

Anatomic Magnetic Resonance Imaging Measurements in First-Time Patellar Dislocators by Sex and Age

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Context: Anatomic differences of the knee in first-time patellar dislocators have not been clearly elucidated.

Objective: To compare structural differences of the knee in those who have sustained an acute first-time patellar dislocation resulting in a medial patellofemoral ligament (MPFL) tear by sex and age (≤ 17 years old, ≥ 18 years old).

Design: Case series.

Setting: Retrospective magnetic resonance imaging analysis.

Patients or Other Participants: Thirty-five acute first-time patellar dislocators with an associated MPFL tear.

Main Outcome Measure(s): Patellar height using 3 methods, patellar alignment using congruency angles, and trochlear morphology using the sulcus angle. We compared the means of these variables by sex and age. The intraclass correlation coefficient was then calculated to assess the agreement of the independent reviewers.

Results: A total of 21 left and 14 right knees were analyzed. The MPFL tear location did not differ by sex ($P = .34$) or age ($P = .43$). Patellar height did not differ as measured by the Caton-Deschamps ratio ($P = .29$ for sex, $P = .49$ for age), Insall-Salvati index ($P = .15$ for sex, $P = .33$ for age), or patellochlear index ($P = .67$ for sex, $P = .49$ for age). The congruence angle ($P = .81$ for sex, $P = .06$ for age) and trochlear morphology as measured by the sulcus angle ($P = .64$ for sex, $P = .45$ for age) were similar between groups.

Conclusions: Patellar height and trochlear morphology did not differ by sex or age among patients whose first-time patellar dislocations resulted in an MPFL tear. In addition, the location of the tear did not appear to vary by sex or age.

Key Words: anatomy, knee, medial patellofemoral ligament, trochlea

Key Points

- First-time male and female patellar dislocators who sustained medial patellofemoral ligament tears did not display different anatomic characteristics.
- Age did not predict anatomic changes that contributed to patellar dislocations among those who experienced a medial patellofemoral ligament tear.

Lateral patellar dislocation (LPD) is a common injury among both adults and children and is more frequently seen in the athletic population due to the demands of certain sporting activities.¹ The annual incidence of LPD has been estimated to be 43 to 77 per 100 000.^{2,3} This risk of dislocation appeared to be higher in females than in males.^{1,2}

In an otherwise normal knee, the patella is stabilized superiorly by the extensor mechanism, laterally by the retinacula, medially by the retinaculum and medial patellofemoral ligament (MPFL), and posteriorly by the interplay between patellar and trochlear geometry.⁴ Several anatomic factors have been associated with patellar instability, which increases the risk for LPD. These factors include patella alta,^{5,6} trochlear dysplasia,^{4,7} and abnormal patellar morphology,⁴ with patella alta being the most consistent feature associated with patellar instability.⁴ Additionally, female sex has been suggested as an independent risk factor for LPD; however, the explanation for this has not been fully elucidated.¹

The purpose of our study was to determine whether patellar heights differed between females and males who sustained first-time acute patellar dislocations. We also performed a subgroup analysis on these cohorts to analyze whether trochlear or patellar morphology differed based on sex or age.

METHODS

Participants

Before the study, we were granted approval by our institutional review board. Magnetic resonance images (MRI) of 35 knees (35 individuals) were obtained for analysis. Of those, 21 knees were left, and 14 were right. The participants consisted of 23 males and 12 females; 23 were ≤ 17 years old, and 12 were ≥ 18 years old (Table 1).

Volunteers were included if they were first-time patellar dislocators, had confirmed MRI evidence of a medial patellofemoral ligament (MPFL) tear, and displayed no movement artifact on the imaging sequences. Recruits were excluded if they were recurrent dislocators, if there was no

Table 1. Descriptive Data (N = 35)

Characteristic	No.
Sex	
Male	23
Female	12
Injured knee	
Left	21
Right	14
Age, y	
≤17	23
≥18	12
Mean (range)	19 (11–42)

evidence of MPFL tear as seen on MRI, or if movement artifact affected any of the MRI slices in the sequence. Those who had sustained an osteochondral or pure chondral lesion as a result of the dislocation were not excluded.

Measurements

Two musculoskeletal fellowship-trained radiologists (see Acknowledgments) selected participants based on the inclusion criteria and deidentified the MRI studies for analysis. They then noted the location of the MPFL tear: femoral-side 1/3, patellar-side 1/3, or midsubstance 1/3.^{7–9}

Four orthopaedic surgeons (N.L.G., B.M.W., D.M.T., B.J.K.) independently measured patellar morphology, patellar height, trochlear morphology, and patellar alignment. All measurements were obtained using OsiriX imaging software (version 10.0.1; Pixmeo SARL, Bernex, Switzerland).¹⁰ Patellar morphology was based on the classification of Wiberg¹¹ (Figure 1). Patellar height was based on 3 measurements, which had been previously validated using MRI.¹² These measurements were the Caton-Deschamps ratio,¹³ Insall-Salvati index,¹⁴ and patellochlear index¹⁵ (Figures 2–4).

The MRI reference slices for obtaining measurements were standardized and adapted from Barnett et al.¹² Trochlear morphology and patellar alignment were based on the sulcus angle^{16,17} and congruence angle,¹⁷ respectively (Figure 5). These measures have been used in previous analyses of MPFL tears in the context of patellar dislocation.^{8,9,18}

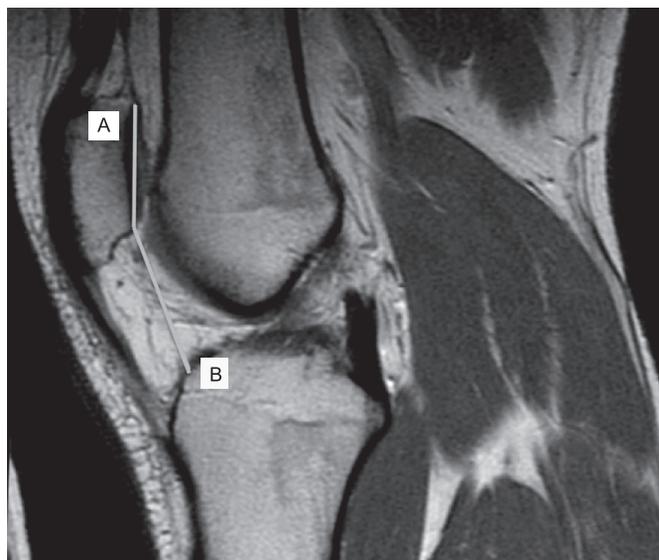


Figure 2. Caton-Deschamps ratio: line B/line A. Line B measures from the inferior margin of the patellar articular cartilage to the anterior margin of the tibial plateau. Line A measures the length of the patellar articular cartilage.

Statistical Analysis

The reviewers initially collected all data in an Excel (version 16.27; Microsoft Corp, Redmond, WA) spreadsheet and then exported them to STATA statistical software (release 13; StataCorp LP, College Station, TX) for analysis. We used the Student *t* test to compare the mean differences between males and females and those ≤17 years old and those ≥18 years old. For the categorical data of tear location and patellar morphology type, a χ^2 analysis was conducted to determine significance. Sample-size estimates for comparing 2 independent samples for patella alta based on sex were calculated using mean and standard deviation estimates published by Shabshin et al¹⁹ to reach a power of 0.80 with α set at .05. Therefore, the level of significance was defined a priori as $P < .05$. This required a minimum of 12 participants per sample.

The interrater reliability of the continuous data of measurements was then tested using an intraclass correlation coefficient (ICC) with a 2-way random-effects model.²⁰ The ICC ranged from 0 to 1.0, with 1.0 indicating *perfect agreement*, and we interpreted these values as follows: >0.80 was *very good*, 0.61–0.80 was *good*, 0.41–

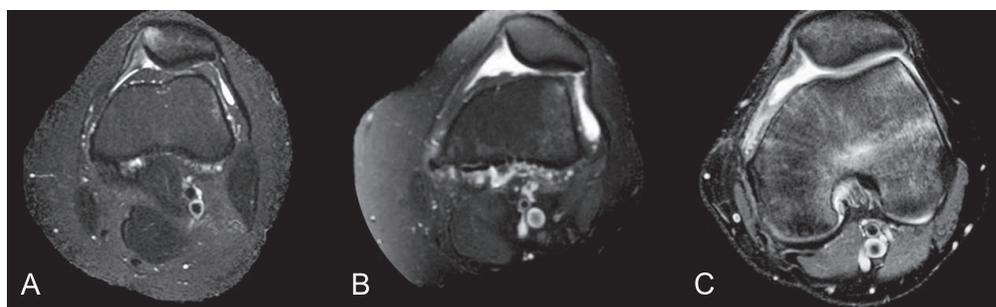


Figure 1. Wiberg classification of patella. A. Type 1: medial and lateral facets are gently concave and nearly equal in size. B. Type 2: medial facet is flat or convex and smaller than the concave lateral facet. C. Type 3: medial facet is very small and is usually prominent and convex, while the lateral facet is broad and concave.

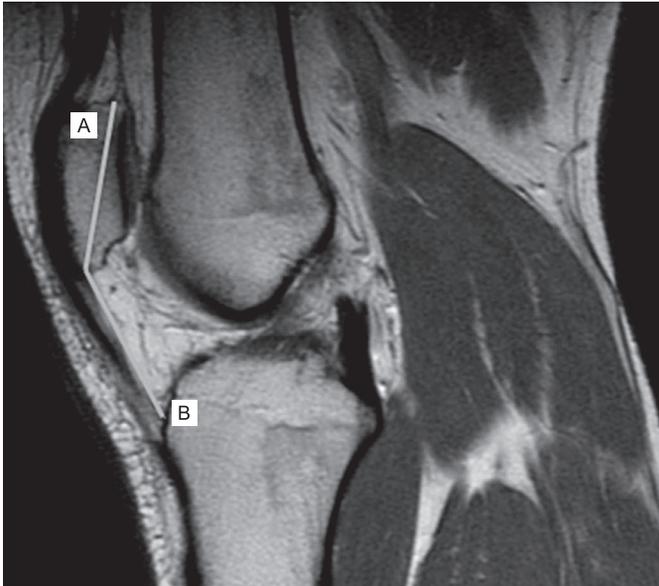


Figure 3. Insall-Salvati index: line B/line A. Line B measures from the inferior pole of the patella to the intersection of the superior portion of the patellar tendon insertion. Line A measures the greatest length of the patella from superior pole to inferior pole.

0.60 was *moderate*, 0.21–0.40 was *fair*, and <0.21 was *poor*.²¹

RESULTS

The inciting activity for the patellar dislocation was football in 2 participants, soccer in 3, softball in 2, 1 each in

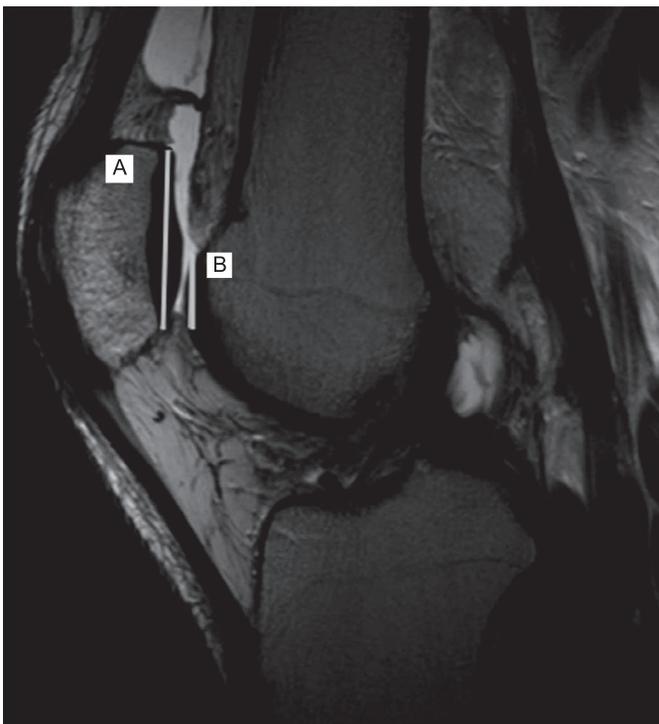


Figure 4. Patellotrochlear index: line B/line A. Line B measures the length of the trochlear articular cartilage surface from the superior-most aspect to the inferior-most aspect of where the adjacent patellar cartilage stops. Line A measures the length of the patellar articular cartilage.

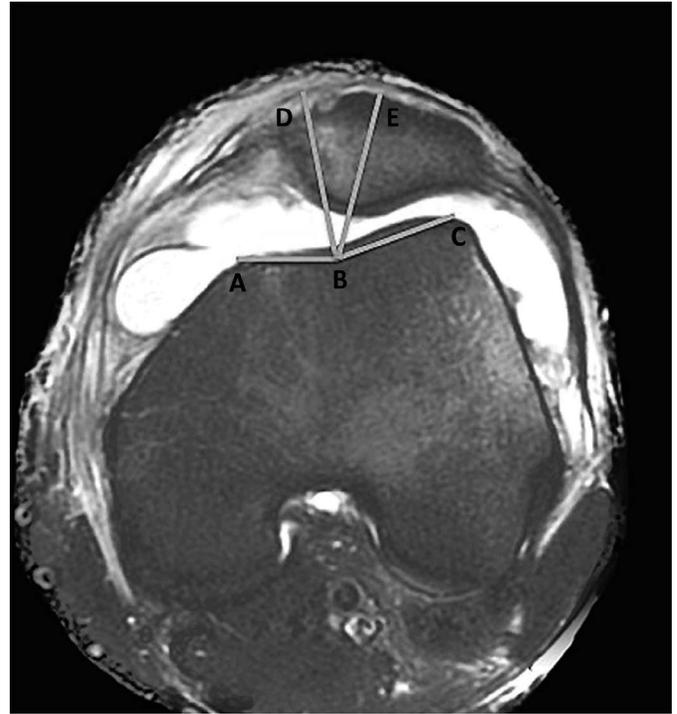


Figure 5. Sulcus angle ($\angle ABC$) and congruence angle ($\angle DBE$) as measured on magnetic resonance imaging.

basketball and hockey, and unspecified trauma in 25. For this cohort of first-time lateral patellar dislocators, the location of the MPFL tear did not differ by sex or age (Table 2). The most common location was the femoral 1/3 of the MPFL, which is consistent with previous reports.^{9,22}

Mean patellar height was greater for females than males (Caton-Deschamps ratio = 1.38 for females versus 1.29 for males, Insall-Salvati index = 1.33 for females versus 1.22 for males, and patellotrochlear index = 0.41 for females versus 0.39 for males); however, these values did not differ by sex or age (Table 3). The interrater reliability of these measurements was high, with ICC values ranging from 0.70 to 0.96. These measurements were rated as *very good* or *good* (Table 4). Additionally, trochlear morphology as measured by the sulcus angle and patellar alignment as measured by the congruence angle were not different by sex or age (Table 5).

The proportions of patellar morphology were similar between males and females, and the Wiberg type 2 was most common for both sexes (75% of females, 61% of males; Table 6).

DISCUSSION

Although a number of measurements have been developed to assess patellar height, many use radiographic

Table 2. Medial Patellofemoral Ligament Tear Location

Location	Sex		Age, y	
	Female	Male	≤17	≥18
Patellar	5	4	4	5
Midsubstance	0	1	1	0
Femoral	6	16	15	7
P value	.25		.34	

Table 3. Patellar Height Measurements

Measure	Mean ± SD	P Value
Caton-Deschamps ratio (AT/AP) ^a		
Sex		.29
Female	1.38 ± 0.35	
Male	1.28 ± 0.15	
Age, y		.49
≤17	1.3 ± 0.16	
≥18	1.36 ± 0.34	
Insall-Salvati index (PTL/PL) ^b		
Sex		.15
Female	1.33 ± 0.18	
Male	1.22 ± 0.20	
Age, y		.33
≤17	1.23 ± 0.2	
≥18	1.31 ± 0.19	
Patellotrochlear index (BLT/BLP) ^c		
Sex		.67
Female	0.41 ± 0.12	
Male	0.39 ± 0.10	
Age, y		.49
≤17	0.39 ± 0.1	
≥18	0.42 ± 0.12	

Abbreviations: AP, articular surface of patella; AT, articular surface of tibia; BLT, baseline trochlea; BLP, baseline patella; PL, patellar length; PTL, patellar tendon length.

^a Patella alta >1.2.¹³

^b Patella alta >1.2.¹⁴

^c Patella alta >1.25.¹⁵

methods. Some authors have suggested that the most important factor in patellar height is the position of the articular surface as it relates to the trochlear cartilage, which cannot be appreciated on radiograph imaging; thus, MRI analysis is required.^{15,25} Consequently, the measurements we chose were either developed for MRI¹⁵ or have been validated on MRI^{13,14} in previously published reports.¹² Although the American Academy of Orthopaedic Surgeons has not issued a position statement on MRI imaging for evaluating LPD at this point, we recommend this method for the evaluation and diagnosis of MPFL tear and preoperative planning for repair. This gives the clinician the opportunity to further evaluate the knee anatomy and devise a plan for the most appropriate treatment.

First-time patellar dislocation is a major concern, as osteoarthritis of the patellofemoral joint is likely to develop with time.²⁶ A further complication is that nonoperative

Table 4. Interrater Reliability^a

Measure	Intraclass Correlation Coefficient	95% Confidence Interval	Agreement
Wiberg classification	0.82	0.70, 0.90	Very good
Caton-Deschamps ratio	0.70	0.50, 0.83	Good
Insall-Salvati index	0.94	0.89, 0.97	Very good
Patellotrochlear index	0.83	0.71, 0.91	Very good
Sulcus angle	0.76	0.63, 0.88	Good
Congruency angle	0.96	0.93, 0.98	Very good

^a Rating of reliability based on Altman DG. *Practical Statistics for Medical Research*. 1st ed. London, United Kingdom: Chapman and Hall; 1991.

Table 5. Trochlear Morphology and Patellar Alignment

Measure	Mean ± SD	P Value
Sulcus angle ^a		
Sex		.64
Female	145.4 ± 5.3°	
Male	144.4 ± 6.73°	
Age, y		.45
≤17	145.3 ± 5.3°	
≥18	143.6 ± 7.8°	
Congruency angle ^b		
Sex		.81
Female	8.5 ± 27.2°	
Male	10.6 ± 23.8°	
Age, y		.06
≤17	4.3 ± 23.9°	
≥18	20.7 ± 23.4°	

^a Normal = 138 ± 6°.²³

^b Normal = >16°.²⁴

treatment of these injuries results in continued instability of the patellofemoral joint at long-term follow up.²⁷ Risk factors for sustaining an LPD can be categorized as anatomic and nonanatomic. Anatomic risk factors include patella alta,^{5,6} trochlear dysplasia,^{4,7} and abnormal patellar morphology,⁴ whereas nonanatomic risk factors include female sex,^{1,28,29} shorter height,³ and lower weight.³ Why females are at an increased risk of LPD is not completely understood.

Our results suggest that the degree of patella alta in female patients was no different than in their male counterparts. Additionally, their degrees of trochlear dysplasia and patellar alignment were no different when compared with the males. This suggests that something other than bony anatomical differences of the knee accounts for the greater risk of acute LPD in females. Further studies are needed to identify this discrepancy, as elucidating the risk factors in the female population will help to guide potential prevention strategies, screening techniques and tools for those at risk, and postinjury treatment options.

Our study was limited by the fact that quadriceps muscle relaxation during MRI is difficult to properly assess and control, which could have affected the measurements. However, we excluded all images that had evidence of movement artifact and therefore assumed the quadriceps were relaxed for the remaining images. Measurements were also limited by variability in user technique. We attempted to control for this by standardizing the slices used for measurements and found excellent agreement among 4 blinded, independent reviewers. Additionally, although our participant number provided sufficient statistical power, more males than females were in our cohort. This may be explained by our exclusion criteria of no recurrent dislocators: women are more likely to become recurrent dislocators than men and therefore were excluded.

Table 6. Patellar Morphology Classification. Wiberg Classification¹¹

Type	Females	Males
1	1	4
2	9	14
3	2	5

However, we did not blind the selection of these patients, so we cannot exclude selection bias as a possibility.

CONCLUSIONS

Our results suggest that the increased risk of LPD in females is not attributed to a more extreme dysmorphic anatomy (eg, patellar height, trochlear morphology, patellar alignment) when compared with their male counterparts. Further studies will need to be performed to identify the factors in females that lead to this apparent increased risk for LPD. Patellar height, trochlear morphology, and patellar alignment can reliably be measured on MRI images even though the original studies involved measurements based on radiographic imaging.

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