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RESEARCH ARTICLE

Clinical Significance of Quadriceps Fat Pad Edema: Its Relation with Anterior Knee Pain and Other Patellofemoral Joint Pathologies

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ABSTRACT

Objective: This study aimed to determine the frequency of edematous changes seen in QFP among patients undergoing MRI due to anterior knee pain (AKP) and to elucidate the relation between such changes and other patellofemoral joint pathologies.

Materials and Methods: In this retrospective case–control study, individuals with (n=340) and without (n=350) AKP undergoing MRI between January 2018 and January 2020 were evaluated. All images were examined for the presence of QFP edema (QFPE), mass effect and other patellofemoral joint pathologies. The cross-sectional area of QFP was measured and the amount of edema was recorded.

Results: QFPE was detected in 79 of the 340 patients with AKP (mean age: 32.29±8.81 years; range: 18–45 years). Mass effects were significantly more common in the AKP group (n=35, 44.3%, p=0.001). The risk of AKP in patients with mass effects was 38.973 times higher compared to patients without mass effects (p=0.001). Patients with diffuse QFPE had a higher risk of AKP than patients with less than 50% edema (p=0.021). Patients with patella alta and increased trochlear sulcus angle had a higher risk of AKP (p=0.029, p=0.006). No other variables were significant risk factors. There was no statistically significant cutoff value for the cross-sectional area.

Conclusion: QFPE and mass effects may be associated with AKP independently of other patellofemoral joint pathologies. Therefore, radiologists should be aware of these common findings when analyzing MR images of patients with AKP.

Keywords: Anterior knee pain, edema, magnetic resonance imaging, quadriceps fat pad

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INTRODUCTION

Quadriceps fat pad (QFP) is a triangular structure located anterior to the knee joint, between the quadriceps tendon and the suprapatellar recess. There are two more fat pads in the anterior compartment of the knee, namely the prefemoral and Hoffa (infrapatellar) fat pads, which are intracapsular and extrasynovial.[1] Regarding their functions and pathophysiology, it has been suggested that these small anatomical structures absorb the loads placed on the joint, play a role in its lubrication, and may be associated with the development of degenerative osteoarthritis in the patellofemoral joint.[2]

Anterior knee pain (AKP) is a common complaint associated with activities involving great forces acting on the patellofemoral joint, such as climbing, running, squatting, and climbing stairs. Although it is known that patellofemoral joint disorders are the most common causes, the exact roles of other anatomical structures of the anterior compartment in the development of pain and their interactions remain unclear.[3–5]

Pathologies of the fat pads in the knee joint have attracted increasing attention with the increasing use of magnetic resonance imaging (MRI) to reveal the source and associated pathologies of AKP in daily practice. It is known that bleeding, edema, and inflammation caused by acute or repetitive

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trauma can result in hypertrophy of the fat pads, leading to impingement syndrome.[6] Many studies have investigated Hoffa's disease, which occurs as a result of the compression of the Hoffa fat pad, and have established a relation between the Hoffa's disease and AKP.[7–9] However, few studies have focused on the clinical significance of edema mass effect and impingement findings in the QFP, which are in fact more common. Moreover, while some studies have suggested that the QFP pathologies and AKP might be related, others have found no relation.[10–12] Furthermore, its coexistence and relation with other pathologies of the patellofemoral joint have not been clearly demonstrated. The relation between QFP volume increase, frequency of diffuse or partial edematous changes, and pain remains unclear. Therefore, in this study, it was aimed to determine the frequency of edematous changes seen in the QFP among patients undergoing MRI due to complaints of AKP and to elucidate the relation between such changes and other patellofemoral joint pathologies, especially knee pain.

MATERIALS and METHODS

This study was approved by the institutional ethics committee. Due to its retrospective nature, informed consent was waived.

Patient Selection

A total of 2050 consecutive patients presenting to our department with a preliminary diagnosis of knee pain and undergoing knee MRI between January 2018 and January 2020 were retrospectively evaluated. The images of 1045 patients aged between 18 and 45 years were screened. Patients with poor image quality and signs of tumor, infection, ligament injury, meniscal rupture, or acute trauma were excluded from the study. Exclusion criteria are shown in Figure 1. Finally, the images of 340 patients were analyzed. A control group consisting of 350 patients in the same age range undergoing MRI for reasons other than AKP was formed, and their images were evaluated in terms of the same parameters.

MR Imaging and Analysis

All MR images were acquired with the patients in supine position using 1.5 T or 3 T systems from different manufacturers with a phased-array knee coil. Standard sequences at our institution are as follows: Axial fat-suppressed turbo spin-echo (TSE) proton density–weighted images (TR/TE: 2933/41; echo-train length: 9; slice thickness: 3.5 mm; matrix: 320×256; FOV: 16 cm); sagittal fat-suppressed TSE proton density–weighted images (TR/TE: 2951/38; echo-train length: 10; slice thickness: 3.5 mm; matrix: 300×256: FOV: 15 cm); coronal fat-suppressed (TSE) T2-weighted spin-echo images (TR/TE: 3300/37; echo-train length: 9; slice thickness: 3.5 mm;

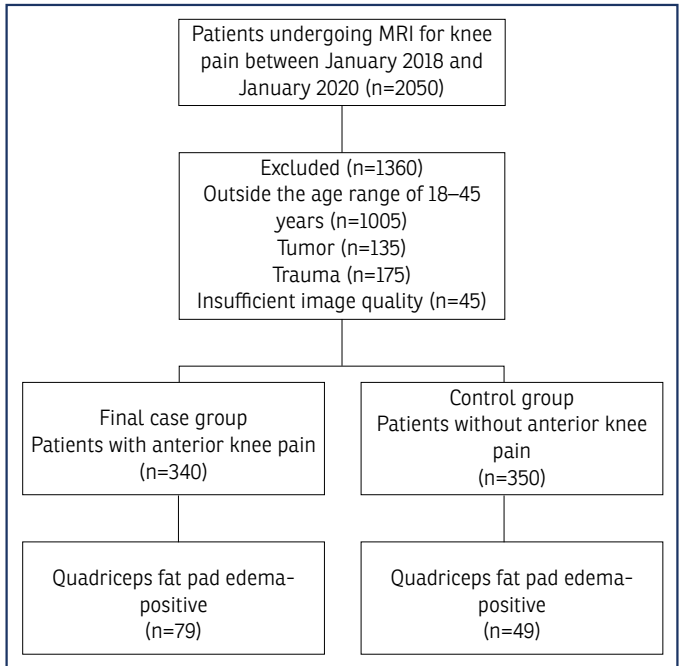

Figure 1. Flowchart of the patient selection process

MRI: Magnetic resonance imaging

matrix: 320×256; FOV: 16 cm). Sagittal T2*-weighted multiple-echo recombined gradient echo images (TR/TE: 40/17; echo-train length: 0; slice thickness: 3 mm; matrix: 288×192; FOV: 15 cm); and coronal T1-weighted spin-echo images (TR/TE: 400–500/12; echo-train length: 3; slice thickness: 4 mm; spacing between slices: 5 mm; matrix: 260×260; FOV: 16 cm).

The images were reviewed using PACS radiology information system. All images were independently examined for the presence of QFP edema (QFPE) by a musculoskeletal radiologist (ABÖ) with 10 years of experience and a general radiologist (CK) with two years of experience. The evaluation was performed on sagittal fat-suppressed proton density–weighted images, as in previous studies.[11–13] With the signal of the prefemoral fat pad taken as a reference, the case group consisted of patients exhibiting an increase in the signal of QFP. In these patients, a distortion of the typical triangular form and convexity observed in at least two consecutive sections in the posterior contour were considered mass effects (Fig. 2). In the absence of these findings, QFP was considered normal. The cross-sectional area was measured from the section where QFP was most prominent (Fig. 3). In cases with edema, the amount of edema was recorded as less than 50%, more than 50%, or 100%.

All images were also examined in terms of other pathologies causing AKP as follows:

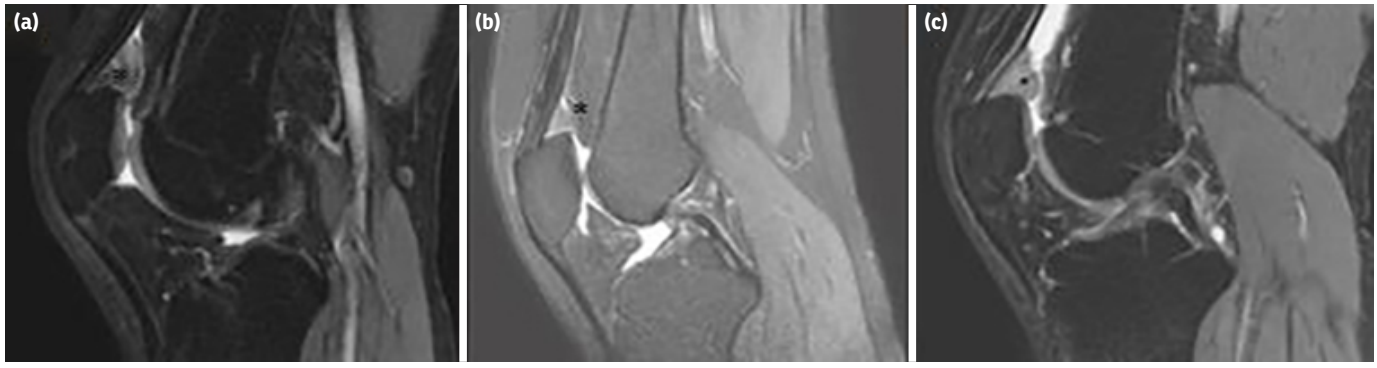

Figure 2. Three different patients in the anterior knee pain group have increased QFP signals when compared with prefemoral fat pad on fat suppressed PD sequences in midsagittal plane. The amount of edema (asteriks) is less than 50_ **(a)**, more than 50_ **(b)**

QFP: Quadriceps fat pad; PD: Proton-density

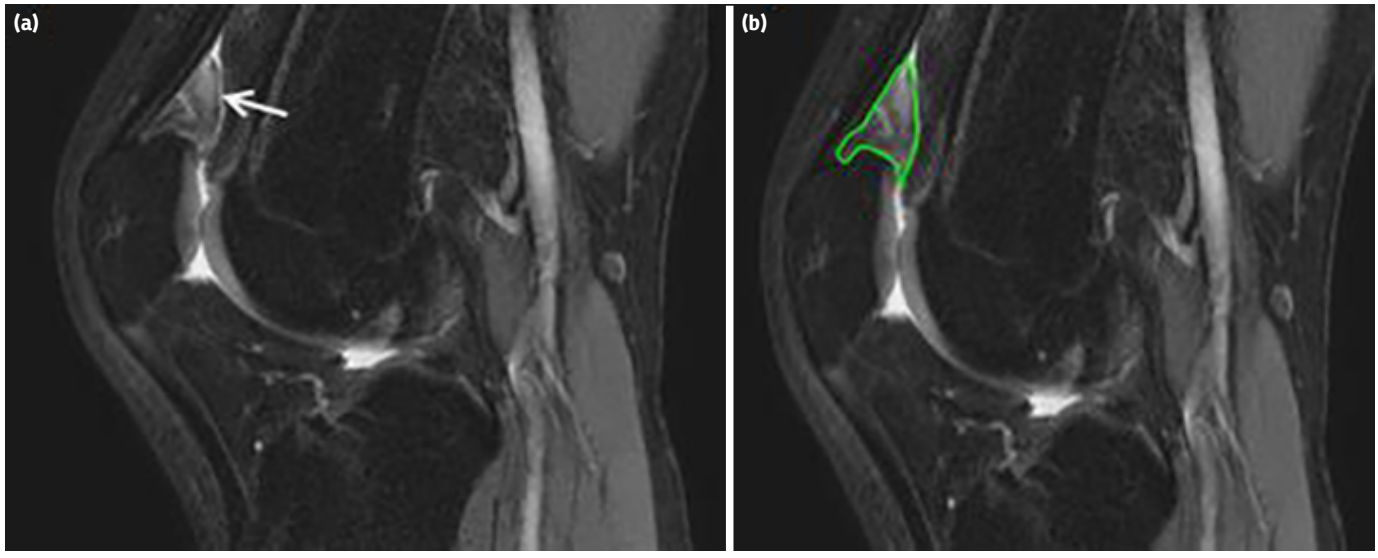

Figure 3. QFP edema and mass effect with increased posterior convexity (pointed by the arrow) is observed in a 35-year-old patient who presented with anterior knee pain **(a)**, cross-sectional area of QFP (green line) is measured as 1.883 cm^2 on fat suppressed **(b)**

QFP: Quadriceps fat pad

- Patellar/quadriceps tendon pathologies: Abnormal morphology and/or abnormal signal intensity.
- Medial plica syndrome: Medial fold thicker than 2 mm and interposed into the patellofemoral joint space.
- Hoffa/prefemoral fat pad compression: Edema volume increase in the Hoffa or prefemoral fat pad.[5]
- Prepatellar/infrapatellar bursitis: Localized fluid in the bursae in the anterior compartment.
- Patellar instability (patella alta/baja, trochlear dysplasia): Patella alta and baja evaluated by calculating the Insall–Salvati ratio (range: 0.8–1.2). Trochlear sulcus angle measured as previously described, and trochlear dysplasia noted.[14,15]
- Patellofemoral osteoarthritis and chondromalacia (Grades 1–4): Modified Outer bridge classification used for the evaluation of chondromalacia.[16]
- Iliotibial band syndrome: Edema in the iliotibial band and contamination in the adjacent fat planes.[17]

Statistical Analysis

Data were analyzed using IBM SPSS Statistics version 23. Conformity to the normal distribution was evaluated using

Table 1.Examination of risk factors affecting pain with logistic regression analysis

	Anterior Knee Pain				Total		Univariate OR (95% CI)	p	Multivariate OR (95% CI)	p
	No		Yes							
	n	%	n	%	n	%				
Sex										
Male	32	41.6	45	58.4	77	100	Reference			
Female	17	33.3	34	66.7	51	100	1.422 (0.68–2.974)	**0.349**	0.311 (0.086–1.1)	0.074
Age	38.76±6.61		32.29±8.81		34.77±8.61		0.903 (0.858–0.95)	**<0.001**	0.866 (0.799–0.9)	**<0.001**
QFPE										
1	31	49.2	32	50.8	63	100	Reference			
2	12	31.6	26	68.4	38	100	2.099 (0.903–4.88)	0.085	4.399 (0.996–19.4)	0.051
3	6	22.2	21	77.8	27	100	3.391 (1.207–9.526)	**0.021**	5.167 (0.39–68.4)	0.213
Volume	1.14±0.34		1.13±0.34		1.13±0.34		0.917 (0.32–2.63)	0.872	0.005 (0–0.1)	**<0.001**
Mass effect										
No	43	49.4	44	50.6	87	100	Reference			
Yes	6	14.6	35	85.4	41	100	5.701 (2.177–14.928)	**<0.001**	38.973 (4.296–353.5)	**0.001**
Hoffa fat pad pathology										
No	35	36.8	60	63.2	95	100	Reference			
Yes	14	42.4	19	57.6	33	100	0.792 (0.353–1.773)	0.570	0.634 (0.151–2.7)	0.534
Prefemoral fat pad pathology										
No	35	36.8	60	63.2	95	100	Reference			
Yes	14	42.4	19	57.6	33	100	0.605 (0.117–3.125)	0.549	0.382 (0.05–2.9)	0.353
Patellar tendon pathology										
No	47	39.2	73	60.8	120	100	Reference			
Yes	2	25	6	75	8	100	1.932 (0.374–9.975)	0.432	5.422 (0.597–49.3)	0.133
Quadriceps tendon pathology										
No	49	39.2	76	60.8	125	100	Reference			
Yes	0	0	3	100	3	100	–	–		
Bursa pathologies										
0	19	30.6	43	69.4	62	100	Reference			
1	26	48.1	28	51.9	54	100	0.476 (0.223–1.017)	0.055	1.296 (0.321–5.2)	0.716
2	4	33.3	8	66.7	12	100	0.884 (0.237–3.295)	0.854	4.205 (0.443–39.9)	0.211
Medial plica syndrome										
No	48	38.7	76	61.3	124	100	Reference			
Yes	1	25.0	3	75.0	4	100	1.895 (0.192–18.745)	0.585	4.089 (0.162–103.4)	0.393

Table 1. Cont.

	Anterior Knee Pain				Total		Univariate OR (95% CI)	p	Multivariate OR (95% CI)	p
	No		Yes							
	n	%	n	%	n	%				
Chondromalacia										
0	44	39.6	67	60.4	111	100	Reference			
1	4	33.3	8	66.7	12	100	1.313 (0.373–4.626)	0.671	3.689 (0.58–23.5)	0.167
2	1	20	4	80	5	100	2.627 (0.284–24.285)	0.395	2.066 (0.083–51.3)	0.658
Angle of trochlear sulcus	144.2±4.24		141.58±6.2		142.59±5.66		0.917 (0.856–0.981)	**0.012**	0.841 (0.743–1)	**0.006**
Patella alta	0.03±0.18		0.22±0.51		0.15±0.43		5.612 (1.137–27.688)	0.034	18.662 (1.358–256.4)	**0.029**
Patella baja	0.03±0.15		0.01±0.08		0.02±0.11		0.187 (0.007–4.96)	0.316	0.055 (0–36.5)	0.382

Cox & Snell R^2=45.6%; Nagelkerke R^2=61.9%. OR: Odds ration; CI: Confidence interval; QFPE: Quadriceps fat pad edema

the Shapiro–Wilk test. Independent-samples t-test was used to compare normally distributed data between the groups, and Mann–Whitney U test was used to compare non-normally distributed data. Pearson's chi-squared test, Yates's correction, and Fisher's exact test were used to compare categorical data between the groups. Interobserver agreement was assessed using kappa statistics for categorical data and intraclass correlation coefficients for quantitative data. A binary logistic regression analysis was performed to examine the risk factors for AKP. Receiver operating characteristic (ROC) analysis was performed to determine the threshold value of surface area for anterior knee pain outcome. Categorical data were expressed as frequencies (percentages), and quantitative data were expressed as means±standard deviations. Values of p<0.05 were considered statistically significant.

RESULTS

QFPE was detected in 79 of the 340 patients with AKP (mean age: 32.29±8.81 years; range: 18–45 years) and 49 of the 350 patients without AKP (mean age: 38.76±6.61 years; range: 18–45 years). Among the patients with QFPE, mass effects were significantly more common in the AKP group (n=35, 44.3%) than in the control group (n=6, 12.2%; p=0.001).

Risk factors for AKP determined by binary logistic regression are displayed in Table 1. With increasing age, the risk of AKP increased 0.903 times in the univariate model and 0.866 times in the multivariate model (p<0.001). The risk of AKP in patients with mass effects was 5.701 times higher (p<0.001) in the univariate model and 38.973 times higher in the multivariate model compared to patients without mass effects (p=0.001). According to the univariate model, patients with diffuse QFPE had a 3.391 times higher risk of AKP than patients with less than 50% edema (p=0.021). With an increasing Insall–Salvati ratio, patients with patella alta had a 5.612 times higher risk of AKP in the univariate model (p=0.034) and an 18.662 times higher risk in the multivariate model (p=0.029). Moreover, the risk of AKP increased 0.841 times as the trochlear sulcus angle increased (p=0.006). No other variables were significant risk factors for AKP.

The risk of developing AKP with an increased cross-sectional area was not significant in patients with QFPE according to the univariate model (p=0.872) but was significant according to the multivariate model (p=0.001). In ROC analysis, the area under the curve value of the cross-sectional area was not statistically significant. Accordingly, there was no statistically significant cutoff value for the cross-sectional area.

In the AKP and QFPE groups, there were no statistically significant differences in terms of sex in either the univariate model (p=0.349) or the multivariate model (p=0.074). However, the incidence of QFPE was higher among males in both the AKP and control groups.

In the AKP group, Hoffa and prefemoral fat pad edema, infrapatellar/prepatellar bursitis, patellar and quadriceps tendinopathy, chondromalacia, medial folds, edema in the

Table 2. Comparison of the results according to QFPE in the group with anterior knee pain

	QFPE						p*
	1		2		3		
	n	%	n	%	n	%	
Hoffa fat pad pathology							
No	26	81.3	19	73.1	15	71.4	0.656
Yes	6	18.8	7	26.9	6	28.6	
Prefemoral fat pad pathology							
No	31	96.9	25	96.2	20	95.2	–
Yes	1	3.1	1	3.8	1	4.8	
Patellar tendon pathologies							
No	31	96.9	22	84.6	20	95.2	0.183
Yes	1	3.1	4	15.4	1	4.8	
Quadriceps tendon pathologies							
No	32	100	23	88.5	21	100	0.051
Yes	0	0	3	11.5	0	0	
Bursa pathologies (0–1–2)							
0	19	59.4	15	57.7	9	42.9	0.051
1	12	37.5	5	19.2	11	52.4	
2	1	3.1	6	23.1	1	4.8	
Medial plica syndrome							
No	31	96.9	25	96.2	20	95.2	0.954
Yes	1	3.1	1	3.8	1	4.8	
Chondromalacia (0–1–2–3–4)							
0	30	93.8	20	76.9	17	81	0.268
1	2	6.3	3	11.5	3	14.3	
2	0	0	3	11.5	1	4.8	
Iliotibial band syndrome							
No	32	100	26	100	21	100	–
Angle of trochlear sulcus							
<145	24	75	21	80.8	15	71.4	0.748
>145	8	25	5	19.2	6	28.6	
Patella alta							
No	28	87.5	21	80.8	18	85.7	0.770
Yes	4	12.5	5	19.2	3	14.3	
Patella baja							
Yes	32	100	26	100	21	100	–

*: Chi-square test. QFPE: Quadriceps fat pad edema

iliotibial band, patella alta/baja, and trochlear sulcus angle were not significantly associated with QFPE (Table 2).

Interobserver agreement was very good in terms of QFPE and cross-sectional area in both the AKP and control groups ($p<0.001$) and moderate in terms of mass effects ($p<0.001$).

DISCUSSION

In this study, we analyzed QFPE, mass effects, and their relations with AKP. We found that QFPE was a significant risk factor for AKP independently of other patellofemoral joint pathologies. The prevalence of QFPE in the AKP group was

23.2% while the prevalence of mass effects was 44.3%. Roth et al.[11] have reported a QFPE rate of 12%, while Tsavalas and Karantanas have reported a rate of 13.8% among non-AKP patients.[6] The higher rate in our study concerns only the AKP group. The incidence of QFPE in the non-AKP group was 14%, which is similar to those reported previously.

To our knowledge, our study is the first to show that the risk of developing AKP among patients with diffuse QFPE is significantly higher than in patients with less than 50% edema. Roth et al.[11] have found that QFPE was associated with mass effects when the signal intensity approached the fluid signal. Wang et al.[13] have reported that mass effects and edema in the QFP were associated with knee pain due to osteoarthritis but could not establish a cause–effect relation. On the other hand, Tsavalas and Karantanas[6] have found no significant relation between QFPE and AKP but suggested that AKP might be associated with patellofemoral joint osteoarthritis. In this study, we aimed to evaluate QFPE independently of degenerative changes by setting an age above 45 years as an exclusion criterion in both the AKP and non-AKP groups to largely rule out osteoarthritis.

Some previous studies have suggested that there may be a relation between extensor mechanism pathologies and QFPE, whereas others have reported that edema is independent of these pathologies.[2,13,18–20] In this study, we found that only patella alta and the trochlear sulcus angle significantly correlated with QFPE and patellofemoral joint pathologies in the AKP group.

A clear criterion for the diagnosis of QFPE has yet to be established. In general, an increase in the signal, an increase in the anteroposterior (AP) diameter, and convexity of the posterior contour are considered QFP mass effects. Staeubli et al.[21] have reported normal AP diameters of 6±2 mm in women and 7±2 mm in men. Roth et al.[11] have evaluated the mean values between groups with and without mass effect and suggested that abnormal convexity of the posterior surface may be the most effective method for diagnosing quadriceps fat pad enlargement. In our clinical experience, signal enhancement and mass effects are important only when they are associated with AKP. Therefore, we aimed to determine a mass effect cutoff value. To this end, we evaluated QFP by measuring the cross-sectional area instead of only the AP diameter, as has been done previously. Our results showed that the risk of developing AKP increased significantly as the cross-sectional area increased. However, a significant cutoff value could not be determined.

Our study has several limitations. First, QFPE was evaluated only by visual examination; histopathological evaluations were not performed. However, histopathological evaluations are often not possible in daily practice. Second, this was a retrospective study of patients with an indication for MRI. Therefore, it was not possible to determine the frequency and findings of QFPE in truly asymptomatic individuals. However, we believe that we partially mitigated this limitation by comparing the case group to a non-AKP group. Finally, due to the cross-sectional design of this study, it was not possible to assess changes in QFP over time. Such changes may be revealed by longitudinal studies and perhaps by adding ultrasound findings.

In conclusion, this study shows that QFPE and mass effects may be associated with AKP independently of other patellofemoral joint pathologies. Therefore, radiologists should be aware of these common findings when analyzing MR images of patients with AKP.

Disclosures

Ethics Committee Approval: The study was approved by the Ondokuz Mayıs University Clinical Research Ethics Committee (No: B.30.2.ODM.0.20.08/401, Date: 26/06/2020).

Informed Consent: Written informed consent was obtained from all patients.

Peer-review: Externally peer reviewed.

Authorship Contributions: Concept: A.B.Ö.; Design: A.B.Ö.; Supervision: A.B.Ö.; Data Collection or Processing: A.B.Ö., C.K.; Analysis or Interpretation: A.B.Ö., C.K.; Literature Search: A.B.Ö., C.K.; Writing: A.B.Ö.; Critical review: A.B.Ö.

Conflict of Interest: No conflict of interest was declared by the authors.

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