The Diagnostic Performance of Anterior Knee Pain and Activity-related Pain in Identifying Knees with Structural Damage in the Patellofemoral Joint: The Multicenter Osteoarthritis Study

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ABSTRACT. ***Objective.*** To determine the diagnostic test performance of location of pain and activity-related pain in identifying knees with patellofemoral joint (PFJ) structural damage.

Methods. The Multicenter Osteoarthritis Study is a US National Institutes of Health-funded cohort study of older adults with or at risk of knee osteoarthritis. Subjects identified painful areas around the knee on a knee pain map and the Western Ontario and McMaster Universities Osteoarthritis Index was used to assess pain with stairs and walking on level ground. Cartilage damage and bone marrow lesions were assessed from knee magnetic resonance imaging. We determined the sensitivity, specificity, positive and negative predictive values for presence of anterior knee pain (AKP), pain with stairs, absence of pain while walking on level ground, and combinations of tests in discriminating knees with isolated PFJ structural damage from those with isolated tibiofemoral joint (TFJ) or no structural damage. Knees with mixed PFJ/TFJ damage were removed from our analyses because of the inability to determine which compartment was causing pain.

Results. There were 407 knees that met our inclusion criteria. "Any" AKP had a sensitivity of 60% and specificity of 53%; and if AKP was the only area of pain, the sensitivity dropped to 27% but specificity rose to 81%. Absence of moderate pain with walking on level ground had the greatest sensitivity (93%) but poor specificity (13%). The combination of "isolated" AKP and moderate pain with stairs had poor sensitivity (9%) but the greatest specificity (97%) of strategies tested.

Conclusion. Commonly used questions purported to identify knees with PFJ structural damage do not identify this condition with great accuracy. (J Rheumatol First Release June 15 2014; doi:10.3899/ jrheum.131555)

Key Indexing Terms:
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Knee osteoarthritis (OA) can be present in the patellofemoral joint (PFJ), tibiofemoral joint (TFJ), or both. While prior research has focused primarily on TFJ OA, recent evidence suggests that PFJ OA is at least as common, if not more common, than TFJ OA[1,2,3] and is associated with pain and functional limitation[4,5,6,7,8]. Given that nonpharmacological treatment approaches (e.g., biomechanical and rehabilitation strategies) to manage TFJ and PFJ OA may be different[9], clinicians need to know which compartment of the knee is primarily affected and may be causing pain. Focusing treatment on the wrong joint compartment could be ineffective or even detrimental. Clinicians therefore need to be able to assess patients' reports of pain location and activity-related pain to determine the primary compartment affected in the disease process to optimize management approaches. Knowing the diagnostic utility of self-reported pain measures would also optimize the likelihood that treatment strategies could be developed for PFJ OA.

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It is commonly thought that PFJ structural damage causes pain in the anterior region of the knee and pain during activities in which the knee is flexed (e.g., going up and down stairs and squatting)[8,10,11,12]. However, there is little evidence that anterior knee pain (AKP) and/or pain with these activities results from structural changes specifically in the PFJ. As the knee flexes during weight-bearing activities, forces are increased in the PFJ while the quadriceps contracts to prevent the knee from buckling. However, forces are also transmitted through the TFJ during knee flexion activities. Although AKP is related to increased stress in the PFJ[13], individuals with AKP may also have TFJ structural damage. If pain with flexion activities could originate from anywhere in the knee, pain while ambulating on flat surfaces (an activity that probably does not increase load across the PFJ joint because of the small degree of knee flexion) could emanate entirely from the TFJ.

OA has historically been assessed using radiographs; however, magnetic resonance imaging (MRI) provides a unique advantage in detecting structural damage in the TFJ and PFJ because radiographs are insensitive to cartilage loss and do not show evidence of damage in other joint tissues[14]. Additionally, radiographs show changes late in the OA disease process when disease may appear isolated to 1 compartment but may not be truly isolated (because of the poor sensitivity of radiographs). In addition, identification of PFJ OA on radiographs is problematic because the lateral radiographic view does not permit sensitive assessment of joint space narrowing[1,15,16].

The objective of this current study was to determine the test performance characteristics of the location of knee pain and pain with specific activities in discriminating knees with isolated PFJ structural damage on MRI from knees with isolated TFJ or no structural damage.

MATERIALS AND METHODS

Study population. The Multicenter Osteoarthritis Study is a prospective cohort study of older adults, 55 to 84 years old, with or at risk of knee OA. It is funded by the US National Institutes of Health. Subjects were recruited from 2 communities in the United States: Birmingham, Alabama, and Iowa City, Iowa. We used data from the 60-month visit, the first visit at which a knee pain map was obtained. We limited our sample to knees with pain, aching, or stiffness in the past year.

Diagnostic tests evaluated. Subjects identified painful areas around their knee on a knee pain map (Figure 1). This map was developed interactively with patients with knee pain to optimize identification of common locations of knee pain and has been used in previous studies from our group[17]. Subjects were asked, "When your knee hurts where does it hurt?" Subjects could report as many areas as they wanted. AKP was defined as pain in region 1 on the knee pain map, regardless of other regions identified. We defined "any" AKP to be present when subjects reported pain in region 1 in addition to pain (if any) in another region; "isolated" AKP was considered present when subjects reported pain in region 1 without pain in any other region. Subjects also completed a knee-specific Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC)[18] pain subscale, with pain severity assessed on an ordinal scale (none, mild, moderate, severe, extreme). The WOMAC contains questions asking about pain while going up and down stairs (which we assessed separately) and walking on level ground. We assessed pain with each of these activities (at least mild pain and at least moderate pain) as separate diagnostic tests. Because of the small degree of knee flexion during walking, the absence of pain walking on level ground in a person with knee pain might make it more likely that their pain is from PFJ structural damage; its presence might suggest TFJ structural damage.

MRI assessment. Axial and sagittal fat-suppressed proton density-weighted fast spin echo and coronal short-tau inversion recovery sequences were acquired at the 60-month visit, including all eligible participants. Two musculoskeletal radiologists (FWR, AG) used the Whole-Organ Magnetic Resonance Imaging Score (WORMS) to assess structural damage, cartilage morphology, and bone marrow lesions (BML) in the PFJ and TFJ[19]. The WORMS cartilage scale ranges from 0–6, where 0 = normal cartilage morphology; 1 = normal thickness but increased signal on proton density-weighted fat-suppressed images; 2.0 = a single partial thickness focal defect < 1 cm in greatest width; 2.5 = a single full thickness focal defect < 1 cm in greatest width; 3 = multiple areas of partial-thickness (Grade 2.0) defects intermixed with areas of normal thickness, or a Grade 2.0 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 grade 2.5 lesion wider than 1 cm but < 75% of the region; 6 = diffuse (≥ 75% of the region) full-thickness loss. The WORMS BML scale ranges from 0–3, where 0 = normal; 1 = small, < 25% of region; 2 = medium, 25–50% of region; 3 = large, > 50% of region. Interreader weighted κ values for WORMS scores ranged from 0.62 to 0.78.

We defined knees as having isolated PFJ damage if they had full-thickness cartilage loss or a BML in the PFJ and did not have full-thickness cartilage loss or BML in the TFJ. We defined isolated TFJ damage in the same manner. Knees meeting criteria for damage in both compartments were excluded because we would not be able to determine which compartment was generating the knee pain. Knees not meeting the above criteria in either the PFJ or TFJ were considered to not have structural damage in either compartment.

Statistical analysis. We determined the sensitivity, specificity, positive likelihood ratios, positive and negative predictive values for AKP, pain with stairs, absence of pain while walking on level ground, and combinations of these symptoms in identifying isolated PFJ damage. Because other person level or structural factors can influence the pain experience, we performed further analyses. We first stratified our analysis by age (above and below median value of 65.9 yrs), sex, and body mass index (≥ 30 vs < 30). Then, separate analyses were performed removing knees with (1) history of surgery or injury, (2) presence of periarticular lesions (bursitis), (3) history of daily medication use, and (4) knee injection in the last 6 months. Additionally, we examined different definitions of structural damage [full-thickness cartilage loss regardless of BML, BML (WORMS > 1 and > 2) regardless of full-thickness cartilage loss, and both full-thickness cartilage loss and a BML]. Finally, we included mixed damage in the no damage group and reassessed the specificity of the diagnostic tests and then included mixed damage in the isolated PFJ group and reassessed sensitivity.

RESULTS

Of 1119 knees with complete MRI readings at the 60-month visit, 728 knees had pain, aching, or stiffness in the past year, but 321 knees had structural damage in both the PFJ and TFJ, leaving 407 knees that met our inclusion criteria. The mean (± SD) age and BMI were 66.2 years (7.5) and 29.5 (4.7) kg/m^2, respectively, and 68% were female (Table 1). Of these, 193 (47%) had isolated PFJ damage, while 214 (53%) had either no damage (102; 25%) or isolated TFJ damage (112; 28%). Table 1 gives the frequency of knee surgery or injury, presence of periarticular lesions (bursitis),

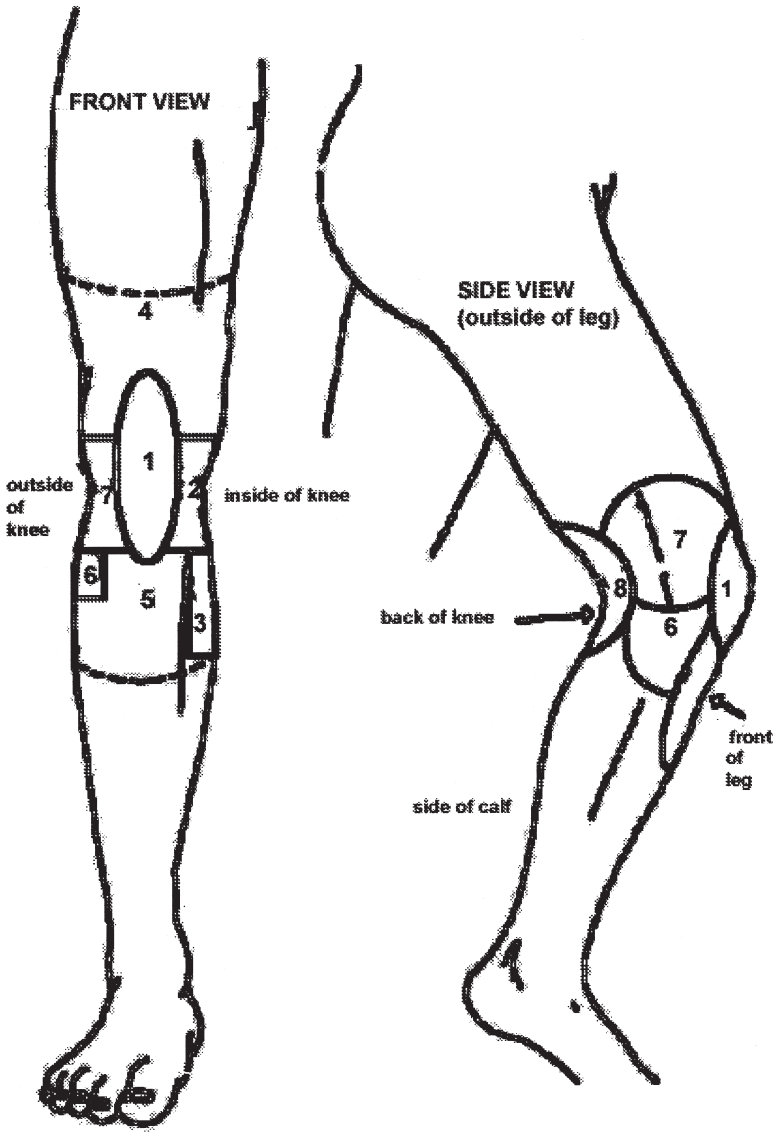

Figure 1. Knee pain map. Subjects were asked, "When your knee hurts where does it hurt?" Subjects identified painful areas around their knee and could report any number of areas.

daily medication use, and knee injection in the last 6 months in all knees and in each category of structural damage. The overall prevalence of each type of pain and combinations of pain types can be found in Table 2. "Any" and "isolated" AKP were present in 53% and 23% of knees, respectively; absence of moderate pain walking on level ground was the most prevalent activity-related variable (90%).

"Any" AKP had a sensitivity of 60% and specificity of 53%; "isolated" AKP had a sensitivity of 27% and specificity of 81% (Table 2). Absence of moderate pain while walking on level ground had the highest sensitivity (93%) but also the lowest specificity (13%; i.e., most persons with TFJ structural damage or no damage did not have moderate or worse pain walking on level ground). The combination of isolated AKP and moderate pain with stairs had the greatest specificity (97%) and positive likelihood ratio (3.0), but low sensitivity (9%).

When stratifying our results by age (at median), sex, and obesity status, the sensitivity and specificity for the majority of diagnostic tests were within 10 percentage points of the main analyses (Appendix 1). Also, in older individuals (≥ 66 yrs), the positive likelihood ratio was 12.0 for the combination of isolated AKP and moderate pain with stairs. When removing knees with a history of knee surgery or injury, presence of periarticular lesions (bursitis), history of daily medication use, and knee injection in the last 6 months, the sensitivity and specificity for all diagnostic tests were within 5 percentage points of the main analyses (Appendix 2). Additionally, when including mixed damage in the analyses and when using different definitions of structural damage,

Table 1. Descriptive statistics for the study population. N (%) is given for categorical variables; mean (± SD) for continuous variables.

	All Subjects, n = 728	Isolated PFJ, n = 193	Isolated TFJ, n = 112	Mixed, n = 321	None, n = 102
Age, yrs	66.5 (7.4)	66.1 (7.2)	66.7 (8.1)	66.7 (7.4)	66.0 (7.2)
BMI, kg/m^2	29.4 (4.8)	29.8 (4.5)	29.9 (4.5)	30.1 (4.9)	28.7 (5.1)
BMI (% obese)	326 (45)	85 (44)	51 (46)	155 (48)	35 (34)
Sex (% female)	499 (68)	146 (76)	70 (63)	223 (69)	60 (59)
History of knee surgery or injury	156 (21)	35 (18)	37 (33)	70 (22)	14 (14)
Presence of periarticular lesions*	128 (18)	21 (11)	27 (24)	68 (21)	12 (12)
Daily medication use	96 (13)	22 (11)	17 (15)	43 (13)	14 (14)
Injection in last 6 months	328 (45)	79 (41)	55 (49)	130 (41)	64 (63)

* Defined as prepatellar or pes anserine bursitis on magnetic resonance imaging. PFJ: patellofemoral joint; TFJ: tibiofemoral joint; BMI: body mass index.

Table 2. Diagnostic utility of self-reported pain in identifying PFJ damage (comparing knees with isolated PFJ full-thickness cartilage damage or BML to knees with either isolated TJF or no full-thickness cartilage damage or BML).

		Prevalence	Sensitivity	Specificity	LR+	PPV	NPV
AKP	Any	53	60	53	1.3	53	59
	Isolated	23	27	81	1.4	57	55
Max pain with stairs (up or down)	(≥ min)	70	74	33	1.1	50	58
	(≥ mod)	35	40	70	1.3	54	56
Pain going up stairs	(≥ min)	69	72	34	1.1	49	57
	(≥ mod)	30	35	74	1.3	54	56
Pain going down stairs	(≥ min)	62	64	40	1.1	49	55
	(≥ mod)	25	32	80	1.6	59	57
Absence of pain walking on level ground	(≥ min)	57	58	44	1.0	48	54
	(≥ mod)	90	93	13	1.1	49	68
Any AKP + max pain with stairs	(≥ min)	42	49	64	1.4	56	58
	(≥ mod)	23	29	82	1.6	60	56
Any AKP + absence of pain walking on level ground	(≥ min)	27	30	76	1.3	52	54
	(≥ mod)	47	56	60	1.4	56	60
Isolated AKP + max pain with stairs	(≥ min)	15	20	90	2.0	63	55
	(≥ mod)	6	9	97	3.0	72	54
Isolated AKP + absence of pain walking on level ground	(≥ min)	16	20	86	1.4	57	54
	(≥ mod)	22	26	82	1.4	57	55

LR+: positive likelihood ratio (Sn/1-Sp); PPV: positive predictive value; NPV: negative predictive value; AKP: anterior knee pain; max: maximum; min: minimal; mod: moderate; PFJ: patellofemoral joint; TFJ: tibiofemoral joint; BML: bone marrow lesions.

sensitivity and specificity for the majority of diagnostic tests were within 5 percentage points of the main analyses (Appendices 3 and 4). For all secondary analyses, absence of moderate pain while walking on level ground had the highest sensitivity and the combination of isolated AKP and moderate pain with stairs had the greatest specificity.

DISCUSSION

Based on the current study, none of the self-reported pain variables evaluated performed well as a diagnostic test for PFJ structural damage. Pain with either stair ascent or descent, commonly used tests thought to indicate PFJ structural damage, performed poorly as diagnostic tests. The absence of moderate pain when walking on a flat surface had the greatest sensitivity (93%) for isolated PFJ structural damage, but poor specificity. Thus, although most persons with PFJ structural damage did not have at least moderate pain walking on a flat surface, most persons with no PFJ structural damage (either no structural damage in either compartment or isolated TFJ) did not have at least moderate pain walking on flat surfaces either (specificity 13%). At least minimal pain with stairs also had moderate sensitivity

but low specificity, reflecting that many persons with TFJ damage or even no damage by our definition had at least minimal pain with stairs. Isolated AKP in combination with at least moderate pain with stairs had the greatest specificity (97%), meaning that these tests could be used confidently to rule in isolated PFJ structural damage. However, the same combination had a very low sensitivity, indicating that it is not a common feature of isolated PFJ structural damage. Overall, similar results were found when accounting for other person level factors and structures around the knee joint that may contribute to the pain experience and when including mixed structural damage in our analyses. While in older individuals the positive likelihood ratio was high for the combination of isolated AKP and moderate pain with stairs, these estimates are based on small numbers, and tiny changes in specificity would have dramatically changed the likelihood ratio; thus, this finding may not be significant.

While previous studies used radiographs to define OA, radiographs are insensitive to evidence of cartilage loss[14]. Nonetheless, using MRI to detect features of OA, which is more sensitive than radiographs, we were unable to find a combination of self-reported pain location and pain with activities that had both high sensitivity and specificity. Clinical examination measurements may perform better in identifying isolated PFJ structural damage than self-reported pain measures. Peat, *et al,* reported on a combination of clinical features that may help clinicians to make a diagnosis of radiographic PFJ OA[20]. With this combination, isolated radiographic PFJ OA was only somewhat distinguished from no radiographic OA (area under the curve 0.71, 95% CI 0.66, 0.76). The authors concluded that confident diagnosis of radiographic PFJ OA may be limited in the community setting.

Pain while ambulating up and down stairs and AKP are commonly thought and taught in clinical practice to represent underlying structural damage in the PFJ[8,10,11,12]. Studies of patellofemoral pain syndrome (but not PFJ OA) typically include individuals with particular findings from clinical examination or symptoms such as pain located around the patellofemoral articulation and pain with stair ascent or descent, squatting, kneeling, or prolonged sitting. When the knee is flexed during stair climbing and the quadriceps muscles are contracting to keep the knee from buckling, there are increased forces being transmitted through the PFJ. However, the weight of the body also exerts force through the TFJ during stair climbing, which may also cause pain. Pain with stair climbing (using any definition) alone did not perform well in discriminating structural damage in the PFJ and TFJ, suggesting a similar prevalence of pain with stairs in knees with isolated PFJ and TFJ structural damage. We found similar diagnostic utility for pain going up versus down stairs. Similar to pain with stairs, any AKP was also common in knees with isolated TFJ or no structural damage yielding low sensitivity and specificity. Indeed, isolated AKP was present in 16% and 22% of knees with isolated TFJ structural damage and no damage, respectively.

One potential explanation for the poor diagnostic results may be that pain in and around the knee may originate in other knee joint structures, some of which may not be compartment-specific. For example, synovitis triggered by patellar cartilage loss may occur in Hoffa's fat pad or the lateral synovium. However, in our current study we chose to focus on tissues that are compartment-specific and may respond to compartment-specific treatments developed in future trials for biomechanical and/or rehabilitation treatments.

The results of our study can provide a guide to clinicians and researchers who need to identify patients and subjects with isolated PFJ OA to manage their care or to enroll subjects in clinical trials. In the few studies that specifically recruited subjects with isolated PFJ OA, subjects were recruited based on the presence of AKP and pain during stair ambulation[21,22]. For researchers enrolling subjects in interventions or other studies, diagnostic tests that maximize specificity should be used to avoid enrolling subjects who truly do not have "disease". The strategy that best maximized specificity in our study was to use a combination of diagnostic tests: having knee pain, aching, or stiffness in the past year along with isolated AKP and at least moderate pain with stairs (specificity 97%). Clinicians managing patients with knee pain may want to select the best of tested strategies to either identify those with PFJ "disease" or be confidently assured that their patient does not have PFJ "disease". None of our tested strategies does either of these optimally. Among those with isolated AKP and at least moderate pain with stair climbing, 72% had isolated PFJ structural damage. And among those who had moderate or worse pain when walking on level ground, 68% did not have isolated PFJ structural damage.

We recognize limitations of our current study. Subjects could have reported pain in more than 1 region around their knee and we do not know the severity of pain in each area or which area of pain was their primary location of knee pain. To address this we defined knees with isolated AKP, which resulted in improvement in specificity at the cost of worsening sensitivity compared with analysis of any AKP. We did not include some activity-related pain such as pain while kneeling or squatting or sitting that may more accurately identify pain emanating from the PFJ. However, because all of these activities, like stair climbing, increase stress across both the TFJ and PFJ, we suspect the results for these would be similar to those we report. We also recognize that there are other factors that may contribute to the pain experience that cannot be easily controlled for (e.g., genetic, psychosocial, sociocultural, etc.), which may affect our results.

Self-reported location of pain and pain with activities performed poorly in discriminating MRI-detected structural

damage isolated to the PFJ from isolated TFJ or no damage, suggesting that clinicians cannot rely solely on these variables to identify the source of symptoms or to plan management strategies. Future research studies are needed that include easily performed clinical tests and measures in addition to self-reported location of pain and pain with activities.

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APPENDIX 1. Results stratified by age (at median), sex, and obesity status.

		Age (> median)			Age (< median)			Female			Male			Obese			Not Obese		
		Sn	Sp	LR+	Sn	Sp	LR+	Sn	Sp	LR+	Sn	Sp	LR+	Sn	Sp	LR+	Sn	Sp	LR+
AKP	Any	63	55	1.4	57	51	1.2	64	48	1.2	47	61	1.2	57	58	1.4	64	45	1.2
	Isolated	28	84	1.8	26	79	1.2	29	81	1.5	21	82	1.2	28	84	1.8	27	77	1.2
Max pain with stairs (up or down)	(≥ min)	78	38	1.3	68	28	0.9	73	27	1.0	74	42	1.3	69	38	1.1	80	26	1.1
	(≥ mod)	43	71	1.5	36	68	1.1	42	68	1.3	34	73	1.3	33	74	1.3	48	63	1.3
Pain with up stairs	(≥ min)	77	38	1.2	65	29	0.9	71	28	1.0	74	42	1.3	66	38	1.1	79	27	1.1
	(≥ mod)	35	76	1.5	34	72	1.2	36	73	1.3	32	75	1.3	27	77	1.2	45	69	1.5
Pain with down stairs	(≥ min)	73	46	1.4	54	34	0.8	66	35	1.0	55	48	1.1	60	46	1.1	68	30	1.0
	(≥ mod)	36	80	1.8	26	81	1.4	33	79	1.6	28	82	1.6	28	85	1.9	36	73	1.3
Absence of pain walking on level ground	(≥ min)	56	39	0.9	60	48	1.2	58	46	1.1	60	40	1.0	62	40	1.0	53	50	1.1
	(≥ mod)	93	14	1.1	93	12	1.2	93	17	1.1	94	7	1.0	94	10	1.0	92	17	1.1
Any AKP + max pain with stairs	(≥ min)	56	67	1.7	42	62	1.1	53	58	1.3	38	74	1.5	45	70	1.5	54	56	1.2
	(≥ mod)	34	83	2.0	23	82	1.1	33	81	1.7	17	85	1.1	25	87	1.9	34	76	1.4
Any AKP + absence of pain walking on level ground	(≥ min)	30	77	1.3	29	75	1.3	30	73	1.1	28	80	1.4	31	77	1.3	28	73	1.0
	(≥ mod)	59	65	1.7	53	55	1.2	59	58	1.4	47	64	1.3	54	63	1.5	59	56	1.3
Isolated AKP + max pain with stairs	(≥ min)	25	93	3.6	14	86	1.0	21	88	1.8	17	93	2.4	19	92	2.4	21	86	1.5
	(≥ mod)	12	99	12.0	7	95	1.4	11	96	2.8	4	98	2.0	7	98	3.5	12	94	2.0
Isolated AKP + Absence of pain walking on level ground	(≥ min)	19	88	1.6	21	85	1.4	21	86	1.5	17	87	1.3	21	88	1.8	18	85	1.2
	(≥ mod)	26	85	1.7	26	80	1.3	28	82	1.6	21	82	1.2	27	85	1.8	26	78	1.2

Sn: Sensitivity; Sp: Specificity; LR+: Positive likelihood ratio; AKP: anterior knee pain; max: maximum; min: minimal; mod: moderate.

APPENDIX 2. Results after removing from analysis knees with a history of surgery, bursitis, daily medication use, and injection in last 6 months.

		Knees Without History of Surgery or Injury			Knees Without Bursitis			Knees Without Daily Medication Use			Knees Without History of Injection in Last 6 Mos		
		Sn	Sp	LR+	Sn	Sp	LR+	Sn	Sp	LR+	Sn	Sp	LR+
AKP	Any	60	53	1.3	60	51	1.2	62	54	1.3	61	49	1.2
	Isolated	27	78	1.2	27	81	1.4	29	81	1.5	25	80	1.3
Max pain with stairs (up or down)	(≥ min)	72	36	1.1	73	34	1.1	71	33	1.1	75	34	1.1
	(≥ mod)	37	74	1.4	38	73	1.4	37	73	1.4	41	65	1.2
Pain going up stairs	(≥ min)	70	37	1.1	71	35	1.1	69	34	1.0	74	35	1.1
	(≥ mod)	32	79	1.5	33	77	1.4	32	77	1.4	33	71	1.1
Pain going down stairs	(≥ min)	63	44	1.1	64	41	1.1	60	40	1.0	61	40	1.0
	(≥ mod)	28	83	1.6	31	82	1.7	29	85	1.9	32	82	1.8
Absence of pain walking on level ground	(≥ min)	60	39	1.0	58	42	1.0	60	42	1.0	57	41	1.0
	(≥ mod)	95	9	1.0	92	12	1.0	94	10	1.0	93	14	1.1
Any AKP + max pain with stairs	(≥ min)	49	65	1.4	49	63	1.3	50	64	1.4	49	62	1.3
	(≥ mod)	28	84	1.8	28	83	1.6	28	83	1.6	30	80	1.5
Any AKP + absence of pain walking on level ground	(≥ min)	30	74	1.2	29	74	1.1	32	76	1.3	29	72	1.0
	(≥ mod)	57	58	1.4	55	58	1.3	57	60	1.4	55	58	1.3
Isolated AKP + max pain with stairs	(≥ min)	18	88	1.5	20	89	1.8	20	88	1.7	18	87	1.4
	(≥ mod)	9	97	3.0	9	98	4.5	9	96	2.3	8	96	2.0
Isolated AKP + absence of pain walking on level ground	(≥ min)	20	83	1.2	19	85	1.3	21	87	1.6	18	84	1.1
	(≥ mod)	26	79	1.2	26	82	1.4	27	83	1.6	24	80	1.2

AKP: anterior knee pain; max: maximum; min: minimal; mod: moderate.

APPENDIX 3. Results using different definitions of structural damage.

		Any BML + Full-thickness Cartilage Loss			Full-thickness Cartilage Loss			Any BML (WORMS > 0)			Large BML (WORMS > 2)		
		Sn	Sp	LR+	Sn	Sp	LR+	Sn	Sp	LR+	Sn	Sp	LR+
AKP	Any	68	51	1.4	62	50	1.2	61	53	1.3	62	51	1.3
	Isolated	30	79	1.4	26	81	1.4	28	81	1.5	24	81	1.3
Max pain with stairs (up or down)	(≥ min)	79	32	1.2	79	27	1.1	78	34	1.2	84	27	1.2
	(≥ mod)	49	69	1.6	38	66	1.1	42	71	1.4	43	66	1.3
Pain going up stairs	(≥ min)	78	34	1.2	75	29	1.1	76	35	1.2	80	30	1.1
	(≥ mod)	45	74	1.7	35	70	1.2	37	75	1.5	36	70	1.2
Pain going down stairs	(≥ min)	71	41	1.2	72	37	1.1	68	40	1.1	77	35	1.2
	(≥ mod)	41	79	2.0	31	76	1.3	33	81	1.7	37	75	1.5
Absence of pain walking on level ground	(≥ min)	52	42	0.9	58	44	1.0	56	43	1.0	58	45	1.1
	(≥ mod)	93	11	1.0	93	12	1.1	92	12	1.0	89	11	1.0
Any AKP + max pain with stairs	(≥ min)	61	63	1.6	55	62	1.4	51	63	1.4	57	60	1.4
	(≥ mod)	41	82	2.3	29	80	1.5	29	83	1.7	29	80	1.5
Any AKP + absence of pain walking on level ground	(≥ min)	30	74	1.2	33	74	1.3	30	75	1.2	33	75	1.3
	(≥ mod)	62	57	1.4	57	57	1.3	55	60	1.4	54	57	1.3
Isolated AKP + max pain with stairs	(≥ min)	25	88	2.1	22	88	1.8	21	89	1.9	21	87	1.6
	(≥ mod)	14	96	3.5	9	96	2.3	9	97	3.0	9	96	2.3
Isolated AKP + absence of pain walking on level ground	(≥ min)	21	85	1.4	20	86	1.4	20	87	1.5	18	86	1.3
	(≥ mod)	28	80	1.4	25	82	1.4	26	82	1.4	22	81	1.2

AKP: anterior knee pain; max: maximum; min: minimal; mod: moderate.

APPENDIX 4. Sensitivity when including mixed damage in the isolated PFJ damage group and specificity if mixed damage included in the none/isolated PFJ damage group.

		Sensitivity (Including Mixed)	Specificity (Including Mixed)
AKP	Any	55	50
	Isolated	22	82
Max pain with stairs (up or down)	(≥ min)	79	24
	(≥ mod)	38	65
Pain going up stairs	(≥ min)	74	28
	(≥ mod)	33	70
Pain going down stairs	(≥ min)	71	31
	(≥ mod)	31	74
Absence of pain walking on level ground	(≥ min)	56	45
	(≥ mod)	90	13
Any AKP + max pain with stairs	(≥ min)	48	58
	(≥ mod)	24	81
Any AKP + absence of pain walking on level ground	(≥ min)	29	73
	(≥ mod)	49	57
Isolated AKP + max pain with stairs	(≥ min)	17	86
	(≥ mod)	6	97
Isolated AKP + absence of pain walking on level ground	(≥ min)	16	86
	(≥ mod)	20	83

AKP: anterior knee pain; max: maximum; min: minimal; mod: moderate.