, the overall exposure to these particular activities is likely to be greatest during employment. While we used a validated questionnaire to identify occupational exposure to squatting, kneeling, and heavy lifting, we do not have enough information on the duration of exposure to the occupational activities of interest among the different participants to assess this potential influence on results. Among men reporting exposure to both squatting/kneeling and heavy lifting, we have insufficient information available to discriminate whether these exposures occurred concurrently or not. Too few men reported an occupational exposure to squatting or kneeling alone for adequate evaluation. Our study participants were also recruited largely from the VA. While we have adjusted for history of knee injury or surgery, this information was based on self-report. Our study results are also based on cross-sectional data, thus we are unable to assess the relation between frequent squatting/kneeling and/or heavy lifting on longitudinal cartilage loss. We could not assess the effect of exposure to these particular occupational activities in women from our study cohort, as too few reported past employment involving these activities.

Compared to radiographic studies that involved individuals without any knee OA as controls or cohort members, our study participants all had knee OA (including those not exposed to occupational activities) and therefore, our measures of risk are not comparable to these other studies. Even so, our results are similar to those employing radiographic methods to evaluate the relation of occupational activities and knee OA[7,8,10,16]. These studies reported a relation between occupational squatting/kneeling and heavy lifting and knee OA, although the compartment affected was not specified[7,8,10,16]. Most of these studies examined only the tibiofemoral joint[7,10,16] and results from these studies likely speak to disease in the medial compartment, since it is the site often affected in the tibiofemoral joint. One study incorporated lateral radiographic views[8] to permit assessment of the patellofemoral joint and suggested that the association of occupational activities with knee OA was stronger for the tibiofemoral joint. However, as noted by these authors, lateral views may not be sensitive to pathology in the patellofemoral joint[8], which may account, in part, for why their findings differ from ours. Further, joint space narrowing at the tibiofemoral joint, which is assessed on knee radiographs, is an indirect assessment of cartilage, and represents meniscal extrusion as well as thinning of cartilage[25]. Our report is the first to examine the effect of occupational exposures of squatting/kneeling and/or heavy lifting on the different compartments of the knee using MRI to assess cartilage directly.

We report unique findings, based on MRI, that occupational exposures to both heavy lifting and frequent squatting/kneeling increase the risk for knee cartilage degeneration, particularly at the patellofemoral joint, in men. Our findings support an important biomechanical role of loading extremes on the pathogenesis of knee OA at the patellofemoral joint.

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