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Association of Frequent Knee Bending Activity with Focal Knee Lesions Detected with 3T MRI - Data from the Osteoarthritis Initiative

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Abstract

Objectives—To evaluate the association of baseline frequent knee bending activities with the prevalence and progression of cartilage and meniscal abnormalities over 3 years and to assess the effect of frequent knee bending on the different knee compartments with 3-Tesla MRI.

Methods—We studied 115 subjects without radiographic knee osteoarthritis (OA) but with risk factors for OA from the Osteoarthritis Initiative database. The inclusion criteria at baseline were: (1) age 45–55 years old, (2) BMI of 19–27 kg/m2, (3) Western Ontario and McMaster University pain score of zero, and (4) Kellgren and Lawrence grade<2. Knee bending activities (kneeling, squatting, stair climbing, and weight lifting) were assessed by questionnaire at the baseline clinic visit. Cartilage and meniscal abnormalities were graded using the Whole-Organ MRI Score (WORMS). Logistic regression was used to determine the association of frequent knee bending with cartilage and meniscal abnormalities.

Results—Frequent knee bending activities were associated with an increased risk of prevalent cartilage lesions (OR 3.63, 95%CI 1.39–9.52), in particular in the patellofemoral compartment (OR 3.09, 95%CI 1.22–7.79). The increase in risk was higher in subjects involved in ≥ 2 knee bending activities. At 3-year follow-up, individuals reporting frequent knee bending were more likely to show progression of cartilage damage (OR 4.12, 95%CI 1.27–13.36) and meniscal abnormalities (OR 4.34, 95%CI 1.16–16.32).

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Conflict of interest
None of the authors have any financial or other interests related to the manuscript submitted to Osteoarthritis and Cartilage that might constitute a potential conflict of interest.

Conclusion—Frequent knee bending activities were associated with higher prevalence of knee cartilage lesions (particularly in the patellofemoral compartment) and with an increased risk of progression of cartilage and meniscal lesions in asymptomatic middle-aged subject.

Osteoarthritis (OA) of the knee is one of the major causes of functional limitation and physical disability worldwide. The overall lifetime risk of symptomatic knee OA has been found to be as high as 40–50% (1). The etiology of knee OA is multifactorial. Excessive loading across the knee joint is considered an important risk factor in the pathogenesis of knee OA (2, 3). Activities during which the knee is flexed beyond 90 degrees are known to place a greater load across the whole knee joint and potentially cause more damage to the articular cartilage (4–6). Several studies have reported that the risk of knee OA is increased by work that involves prolonged bending of the knees (7–9). These studies, however, have relied on job title as an index of presumed workplace activity, rather than directly monitoring the particular types of repetitive knee movements (5, 10). Furthermore, it is increasingly recognized that for the given activity, the tibiofemoral and patellofemoral joints are exposed to different loads and contact stresses (4–6). Previous epidemiologic studies have mostly evaluated knee OA based on radiographs, which are insensitive to early changes in cartilage morphology, and are not well suited for identification of the location where cartilage is most affected (7, 8, 11–19). Magnetic resonance imaging (MRI) based studies can directly visualize structural morphology in all compartments of the knee, therefore it plays a key role in assessing the severity of OA and in monitoring its progression. Understanding how frequent knee bending activities may affect cartilage and menisci, by observing morphological change on MRI may provide further insights into the role of biomechanical loading in the pathogenesis of OA in different compartments of the knee joint.

While many previous studies have evaluated subjects with symptomatic and radiographic OA (10, 11, 14, 20), the present study focuses on subjects who are at risk for developing OA, but in knees that do not have radiographic evidence or pain. Since early morphologic degeneration in the joint may not be detected using radiography (21, 22), this study uses MRI to assess cartilage and meniscal abnormalities. Moreover, we classified subjects with frequent knee bending using questionnaires, which assessed certain types of physical activity directly. Hence the goals of our study were (i) to study the association between repetitive knee bending activity and focal knee abnormalities both cross-sectionally and longitudinally over a period of 3 years and (ii) also to separately examine the impact of knee bending activities on the different compartments of the knee.

Materials and Methods

Subjects

Data used in this study were obtained from the publically accessible Osteoarthritis Initiative (OAI) database (http://www.oai.ucsf.edu/). The Osteoarthritis Initiative is a multi-center, longitudinal study aimed at assessing biomarkers of OA including those derived from MRI and their impact on the natural evolution of joint degeneration. The OAI provides a cross-sectional and longitudinal dataset, which includes both MRI and radiographic images of

4796 subjects scanned annually over 4 years. We used clinical and imaging datasets at baseline (0.2.2 and 0.E.1) and at 36 months of follow-up (5.2.1 and 5.E.1).

A total of 115 subjects were selected from the incidence subcohort of the OAI, aiming to exclude subjects who have knee symptoms and/or radiographic knee OA. OAI defined a participant as having knee OA if one or both knee radiographs showed a Kellgren and Lawrence (KL) grade ≥ 2 combined with pain or stiffness in that knee on most days of the month for the last year. Participants in the incidence subcohort of OAI did not have symptomatic, radiographic knee OA in either knee, but had risk factors for developing knee OA (e.g. obesity, history of knee injuryor knee surgery, a family history of total knee replacement, or Heberden's Nodes). The flow diagram provided in figure 1 details the process of subject selection from the OAI. We excluded participants with KL grade ≥ 2 and also participants with knee pain. Further exclusion criteria for the OAI included rheumatoid arthritis, bilateral severe knee joint space narrowing and a positive pregnancy test. The specific inclusion criteria for this study were: i) age range of 45–55 years, ii) body mass index (BMI) of 19–27 kg/m^2, iii) Western Ontario and McMaster University (WOMAC) pain score (23) of zero in both knees and iv) Kellgren Lawrence (KL) score (24) of ≤ 1 at baseline in the right knee. These criteria were chosen in order to examine a middle-aged, non-obese, asymptomatic population, without radiographic evidence of OA.

Clinical assessment

WOMAC and PASE Questionnaires—The WOMAC Osteoarthritis Index is a well-established clinical tool used to assess clinical symptoms of osteoarthritis, including pain, stiffness, physical and emotional function (23). In this study, a WOMAC pain score of 0 was used to exclude patients with knee pain in the 7 days prior to the baseline MRI. The PASE is a well-established questionnaire to quantify physical activity in older individuals and was used to quantify physical activity levels in all subjects (25).

Repetitive knee bending exposure—Using a questionnaire on repetitive knee bending activity, subjects were asked at their initial eligibility interview: “As part of your daily activities, either at work or outside of work, do you currently do any of the following physical activities on most days? These activities do not have to be done all at once. They can be done over the course of the day”. Among the physical activities queried were (i) climbing up a total of 10 or more flights of stairs, (ii) kneeling for 30 minutes or more, (iii) squatting or deep knee bending for 30 minutes or more, and (iv) moving objects weighting 25 lbs. or more by hand. We categorized participants into frequent knee bending group if they reported exposure to at least one of these activities.

Radiographic knee assessment

Baseline weight-bearing posterior-anterior (PA) bilateral knee radiographs with “fixed flexion” technique (20–30 degrees of flexion and 10 degrees of internal rotation) were obtained (26). Two readers (W.V. and L.N.) quantified the osteoarthritis findings of the right knee in consensus using the Kellgren-Lawrence (KL) grading scale (24).

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MR imaging evaluation

MR images were obtained using four identical 3.0 Tesla scanners (Siemens Magnetom Trio, Erlangen, Germany) at four clinical sites taking part in this study; Ohio State University, Columbus, Ohio; University of Maryland, Baltimore, Maryland; University of Pittsburg, Pittsburg, Pennsylvania; Brown University, Pawtucket, Rhode Island. The OAI MRI protocol has been described in depth previously (27). For the analyses performed in this study we used specific, standard MRI sequences (28); in brief we used the following sequences for this study: a sagittal 2D intermediate-weighted (IW) fast spin-echo (FSE) sequence with fat suppression (FS) (TR/TE = 3200/30 ms, spatial resolution = 0.357 mm × 0.511 mm, slice thickness = 3.0 mm), a coronal 2D intermediate-weighted (IW) fast spin-echo (FSE) sequence (TR/TE = 3700/29 ms, spatial resolution = 0.365 mm × 0.456 mm, slice thickness = 3.0 mm), a sagittal 3D dual-echo in steady state (DESS) sequence (TR/TE = 16.3/4.7 ms, spatial resolution = 0.365 mm x 0.456 mm, slice thickness = 0.7 mm) and a 3D fast low angle shot (FLASH) sequence with selective water excitation (WE, TR/TE = 20/7.57 ms, spatial resolution = 0.313 mm × 0.313 mm, slice thickness = 1.5 mm).

MR images of the right knee were reviewed on picture archiving communication system (PACS) workstations (Agfa, Ridgefield Park, NJ, USA). A board-certified radiologist with 5 years of experience with musculoskeletal imaging (W.V.) and a 4th-year radiology resident (L.N.) reviewed all the images independently and graded cartilage and meniscal abnormalities for each image in total at the same time using a modified semi-quantitative whole-organ magnetic resonance imaging scores (WORMS) (29, 30) as outlined below. The readers were blinded to knee bending status, clinical and radiographic data and read the paired images, with knowledge of the time sequence.

The weighted kappa for the WORMS grade for intrarater reliabilities for reader 1 and reader 2 were 0.98 and 0.95 for cartilage score grading and 0.99 and 0.94 for meniscal score grading. The inter-rater reliabilities for cartilage and meniscal score grading were 0.90 and 0.91, respectively. In case of disagreement, a consensus reading was performed with a musculoskeletal radiologist with more than 20 years of experience (T.M.L.). All readers were blinded to frequent knee bending status of the subjects.

Cartilage morphology grading

Since only relatively mild cartilage abnormalities were expected, we analyzed only 6 rather than the 15 compartments of the original WORMS. This included the patella, trochlea, medial and lateral femur, and medial and lateral tibia. Decreasing the number of compartments could have potentially affected the number of grade 4 and grade 6 lesions, which, however, are expectedly rare in this patient population. Cartilage signal and morphology were scored using an eight-point scale: 0 = normal thickness and signal; 1 = normal thickness but increased signal on fluid sensitive (intermediate-weighted) sequences; 2 = partial-thickness focal defect <1 cm in greatest width; 2.5 = full-thickness focal defect <1 cm in greatest width; 3 = multiple areas of partial-thickness (Grade 2) defects intermixed with areas of normal thickness, or a partial-thickness defect wider than 1 cm but <75% of the region; 4 = diffuse (≥75% of the region) partial-thickness loss; 5 = multiple areas of full-thickness loss (grade 2.5) or a full-thickness defect wider than 1 cm but <75% of the region; 6 = diffuse (≥75% of the region) full-thickness loss.

Meniscal morphology scoring

Meniscal morphology was assessed in 6 regions: the medial and lateral sides of the anterior, body, and posterior region; an additional grade was added to the meniscal WORMS classification: "intrasubstance degeneration" to better assess early degenerative disease. The grading scale ranged from 0 to 4: 0 = normal, 1 = intrasubstance abnormalities, 2 = non-displaced tear, 3 = displaced or complex tear, and 4 = complete destruction and maceration of the meniscus.

Statistical Analysis

Statistical analysis was performed using STATA 11 software (StataCorp, College Station, TX, USA). Descriptive statistics for baseline demographic data (i.e. age, gender, BMI), Physical activity Scale for the Elderly (PASE) (25), Kellgren-Lawrence (KL) score were calculated for each group. Continuous variables were presented as mean ± standard deviation (SD) and compared using the independent sample *t* test. Categorical variables were presented as frequency (%) and compared using the chi-square test.

Since WORMS is not a true ordinal or continuous scale, we analyzed the prevalence and progression outcomes as binary; three separate outcomes of cartilage abnormalities were analyzed to examine association with frequent knee bending activity: (i) the prevalence of cartilage lesions, defined as WORMS ≥1, (ii) the prevalence of cartilage defects, defined as WORMS ≥2, and (iii) the progression of cartilage morphological abnormalities, defined as an increase in any subregion of a compartment of the WORMS from baseline to the 36-month follow-up. The outcomes for the menisci were analyzed in the same way as those of the cartilage: (i) the prevalence of meniscal lesions, defined as WORMS ≥1, (ii) the prevalence of meniscal tear, defined as WORMS ≥2, and (iii) the progression of meniscal morphological abnormalities, defined as increasing of the WORMS. Cartilage inhomogeneity and intrasubstance abnormality of the menisci (WORMS ≥1) were used as an outcome in order to detect the earliest sign of morphological changes, however, these findings were more likely subjective and therefore we used morphological cartilage defect and meniscal tear (WORMS ≥2) as another outcome for evaluation of cartilage and menisci.

Differences in the outcomes between groups were assessed using bivariate and multivariate logistic regression and reported as odds ratio (OR) and 95% confidence interval (CI). The multivariate logistic models were adjusted for the pre-defined potential confounders including age, gender, BMI, history of knee injury and history of knee surgery. All *P*-values were derived from the likelihood ratio test. For the analysis of progression in each compartment, because of the low number of progressing lesions after 3 years, exact logistic regression was used and only gender was entered into the model. A *P*-value of less than 0.05 was considered to be statistically significant.

Results

Among the 115 subjects in this study, 55 were males and 60 were females. The mean age of the participants was 50.8±2.9 years while their mean BMI was 24.1±1.9 kg/m^2. The number of subjects reporting frequent knee bending activities at baseline including stair climbing, kneeling, squatting, heavy lifting, or none of these activities were 62 (53.9%), 18 (15.7%), 20 (17.4%), 41 (35.7%) and 31 (27.0%), respectively. Forty subjects reported exposure to only one kind of these activities and 42 subjects reported exposure to 2 or more kinds of these activities. Characteristics of subjects categorized by their reported exposure to frequent knee bending activity are shown in Table 1. No significant difference in terms of gender, age, BMI, PASE, KL score and other OA risk factors was found between the two groups.

Prevalence of cartilage and meniscal lesions at baseline

Frequent knee bending activities were associated with an increased risk of prevalent cartilage lesions (WORMS ≥1) in the whole knee as shown in Table 2. We also found a trend of increased risk for cartilage defects (WORMS ≥2), however this did not reach statistical significance. In additional exploratory analyses by compartment of the knee, we observed a significant association between frequent knee bending and cartilage lesions in the patellofemoral compartment (Table 2). For prevalent meniscal abnormality, there was no significant association between frequent knee bending activity and increased risk of meniscal abnormality (Table 2 and 3).

Participation in more than one knee bending activity was associated with higher odds ratios of having cartilage abnormalities as demonstrated in Table 3. The odds ratio of having cartilage lesions in the subjects who performed only one type of frequent knee bending was 3.08 (95%CI 1.01–9.35) and for subjects involved in two or more types of frequent knee bending activities was 4.28 (95%CI 1.37–13.35). The odds ratio of having cartilage defects in the subjects who performed only one type of frequent knee bending was 1.33 (95%CI 0.50–3.55) and for subjects involved in two or more types of frequent knee bending was 3.35 (95%CI 1.23–9.06).

We explored whether there are differences by types of knee bending activity and found that each activity was again associated with increased risk for cartilage abnormalities, but odds ratios were no longer statistically significant.

Progression of cartilage and meniscal scores at 3-year follow-up

Thirty-three subjects (28.7%) showed progression of the cartilage score in at least one compartment (Figure 2), whereas 29 subjects (25.2%) had progression of the medial or lateral meniscal score. The progression of cartilage and meniscal scores after 3-year follow-up by frequent knee bending is presented in Table 4. Risk for progression of cartilage morphology scores in any compartment of the knee joint was greater in the group with frequent knee bending (OR 4.12, 95%CI 1.27–13.36). Analyzing the regions separately, we were not able to identify a significant progression of cartilage in any regions with a limited number of outcomes. For menisci, we found significant worsening of the morphology scores overall (OR 4.34, 95%CI 1.16–16.32), as well as for the medial meniscus (OR 7.38, 95%CI 1.06–321.62).

Discussion

Using data from the OAI study, we found that frequent knee bending activity in asymptomatic middle-aged subjects without radiographic OA in the studied knee but who had risk factors for OA is associated with an increased risk of knee cartilage abnormality, especially at the patellofemoral compartment. The results of this study suggest that increased biomechanical loading at the knee during bending activities may have a detrimental effect on cartilage. Deep knee bending is known to dramatically increase the stresses and the loads in the knee, with knee flexion to 90 degrees resulting in tibiofemoral joint stress of up to 26.6 megapascal (MPa), which exceeds the threshold at which cartilage damage occurs (31). Knee bending activities such as squatting have also been shown to increase sheer stresses on the patellofemoral joint (32).

Cooper et al proposed two mechanisms whereby repetitive knee use might increase the risk of osteoarthritis (14): (i) occupations characterized by prolonged periods of kneeling and squatting may increase the risk of meniscal or ligamentous damage to the knee, and such lesions are known risk factors for knee osteoarthritis and (ii) repetitive loading might directly induce cartilage loss. Our observation that the risk of cartilage and meniscal changes from knee bending is independent of that from self-reported knee injury and knee surgery suggests a direct effect. Most other studies that have investigated the role of occupational activities at the knee have used radiographs to examine individuals with knee OA (8, 13, 14). However, radiographic studies cannot discriminate early abnormalities in cartilage and have limitations in evaluating the changes in the patello-femoral compartment.

While conventional radiography did not demonstrate joint space narrowing or significant osteophytes in the knees we studied, MR imaging detected cartilage and meniscal pathology and disease progression over a relatively short observation period of 3 years. The patella cartilage had the highest prevalence of abnormalities compared to the other compartments in our study. Previous studies have also demonstrated that MRI is superior to radiography in illustrating OA related morphological lesions, irrespective of symptomology (21). Thus, soft tissue degeneration in the knee may not closely correspond with joint space narrowing, and radiography may not be optimal for assessing early-stage joint degeneration.

Two recent cross-sectional studies used MRI to evaluate cartilage change in relation to certain types of occupational activities including knee bending and examined the changes in different compartments (20, 33). One study in a male population with knee OA found that occupational exposure to frequent squatting/kneeling and heavy lifting were associated with deleterious patellofemoral cartilage changes (20). The other study enrolled asymptomatic adult females and found an increased risk for prevalent patella cartilage defects in subjects whose vocational tasks necessitated frequent knee flexion (33). Our results, which showed an increased risk of prevalent patellofemoral cartilage lesions with frequent knee bending, are consistent with these previous studies.

The natural history of OA varies greatly. Generally, OA develops progressively over several years. Although, we found an association of progression of the overall cartilage score at the 3-year follow-up period in subjects involved in frequent knee bending, we were not able to show significant results for the individual compartments separately. We also found an association of frequent knee bending and progression of the overall meniscal score and medial meniscal abnormality. The MRI based study by Rytter et al showed that the prevalence of degenerative tears was higher in the medial meniscus among floor layers, who engaged in frequent kneeling work positions, compared to this found in graphic designers (34). They proposed that high medial contact forces and the relative immobility of the posterior part of the medial meniscus combined with its larger size could explain the result of an unbalanced distribution of abnormality between the medial and lateral meniscus.

The strength of our study was that we evaluated focal knee abnormalities using MRI, which allows detecting early changes of the cartilage and evaluation of changes in each compartment of the knee separately. In addition to examining the prevalence of morphological change in a cross-sectional study, we evaluated the changes in a longitudinal 3-year follow-up. In our study, we evaluated asymptomatic subjects, which helped to eliminate recall bias that might occur in subjects with knee OA who are more likely to report their history of frequent knee bending.

Our study has some potential limitations. While we used the activity questionnaire to identify exposure to squatting, kneeling, climbing stairs and heavy lifting, we did not have information on the duration of these activities of interest to assess the potential influence of time of activity on the results. Also we adjusted for history of knee injury or surgery, based on information obtained from self-reported questionnaires. As the number of morphologically progressive lesions over a 3-year period in our study was not large, we were not able to show any significant results in the compartment specific analysis. These findings will need to be confirmed in larger longitudinal studies and/or with longer follow-up. Another limitation of our study was that we did not correlate the development of morphological abnormalities with the development of symptoms. The discordance between clinical and radiographic knee OA is well known, and therefore there is a need to further investigate the correlation of structural abnormalities within the knee with symptomology and functional abnormalities.

The statistical analysis used for this study performs multiple comparisons (such as across different compartments of the knee, medial and lateral meniscus etc.). The higher number of comparisons performed can lead to an increased chance of false positive results. This is an additional limitation of this study.

In conclusion, frequent knee bending activities are associated with an increased risk of prevalence and progression of cartilage abnormalities, and with an increased risk of worsening meniscal damage, in asymptomatic middle-aged subjects at risk for OA, particularly at the patello-femoral joint. Given the concern that these early lesions may progress to advanced stage of OA, our findings emphasize the importance of determining which particular knee bending activities, and at what frequency, increase the risk cartilage and meniscus damage in order to develop behavioral modification and intervention for the preventive management of OA.

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Significance and Innovation

- Frequent knee bending is associated with higher prevalence and with an increased risk of progression of cartilage and meniscal lesions in asymptomatic middle aged subjects.
- Behavior modification may play an important role in delaying onset and progression of OA.

Figure 1.

Flow diagram demonstrating the patient selection process from the Incidence sub-cohort of the OsteoarthritisInitiative. The incidence sub-cohort consisted of individuals with risk-factors for OA, but no radiographic or symptomatic evidence of OA.

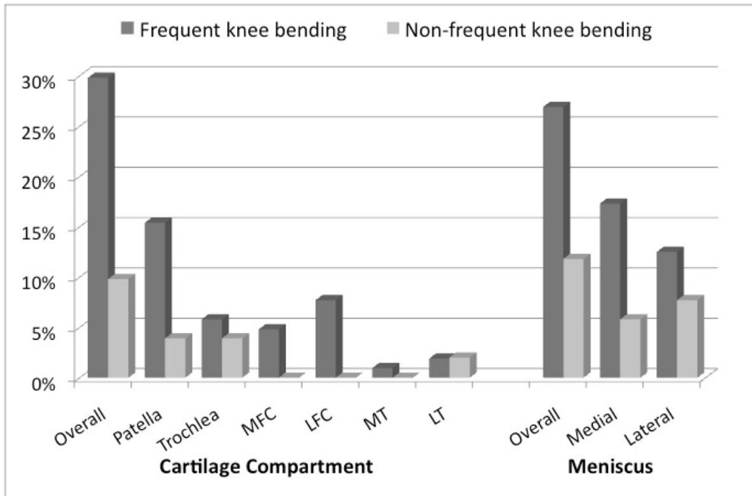

Figure 2.

Comparison of percent progression of cartilage morphology score at 3-year follow-up of the 155 subjects by frequent knee bending activities (Note- overall cartilage progression represents the percentage of cartilage progression in any regions of a joint)

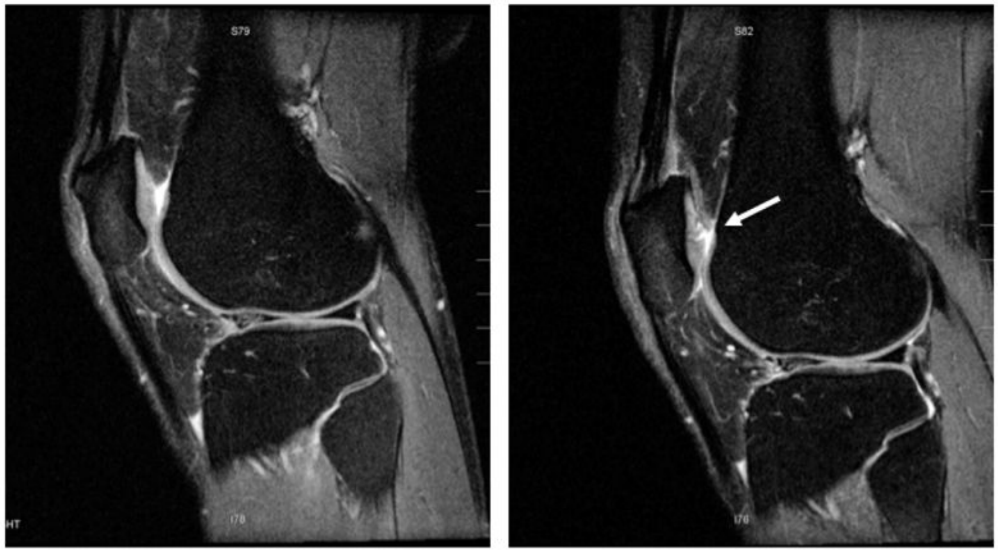

Figure 3.

Sagittal MRI of the patellar cartilage. (A) Baseline MRI shows mild cartilage inhomogeneity without focal defect (grade 1). (B) 3-year follow-up MRI shows focal partial cartilage defect at the same location (grade 2) (arrow).

Table 1

Baseline characteristics of the 115 subjects from the OAI incidence cohort by frequent knee bending activities.

	Frequent knee bending (N=84)	No frequent knee bending (N=31)	*P* value*
	N (%) or Mean±SD		
Male sex	41 (48.8)	14 (45.2)	0.728
Age (years)	50.7±2.9	51.3±2.9	0.347
BMI (kg/m^2)	24.2±1.8	23.7±1.9	0.153
Baseline PASE	207.8±84.5	185.6±76.6	0.203
Other OA risk factors			
Previous knee injury	41 (48.8)	18 (58.6)	0.378
Previous surgery	19 (22.6)	8 (25.8)	0.720
Family History	20 (23.8)	5 (16.7)	0.417
Heberden's node	14 (16.7)	8 (25.8)	0.269
Baseline KL score =1	23 (27.8)	9 (29.0)	0.640

Note- BMI=body mass index; PASE = Physical activity Scale for the Elderly; KL = Kellgren-Lawrence

*A Pearson χ^2 test for categorical variables and an independent sample *t*-test for continuous variables was used

†Statistically significant difference between "Frequent knee bending group" and "No frequent knee bending group"

Table 2

Risk (odds ratio) for cartilage and meniscal abnormalities at baseline according to frequent knee bending activities (n=115), for any abnormality (upper) and morphological abnormalities (lower).

	Frequent knee bending (N=84)	No frequent knee bending (N=31)	Crude OR (95%CI)	*P* value	Adjusted OR* (95%CI)	*P* value*
	N (%)					
Cartilage Lesion (Defect or signal abnormality; WORMS ≥ 1)						
Whole Knee	69 (82.1)	18 (58.1)	3.32 (1.34–8.22)†	0.010†	3.63 (1.39–9.52)†	0.008†
PF joint	63 (75.0)	16 (51.6)	2.81 (1.19–6.65)†	0.019†	3.09 (1.22–7.79)†	0.016†
Medial TF joint	18 (21.4)	5 (16.1)	1.42 (0.48–4.22)	0.521	1.44 (0.46–4.57)	0.525
Lateral TF joint	28 (33.3)	7 (22.6)	1.71 (0.66–4.46)	0.257	1.77 (0.67–4.71)	0.239
Meniscal Lesion (Tear or Signal Abnormality; WORMS ≥ 1)						
Whole knee	46 (54.8)	18 (58.1)	0.87 (0.38–2.01)	0.751	0.78 (0.31–1.96)	0.597
Medial meniscus	40 (47.6)	17 (54.8)	0.75 (0.33–1.71)	0.492	0.65 (0.26–1.66)	0.369
Lateral meniscus	18 (21.4)	4 (12.9)	1.84 (0.57–5.94)	0.287	1.89 (0.57–6.31)	0.279
	Frequent knee bending (N=84)	**No frequent knee bending (N=31)**	**Crude OR (95%CI)**	***P* value**	**Adjusted OR* (95%CI)**	***P* value***
	N (%)					
Cartilage Defect (WORMS ≥2)						
Whole Knee	51 (60.7)	13 (41.9)	2.14 (0.93–4.94)	0.073	2.12 (0.89–5.02)	0.087
PF joint	35 (41.7)	9 (29.0)	1.74 (0.72–4.25)	0.210	1.67 (0.66–4.19)	0.270
Medial TF joint	13 (15.5)	5 (16.1)	0.95 (0.31–2.93)	0.932	0.96 (0.28–3.26)	0.947
Lateral TF joint	19 (22.6)	5 (16.1)	1.52 (0.51–4.50)	0.438†	1.45 (0.48–4.38)†	0.499
Meniscal Tear (WORMS ≥2)						
Whole knee	29 (34.5)	10 (32.3)	1.11 (0.46–2.66)	0.819	1.12 (0.43–2.93)	0.820
Medial meniscus	24 (28.6)	9 (29.0)	0.98 (0.39–2.42)	0.961	1.01 (0.36–2.81)	0.992
Lateral meniscus	8 (9.5)	1 (3.2)	3.16 (0.38–26.35)	0.226	3.69 (0.43–31.71)	0.171

Note- OR = odds ratio; CI = confidence interval; PF = patellofemoral; TF = tibiofemoral

*Adjusted for gender, age, BMI, history of knee injury and knee surgery

†Statistically significant difference between “Frequent knee bending group” and “No frequent knee bending group”

Table 3

Risk (odds ratio) for prevalent cartilage and meniscal abnormalities at baseline by number of frequent knee bending activities involved. Two groups were separated with exposure to one knee bending activities (n=40) and two and more knee bending activities (n=42), such as frequent kneeling and squatting.

	OR* (95%CI)			*P* for trend
	No. of frequent knee bending activity involved			
	0	1	≥2	
Cartilage lesion	Reference	3.08 (1.01–9.35)†	4.28 (1.37–13.35)#	0.012†
Cartilage defect	Reference	1.33 (0.50–3.55)	3.35 (1.23–9.06)#	0.018†
Meniscal lesion	Reference	0.53 (0.18–1.52)	1.09 (0.39–3.06)	0.867
Meniscal tear	Reference	0.78 (0.25–2.37)	1.53 (0.53–4.45)	0.433

Note- OR = odds ratio; CI = confidence interval; cartilage lesion is equivalent to the Whole Organ MRI score ≥ 1; cartilage defect is equivalent to the Whole Organ MRI score ≥ 2; meniscal lesion is equivalent to the Whole Organ MRI score ≥ 1; meniscal tear is equivalent to the Whole Organ MRI score ≥ 2

*Adjusted for gender, age, BMI, history of knee injury, and knee surgery

†Statistically significant difference between subjects performing “1 frequent knee bending activity” and those performing “No frequent knee bending activity”

#Statistically significant difference between subjects performing “≥2 frequent knee bending activities” and those performing “No frequent knee bending activity”

Table 4

Comparison of the progression of focal knee abnormalities at 3-year follow-up of 115 subjects with and without repetitive knee bending activity

	Frequent knee bending (N=84)	No Frequent knee bending (N=31)	OR* (95%CI)	*P* value*
	N (%)			
Cartilage score progression				
Overall	29 (34.5)	4 (12.9)	4.12 (1.27–13.36)	0.009†
PF joint	21 (25.0)	3 (9.68)	3.05 (0.81–17.21)	0.117
Medial TF joint	5 (6.0)	0 (0)	2.51 (0.33-inf)	0.415
Lateral TF joint	7 (8.3)	1 (3.2)	2.93 (0.34–140.19)	0.567
Meniscal score progression				
Overall	26 (31.0)	3 (9.68)	4.34 (1.16–16.32)	0.015†
Medial meniscus	17 (20.2)	1 (3.2)	7.38 (1.06–321.62)	0.040†
Lateral meniscus	12 (14.3)	2 (6.5)	2.65 (0.51–26.65)	0.359

Note- PF = patellofemoral; TF = tibiofemoral

*Multivariable logistic regression adjusted for adjusted for gender, age, BMI, history of knee injury, and knee surgery was used for overall progression and exact logistic regression adjusted for gender only was used for each region

†Statistically significant difference between “Frequent knee bending group” and “No frequent knee bending group”