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BRIEF REPORT

Prevalence of Radiographic and Magnetic Resonance Imaging Features of Patellofemoral Osteoarthritis in Young and Middle-Aged Adults With Persistent Patellofemoral Pain

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Objective. To describe the prevalence of radiographic features of patellofemoral (PF) osteoarthritis (OA) in adults with persistent PF pain, to describe the prevalence of magnetic resonance imaging (MRI)–defined PF OA and compare it to that in age- and sex-matched controls, and to explore the prevalence of radiographic and MRI-defined PF OA across age, sex, and body mass index (BMI) groups.

Methods. This cross-sectional study included 84 individuals with PF pain ≥3 months duration and 26 age- and sex-matched controls. In participants with PF pain, posteroanterior, lateral, and skyline radiographs were obtained. Radiographic OA features were scored using Kellgren/Lawrence (K/L) criteria and a radiographic atlas, with K/L grade ≥2 defined as OA, and K/L grade 1 as early OA. Both groups underwent 3.0 Tesla MRI scans, scored using the MRI Osteoarthritis Knee Score criteria. Compartmental prevalence of MRI OA features was based on cartilage lesions, bone marrow lesions (BMLs), and osteophytes.

Results. Overall, 20 participants (24%) with PF pain had radiographic PF OA (K/L grade ≥2), and 36 participants (43%) had early PF OA (K/L grade 1). MRI-defined PF OA was more prevalent in participants with PF pain (16–29%) than in controls (4–12%), irrespective of how PF OA was defined. Within the PF pain group, the prevalence of PF OA on radiographs and MRI was greater in participants who were older or female or who had a higher BMI.

Conclusion. Features of radiographic and MRI-defined PF OA were evident in 20–30% of adults ages 26–50 years with persistent PF pain, with greater prevalence observed in those who were older, or female, or who had a higher BMI. MRI-defined PF OA was more prevalent in individuals with PF pain than in pain-free controls, especially when defined as a full-thickness cartilage lesion with BML.

INTRODUCTION

Patellofemoral (PF) pain is a common, chronic condition occurring across the lifespan. Individuals with PF pain experience peripatellar or retropatellar pain, typically with activities that load the PF joint (e.g., squatting, stair ambulation, running) (1). Increasing evidence highlights the persistent nature of PF pain, with symptoms remaining for at least 5 to 8 years after first detection (2), but the reason for this persistence is unclear. It is possible that PF pain in young adults represents the earliest manifestation of PF osteoarthritis (OA), based on similarities in symptoms, biomechanics, and muscle function (1). Thus, younger adults with PF pain may have structural PF lesions consistent with PF OA.

This study aimed to describe the prevalence of radiographic features of PF OA in adults with persistent PF pain, to describe

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No potential conflicts of interest relevant to this article were reported.

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SIGNIFICANCE & INNOVATIONS

- One-quarter of young and middle-aged adults with patellofemoral pain have radiographic patellofemoral osteoarthritis.
- Magnetic resonance imaging–defined patellofemoral osteoarthritis is more prevalent in individuals with patellofemoral pain than in pain-free controls, especially when defined as a full-thickness cartilage lesion combined with a bone marrow lesion.
- Individuals with patellofemoral pain who are older, are female, or have a higher body mass index have a higher prevalence of patellofemoral osteoarthritis.

the prevalence of magnetic resonance imaging (MRI)–defined PF OA and compare it to that in age- and sex-matched controls, and to explore radiographic and MRI prevalence across age, sex, and body mass index (BMI) groups.

PARTICIPANTS AND METHODS

Participants. Individuals with PF pain were recruited from the community in Melbourne, Australia via advertisements in university staff and student bulletins and by word-of-mouth referrals from health care practitioners. Inclusion criteria were ages 26–50 years, anteropatellar or retropatellar knee pain aggravated by ≥2 PF joint-loading activities (e.g., walking up or down stairs, squatting, rising from sitting, running), knee pain severity ≥30 mm on a 100-mm visual analog scale during aggravating activities, pain during these activities on most days of the preceding month, and knee pain duration ≥3 months. Volunteers were excluded if they had concomitant pain from other knee structures, hip, or lumbar spine; knee injection <3 months prior; planned or previous lower extremity surgery; moderate-to-severe concomitant tibiofemoral (TF) OA (Kellgren/Lawrence [K/L] grade ≥3 on posteroanterior radiograph) (3); systemic medical conditions (e.g., rheumatoid arthritis); contraindications to having a radiograph taken; and an inability to understand written or spoken English or undertake testing procedures. Participants with contraindications to MRI (e.g., metal implants, claustrophobia) were excluded from MRI evaluation.

Once the PF pain cohort was finalized, we recruited a convenience sample of 26 control participants from the Melbourne community via word-of-mouth. Control participants were eligible if they had no current or history of knee injury or symptoms and no contraindications to MRI. They were matched to the overall characteristics of the PF pain cohort for age, sex, and BMI.

All participants provided written informed consent prior to undergoing testing procedures. Ethics approval was provided by The University of Melbourne's Human Research Ethics Committee (ID: 1136766), and all study procedures conformed to the Declaration of Helsinki.

Procedure. Volunteers with PF pain underwent email or telephone screening, then physical screening to confirm PF pain and exclude other sources of anterior knee pain (e.g., patellar tendon, fat pad). Knee radiographs were acquired at a private radiology clinic to evaluate TF OA eligibility criteria. Participants with PF pain attended a single testing session at The University of Melbourne for collection of demographic data and patient-reported outcome measures (PROMs) and to undergo clinical measures as part of a larger cohort study. MRIs were subsequently acquired at a single private radiology clinic.

Demographic characteristics and PROMs. Information on demographic characteristics (e.g., age, sex, height, weight, education level, employment, smoking history, and physical activity) was collected, along with PF pain duration and bilaterality. The following PROMs were used to characterize the cohort: pain severity (100-mm visual analog scales) (4), the Knee Injury and Osteoarthritis Outcome Score and PF subscale (5), and the Anterior Knee Pain Scale (4).

Radiograph acquisition and evaluation. Participants with PF pain underwent radiography of their study knee (the most symptomatic eligible knee), using standard protocols (6). Posteroanterior and lateral views were obtained in weight-bearing (30–40° knee flexion, feet 10° externally rotated). Skyline PF views were obtained in non–weight-bearing (30° knee flexion).

All radiographs were graded by a single musculoskeletal radiologist (EHGO) with 13 years' experience. Lateral and skyline views were used to grade the PF joint, and posteroanterior views were used for the TF joint. Medial and lateral PF and TF compartments were graded separately. Individual features of OA (joint space narrowing, osteophytes) in each compartment were graded as 0 (normal), 1 (mild), 2 (moderate), or 3 (severe), using a radiographic atlas (7). K/L criteria were applied to each joint compartment (3), with K/L grade 0 (no OA: no OA features), K/L grade 1 (doubtful OA: possible osteophytic lipping, doubtful joint space narrowing), K/L grade 2 (mild OA: definite osteophytes, possible joint space narrowing), K/L grade 3 (moderate OA: moderate multiple osteophytes, definite joint space narrowing, some sclerosis, possible bone contour deformity), or K/L grade 4 (severe OA: large osteophytes, marked joint space narrowing, severe sclerosis, definite bony contour deformity) (6). The presence of radiographic OA was classified as no OA (K/L grade 0), early OA (K/L grade 1) (8), and established OA (K/L grade ≥2) (6).

MRI acquisition and evaluation. Participants with PF pain and control participants underwent unilateral 3.0T MRIs (Philips Achieva) on their nominated study knee (randomly selected for control participants). Participants were supine with 20–30° knee flexion in a 16-channel knee coil (Invivo). We obtained a 3-dimensional proton density, turbo spin-echo (TSE) sequence

(VISTA), acquired at 0.35 mm isotropically, with repetition time (TR) of 1,300 msec, echo time (TE) of 27 msec, 110 × 150 × 150 mm field of view (FOV), and echo train length 64 msec (acquisition time 6 minutes 11 seconds). An axial proton density TSE fat-saturated sequence was also acquired (TR 3,200 msec, TE 30 msec, slice thickness 2.5 mm, slice gap 1.0 mm, voxel size 0.5 × 0.6 × 2.5 mm, FOV 150 × 130 mm, acquisition time 2 minutes 23 seconds).

A senior radiology resident (JLdK) evaluated MRIs semiquantitatively using the MRI OA Knee Score (MOAKS) in 14 articular subregions, encompassing the patella, femur, and tibia (9). Bone marrow lesions (BMLs), articular cartilage lesions (partial- or full-thickness), and osteophytes were graded by size for each region. We evaluated additional PF features applicable to young adults with PF pain (e.g., minor cartilage defects, increased signal in fat pads and retinaculae, plica thickness, and width) (10).

Ordinal MOAKS scores were dichotomized to indicate the presence or absence of features (10). We deemed BMLs to be present if the size of the BML was >0 (i.e., BML of any size). Any cartilage lesion was present when the size of the cartilage lesion was >0 (i.e., cartilage lesion of any size). Full-thickness cartilage lesions were present when the percentage of full-thickness cartilage loss of region score was >0 (i.e., full-thickness cartilage loss of any size). Osteophytes were deemed present if they were small, medium, or large; effusion if medium or large; and Hoffa-synovitis if moderate or severe. Minor cartilage defects were deemed present if high signal intensity, fraying/fissuring, or hypertrophy was present. Plica thickening was indicated if it was 3 mm or greater, and plica widening if it was sufficient to reach the midline in a nondistended joint (10).

Primary OA features were clustered by joint compartment: medial PF compartment (medial patella [including patella crista], medial trochlea), lateral PF compartment (lateral patella, lateral trochlea), and medial and lateral TF joint (central and posterior femur; anterior, central, and posterior tibia, split into medial and lateral compartments). Compartmental prevalence of MRI OA features was defined in 3 ways (11,12): any cartilage lesion (partial- or full-thickness) combined with any BML, full-thickness cartilage lesion combined with any BML, and definite osteophytes combined with any cartilage lesion.

Statistical analysis. Descriptive statistics were used to present participant demographics, PROMs, and the prevalence of OA features. Due to the exploratory nature of this study and zero prevalence of some MRI features in the PF pain and control groups, statistical between-group comparisons were not performed. The relationship of age, sex, and BMI with radiographic and MRI prevalence of PF OA was explored visually using bar graphs.

RESULTS

Between July 2012 and March 2015, 84 participants with PF pain (54 women [64%]) were enrolled from among 284 volunteers (see Supplementary File 1, available on the *Arthritis Care & Research* web site at http://onlinelibrary.wiley.com/doi/10.1002/acr.23726/abstract). Participants with PF pain had a median age of 35 years (interquartile range [IQR] 10), BMI of 24.9 kg/m^2 (IQR 4.6), and a mean ± SD height of 1.70 ± 0.09 meters and weight of 73 ± 13 kg. Overall, 55 participants (67%) had bilateral PF pain, and 57 participants (68%) reported PF pain symptoms >2 years duration (see Supplementary File 2, available on the *Arthritis Care & Research* web site at http://onlinelibrary.wiley.com/doi/10.1002/acr.23726/abstract for additional characteristics and PROMs). A total of 26 control participants were recruited: 15 women (64%), median age 34 years (IQR 7), median BMI 23.3 kg/m^2 (IQR 5.7), mean ± SD height 1.7 ± 0.08 meters, and mean ± SD weight 72 ± 11 kg.

Prevalence of radiographic features of PF OA in participants with PF pain. Radiographs were available for 83 participants. Figure 1A shows the prevalence of radiographic PF OA according to the K/L grade. K/L grade 1 PF OA was the most prevalent finding (43% of participants), while K/L grade ≥2 PF OA was present in 24% of participants. Figure 1B shows the prevalence of coexisting TF OA (K/L grades 0, 1, or 2). As the PF K/L grade increased, the prevalence of K/L grade 1 and K/L grade 2 changes in the TF joint also increased.

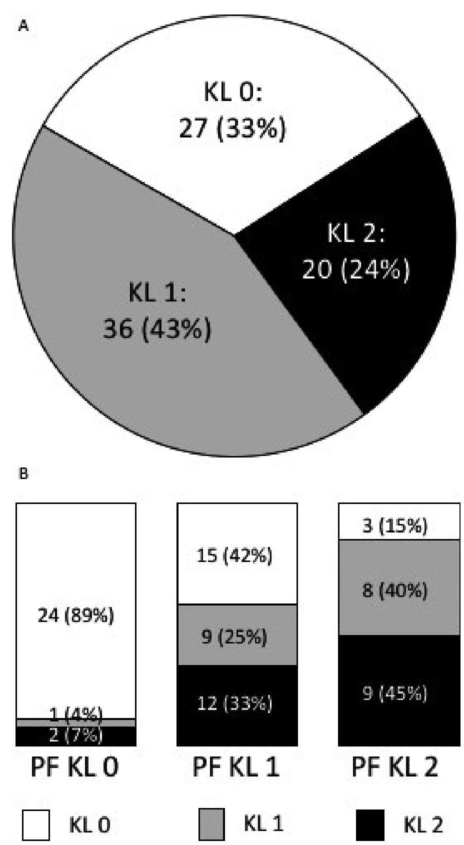

Figure 1. Prevalence of radiographic patellofemoral (PF) osteoarthritis (**A**) and tibiofemoral osteoarthritis (**B**) in participants with persistent PF pain, based on Kellgren/Lawrence (KL) grade.

Table 1 shows compartmental prevalence data for K/L grades and individual OA features. K/L grade 1 features were equally prevalent in the medial and lateral PF compartments, while K/L grade ≥2 features were more common in the lateral PF compartment. The most prevalent individual OA features in the PF joint were osteophytes on the inferior (39%), lateral (36%), and superior (35%) patella. Two participants (2%) had grade 3 (severe) lateral patellar osteophytes, while 10 participants (12%) had grade 2 (moderate) lateral patellar osteophytes. Medial PF osteophytes were less prevalent and occurred on the medial trochlea (20%) more frequently than on the medial patella (12%). Mild-to-moderate lateral PF joint space narrowing was present in 19 participants (23%). Medial PF joint space narrowing was typically not a feature. Overall, 35% of participants had mild-to-moderate osteophytes on the medial tibia, and 26% had mild-to-moderate medial TF joint space narrowing.

Prevalence of MRI features of OA in participants with PF pain compared to controls. In total, 70 participants with PF pain consented to undergo MRI. Supplementary File 3, available on the *Arthritis Care & Research* web site at http://onlinelibrary.wiley.com/doi/10.1002/acr.23726/abstract, shows the prevalence of individual MRI features in the PF pain and control groups. When partial- and full-thickness cartilage lesions were considered together, lateral patellar lesions were more prevalent in

Table 1. Prevalence of Kellgren/Lawrence-defined osteoarthritis and radiographic features of osteoarthritis in the patellofemoral joint and tibiofemoral joint in participants with patellofemoral pain (n = 83)*

	Grade 0	Grade 1	Grade 2	Grade ≥3
Kellgren/Lawrence grade				
Patellofemoral joint				
Medial	61 (74)	20 (24)	2 (2)	0 (0)
Lateral	45 (54)	20 (24)	17 (21)	1 (1)
Overall	27 (33)	36 (43)	19 (23)	1 (1)
Tibiofemoral joint				
Medial	45 (54)	16 (19)	22 (27)	0 (0)
Lateral	65 (78)	17 (21)	1 (1)	0 (0)
Overall	42 (51)	18 (21.5)	23 (27.5)	0 (0)
Osteoarthritis features				
Posteroanterior view				
Joint space narrowing				
Medial tibiofemoral	61 (74)	21 (25)	1 (1)	0 (0)
Lateral tibiofemoral	82 (99)	1 (1)	0 (0)	0 (0)
Osteophytes				
Medial femur	81 (98)	2 (2)	0 (0)	0 (0)
Medial tibia	54 (65)	28 (34)	1 (1)	0 (0)
Lateral femur	81 (98)	2 (2)	0 (0)	0 (0)
Lateral tibia	67 (81)	14 (17)	2 (2)	0 (0)
Lateral view				
Osteophytes				
Superior patella	54 (65)	25 (30)	4 (5)	0 (0)
Inferior patella	51 (61)	27 (33)	5 (6)	0 (0)
Skyline view				
Joint space narrowing				
Medial patellofemoral	80 (96.5)	2 (2.5)	1 (1)	0 (0)
Lateral patellofemoral	64 (77)	18 (22)	1 (1)	0 (0)
Osteophytes				
Medial patella	73 (88)	8 (10)	2 (2)	0 (0)
Medial trochlea	66 (80)	15 (18)	2 (2)	0 (0)
Lateral patella	53 (64)	18 (22)	10 (12)	2 (2)
Lateral trochlea	74 (89)	8 (10)	0 (0)	1 (1)

* Values are the frequency (%).

participants with PF pain (16%) than in controls (0%), while medial cartilage lesions were similar across groups (PF pain 23%, control 19%). Full-thickness cartilage lesions were present on the medial and lateral patella of 11% of participants with PF pain, but absent in controls. We observed a high prevalence of minor patella cartilage defects in the PF pain group (44%) compared to controls (23%), predominantly in the medial compartment.

BMLs were substantially more prevalent in the medial patella (49%) and lateral patella (30%) of the PF pain group, compared to controls (both 12%). Prevalence of BMLs in the trochlea was similar between groups, although these tended to be lateral in participants with PF pain and medial in controls. Osteophytes were identified in both groups. Participants with PF pain had a higher prevalence of osteophytes on the lateral patella (30% versus 15%), lateral trochlea (17% versus 4%), and lateral femur (71% versus 35%). Controls had a higher prevalence of superior patellar osteophytes (35% versus 23%). Tendon thickening or high signal was prevalent in the patellar tendon (50%) and quadriceps tendon (27%) of participants with PF pain but absent in controls. Mild edema was more prevalent in the infrapatellar (Hoffa's) fat pad of the PF pain group (59%) than in controls (31%), although moderate edema was similar between groups. High signal in the infrapatellar bursa was present in 14% of participants with PF pain but absent in controls. The PF pain group also had a greater prevalence of high signal in the anterior suprapatellar fat pad (81%), although high signal also occurred frequently in controls (69%). A high signal was more prevalent in the menisci of control participants (medial 65%, lateral 23%) than in those of participants with PF pain (medial 54%, lateral 7%).

Table 2 shows compartmental prevalence of MRI-defined OA in the PF pain and control groups. Irrespective of how OA was defined, there was a higher prevalence of isolated PF OA in participants with PF pain (16–29%) compared to controls (4–12%). The combination of a full-thickness cartilage lesion with a BML was best able to differentiate PF pain (16%) and control (0%) groups.

Prevalence of radiographic and MRI-defined PF OA across age, sex, and BMI groups in participants with PF pain. Supplementary File 4, available on the *Arthritis Care & Research* web site at http://onlinelibrary.wiley.com/doi/10.1002/acr.23726/abstract, shows OA prevalence data for the PF pain group for each radiographic and MRI definition, split by age, sex, and BMI. PF OA (with or without TF OA) was more prevalent in participants who were older, or female, or who had a higher BMI.

DISCUSSION

Overall, 24% of our PF pain cohort had radiographic PF OA (K/L grade ≥2), frequently combined with K/L grade 1 or K/L grade 2 TF OA. PF OA prevalence was similar to that in an older cohort (26%, mean ± SD age 54 ± 10 years) (6). This finding is likely explained by the greater PF OA frequency in our older participants (ages 41–50 years). Women had a higher prevalence of PF OA than men, which is in contrast to findings in knee pain cohorts age ≥40 years (6,13). Higher PF OA prevalence was also observed in those with greater BMI, supporting previous findings (14).

Almost half (43%) of our participants with PF pain had radiographic signs of early PF OA (K/L grade 1), either in isolation or combined with K/L grade 1 or K/L grade 2 TF OA. This finding may be clinically significant, since K/L grade 1 predicts worsening radiographic OA in older individuals with knee pain (15). Longitudinal studies are required to determine whether younger adults with early radiographic PF OA are an important target group for interventions to slow or prevent OA progression.

Compared to age- and sex-matched controls, our participants with PF pain had a greater prevalence of PF OA on MRI (PF pain: 16–29%, controls: 4–12%), irrespective of which MRI

Table 2. Compartmental prevalence of magnetic resonance imaging–defined osteoarthritis in participants with patellofemoral pain (n = 70) and controls (n = 26)*

	PF pain				Controls			
	None	Isolated PF joint	Isolated TF joint	Mixed PF/TF joints	None	Isolated PF joint	Isolated TF joint	Mixed PF/TF joints
Any cartilage lesion + any BML†	48 (69)	20 (29)	1 (1)	1 (1)	24 (92)	1 (4)	1 (4)	0 (0)
Full thickness cartilage lesion + any BML†	59 (84)	11 (16)	0 (0)	0 (0)	26 (100)	0 (0)	0 (0)	0 (0)
Definite osteophyte + cartilage lesion‡	48 (69)	16 (23)	3 (4)	3 (4)	22 (84.5)	3 (11.5)	1 (4)	0 (0)

* Values are the number (%). PF = patellofemoral; TF = tibiofemoral; BML = bone marrow lesion.
† Combination of cartilage lesion and BML may occur within the same compartment (medial/lateral) or across compartments (e.g., 1 feature in medial compartment, 1 feature in lateral compartment) (11).
‡ Definition of patellofemoral osteoarthritis based on presence of definite osteophyte on patella and/or anterior femur, with partial- or full-thickness cartilage loss on the patella and/or anterior femur; tibiofemoral osteoarthritis definition based on combinations of definite osteophyte, full-thickness cartilage loss (or partial-thickness cartilage loss in the absence of full-thickness loss), BML, and meniscal extrusion, maceration, or tear in central/posterior femur and/or tibia (12).

features were used to define OA. The high prevalence of partial-thickness cartilage lesions and osteophytes observed in controls suggests that future studies using MRI to define PF OA should consider using full-thickness cartilage lesions and BMLs.

Individual MRI features of PF OA, such as lateral cartilage lesions, patellar BMLs, and lateral patellar and trochlear osteophytes, were more prevalent in participants with PF pain than in controls. Our finding contrasts with that of a previous study in adolescents and younger adults (mean ± SD age 23 ± 6 years) (10), which used the same MRI sequences and was scored by the same radiologists as the current study. Our older PF pain cohort had a higher prevalence of full-thickness PF cartilage lesions (16% versus 0%), minor cartilage lesions (44% versus 23%), meniscus high signal (54% versus 23%), and patellar tendon thickening or high signal (50% versus 38%), which could reflect the older age of our PF pain cohort and longer pain duration. These findings lend support to the existence of a spectrum of PF pain disorders, where structural changes in the PF joint begin to appear toward middle-age in some individuals with PF pain.

Interpretation of radiographic findings should be considered in light of known limitations with PF grading methods. There are no PF-specific K/L criteria, and the radiographic atlas has limited examples of the PF joint. Updated guidelines for radiographic scoring of PF OA are urgently required. Our sample size precluded the use of statistical tests to compare the PF pain and control groups, especially since MRI-defined OA and some individual structural features were absent in 1 or both groups. We did not acquire radiographs from controls due to lack of a clinical indication and the risks associated with radiation exposure. Finally, we are unable to draw conclusions regarding causal relationships between PF OA and participant characteristics, highlighting the need for prospective studies.

Young and middle-aged adults with persistent PF pain commonly present with radiographic features of PF OA, with greater prevalence observed in those who are older, female, or had a higher BMI. MRI-defined PF OA is more prevalent in individuals with PF pain than in matched pain-free controls, especially when defined as a full-thickness cartilage lesion combined with a BML.

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AUTHOR CONTRIBUTIONS

All authors were involved in drafting the article or revising it critically for important intellectual content, and all authors approved the final version to be submitted for publication. Dr. Collins had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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Acquisition of data. Collins, Oei, de Kanter.

Analysis and interpretation of data. Collins, Oei, de Kanter, Vicenzino, Crossley.

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