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FREQUENCY OF ANTERIOR CRUCIATE LIGAMENT INJURY ON MAGNETIC RESONANCE IMAGING AND ITS ASSOCIATION WITH KNEE MORPHOMETRICS

Ashraf Nadaf[1], Abdalla Osman Abdelwahab Abdalla[2], Aymen Nasreldin Abdalkariem[*3], Amgad Fadlelseed Ahmed Fadlelseed[4], Abdalmonim Abdoalrhman Mohammed[5], Nife Mohammed Hamid[6], Hussein Khalid Mamdooh[7], Mohammed Tabish[8]

[1]Department of Radiology, Al-Dhannah Hospital, Al Dhannah City, Abu Dhabi, UAE
[2]Aspen Medical, Abu Dhabi, United Arab Emirates
*[*3,5,6]Anatomy Department. Najran University-KSA*
[4]Cork University Hospital, Cork, Ireland
[7]National University of Science and Technology, Oman.
[8]Resident Medical Officer, Department of Orthopedics and Trauma, Medicare Cardiac & General Hospital Karachi

[*3]anaanatomist@yahoo.com

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Corresponding Author: * Aymen Nasreldin Abdalkariem

Abstract

Background: *Anterior cruciate ligament (ACL) injuries are common, especially in young, physically active individuals, and often result in long-term functional impairment.*

Objective: *To determine the frequency of ACL injuries identified on MRI and to assess their association with morphometric parameters of the knee, including intercondylar notch width, posterior tibial slope, and ACL thickness.*

Methods: *This cross-sectional analytical study was conducted at Najran University KSA from 1 Jan 2025 to 30 march 2025. A total of 93 patients were included in the study using non-probability consecutive sampling. All MRI examinations were performed using a 1.5 Tesla scanner employing standard knee imaging protocols. Imaging sequences included T1-weighted, T2-weighted, proton density (PD), and short tau inversion recovery (STIR) sequences in axial, sagittal, and coronal planes. ACL integrity was evaluated based on fiber continuity, signal intensity, and orientation, and categorized as intact, partially torn, or completely torn.*

Results: *ACL injuries were found in 47 out of 93 patients (50.5%), with complete tears observed in 68.1% of those cases. Patients with ACL injury had significantly narrower intercondylar notch widths (13.2 ± 1.6 mm vs. 15.1 ± 1.4 mm, $p < 0.001$), steeper posterior tibial slopes (13.9° ± 2.3° vs. 10.8° ± 2.0°, $p < 0.001$), and thinner ACLs (3.4 ± 0.6 mm vs. 4.8 ± 0.7 mm, $p < 0.001$) compared to those without injury. Although a higher proportion of females had ACL injuries, this was not statistically significant ($p = 0.19$).*

Conclusion: *It is concluded that ACL injuries are significantly associated with specific knee morphometric parameters. MRI-based assessment of intercondylar*

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notch width, posterior tibial slope, and ACL thickness may help identify individuals at increased risk.

INTRODUCTION

The anterior cruciate ligament (ACL) is a critical structure within the knee joint, responsible for maintaining anterior-posterior stability and rotational control of the tibia relative to the femur. ACL injuries are very common among physically active individuals, athletes, military members and participants in sports [1]. Because athletes are focusing more on fitness and sports, worldwide rates of ACL injuries are increasing. Many people who experience these injuries deal with joint instability, lowered ability to function, danger of suffering a damaged meniscus and may develop osteoarthritis as a result [2]. It follows that properly identifying the condition and the reasons behind it are now vital for proper management and prevention. Musculoskeletal diagnostics have improved because of MRI's ability to highlight soft tissues, offer images from different angles and be completely safe for the patient [3]. The MRI imaging test is most often used now to assess the ACL, especially when it is suspected due to the patient's medical history or when the diagnosis is not agreed upon. While it confirms ligament tears, MRI also clearly shows more details about knee features, including the width of the intercondylar notch, how steep the tibia is, the dimensions of the femoral condyles and the ACL's thickness. Researchers have become more interested in these as they could be reasons for ACL injuries [4]. It focuses on measuring and analyzing the structure of the knee. Some prior works indicate that characteristics such as a narrow intercondylar notch or increased posterior tibial slope may increase the risk of ACL injury due to their effects on how the joint moves [5]. Impingement of the ACL during flexion could happen if the intercondylar notch is too narrow and too steep a tibial slope may lead to greater force on the ACL when the knee bears weight. Noticing these types of factors early can help identify those at risk and design unique injury prevention plans for young athletes [6].Additionally, sex-based differences in knee morphometry and ACL injury rates have also been documented, with females reported to have a higher incidence of ACL tears [7]. This disparity has been partly attributed to anatomical differences, hormonal influences, and neuromuscular control patterns [8]. By analyzing knee morphometrics using MRI in diverse populations, further insights into sex-specific risk profiles and injury mechanisms can be obtained [9]. Despite extensive global research on ACL injuries, there remains a significant paucity of local data from developing countries regarding the frequency of MRI-diagnosed ACL injuries and their association with knee morphometrics. Many orthopedic and sports medicine practices in low- and middle-income countries (LMICs) still rely on clinical diagnosis or basic radiography, potentially missing early or partial ACL tears. In such settings, understanding morphometric predispositions to ACL injuries becomes even more crucial as resources for widespread surgical intervention may be limited [10].

Objective

To determine the frequency of ACL injuries identified on MRI and to assess their association with morphometric parameters of the knee, including intercondylar notch width, posterior tibial slope, and ACL thickness.

Methodology

This cross-sectional analytical study was conducted at Najran University KSA from 1 Jan 2025 to 30 march 2025. A total of 93 patients were included in the study using non-probability consecutive sampling.

Inclusion Criteria

- Patients aged >18 years
- Patients who underwent MRI of the knee joint with adequate imaging sequences.
- Both males and females.
- Patients with clinical suspicion of ACL injury

Exclusion Criteria

- History of previous knee surgery or ligament reconstruction.
- Evidence of advanced degenerative joint disease.
- Poor quality or incomplete MRI sequences.
- Patients with congenital or acquired deformities of the lower limb.

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Data Collection

All MRI examinations were performed using a 1.5 Tesla scanner employing standard knee imaging protocols. Imaging sequences included T1-weighted, T2-weighted, proton density (PD), and short tau inversion recovery (STIR) sequences in axial, sagittal, and coronal planes. ACL integrity was evaluated based on fiber continuity, signal intensity, and orientation, and categorized as intact, partially torn, or completely torn. Morphometric measurements were obtained directly from the PACS system. Intercondylar notch width was measured on axial images at the level of the popliteal groove. Posterior tibial slope was calculated on sagittal images by measuring the angle between the tibial plateau and a line perpendicular to the tibial shaft. ACL thickness was assessed in the sagittal plane at the midpoint of the ligament. All MRI scans were independently reviewed by two senior radiologists with over five years of experience in musculoskeletal imaging. The primary dependent variable was the presence or absence of ACL injury as confirmed on MRI. Independent variables included intercondylar notch width, posterior tibial slope, ACL thickness, as well as patient-related factors such as age, gender, and the laterality of the affected knee.

Statistical Analysis

Data were analyzed using IBM SPSS version 27.0. Descriptive statistics were used to summarize the characteristics of the study population. Continuous variables were reported as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. A p-value of less than 0.05 was considered statistically significant for all analyses.

Results

Data were collected from 93 patients, 53 (57%) were male and 40 (43%) were female, with a mean age of 29.8 ± 8.1 years. Right knee involvement was slightly more common (51 cases, 54.8%) than left knee involvement (42 cases, 45.2%). ACL injuries were detected in 47 patients (50.5%), with 32 (34.4%) having complete tears and 15 (16.1%) partial tears, while 46 patients (49.5%) had an intact ACL. The highest frequency of ACL injuries was observed in the 18–25-year age group (38.3%), followed by 26–35 years (34%), indicating a greater burden of injury in younger adults.

Table 1: Demographic Distribution

Variable	Value
Total Patients	93
Gender	
Male	53 (57%)
Female	40 (43%)
Mean Age (years)	29.8 ± 8.1
Side of Knee Involvement	
Right Knee	51 (54.8%)
Left Knee	42 (45.2%)
ACL Injury Status	
Intact	46 (49.5%)
Partial Tear	15 (16.1%)
Complete Tear	32 (34.4%)
Total Injuries	47 (50.5%)
Age Group-wise Distribution of ACL Injuries	
18–25 years	18 (38.3%)
26–35 years	16 (34.0%)
36–45 years	9 (19.1%)
46–50 years	4 (8.5%)

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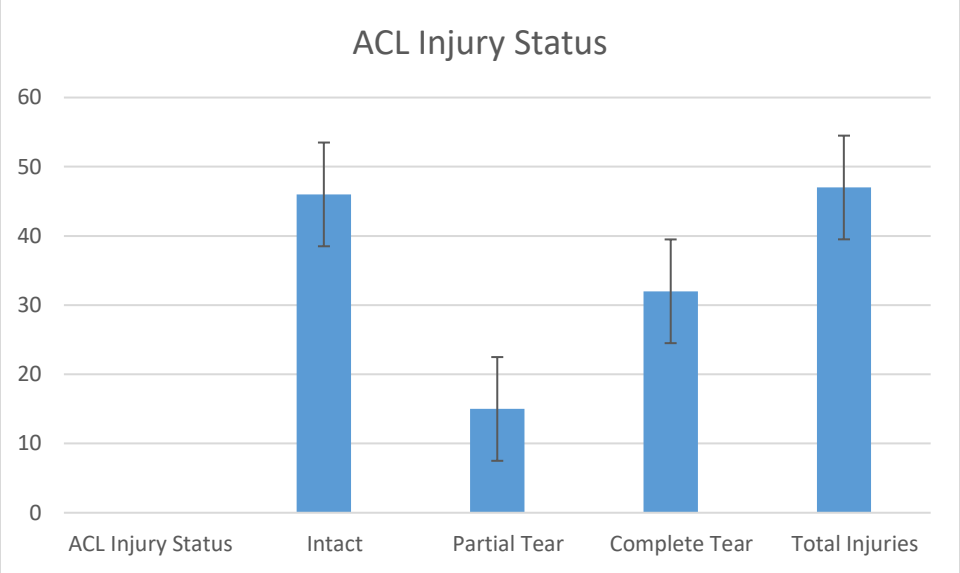

Figure 1: ACL Injury status in patients

The mean intercondylar notch width was notably narrower in the injured group (13.2 ± 1.6 mm) versus the intact group (15.1 ± 1.4 mm), with a p-value < 0.001. Similarly, the posterior tibial slope was significantly steeper among injured patients (13.9° ± 2.3°) compared to those without injury (10.8° ± 2.0°, p < 0.001). ACL thickness was also reduced in the injured group (3.4 ± 0.6 mm) compared to the intact group (4.8 ± 0.7 mm), again with a statistically significant difference (p < 0.001).

Table 2: Comparison of Morphometric Parameters

Parameter	ACL Injured (Mean ± SD)	ACL Intact (Mean ± SD)	p-value
Intercondylar Notch Width (mm)	13.2 ± 1.6	15.1 ± 1.4	<0.001
Posterior Tibial Slope (°)	13.9 ± 2.3	10.8 ± 2.0	<0.001
ACL Thickness (mm)	3.4 ± 0.6	4.8 ± 0.7	<0.001

Among the patients with ACL injuries, 24 were male (45.3%) and 23 were female (57.5%), though this difference was not statistically significant (p = 0.19). Similarly, ACL injuries were slightly more common in the left knee (22 cases, 52.4%) than the right knee (25 cases, 49%), but this difference also lacked statistical significance (p = 0.42).

Table 3: Association with Gender and Side

Variable	Number of Patients (%)	p-value
Male Patients with ACL Injury	24 (45.3%)	0.19
Female Patients with ACL Injury	23 (57.5%)	0.19
Right Knee Involvement with ACL Injury	25 (49%)	0.42
Left Knee Involvement with ACL Injury	22 (52.4%)	0.42

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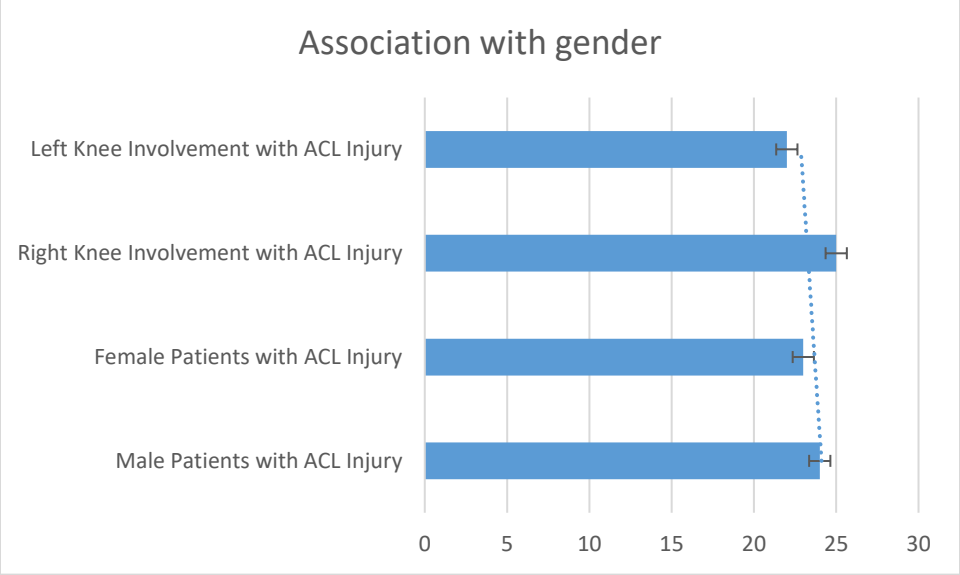

Figure 2: Association of injury with gender

The mean intercondylar notch width was slightly greater in the right knee (13.4 ± 1.5 mm) than the left (13.0 ± 1.7 mm), with a p-value of 0.21. The posterior tibial slope was marginally steeper on the left (14.2° ± 2.4°) compared to the right (13.7° ± 2.1°), but this difference was not significant (p = 0.35). Similarly, ACL thickness showed minor variation (3.5 ± 0.5 mm on the right vs. 3.3 ± 0.7 mm on the left; p = 0.28).

Table 4: Side-Specific Morphometric Comparison

Parameter	Right Knee (Mean ± SD)	Left Knee (Mean ± SD)	p-value
Intercondylar Notch Width (mm)	13.4 ± 1.5	13.0 ± 1.7	0.21
Posterior Tibial Slope (°)	13.7 ± 2.1	14.2 ± 2.4	0.35
ACL Thickness (mm)	3.5 ± 0.5	3.3 ± 0.7	0.28

Discussion

In this cross-sectional study involving 93 patients who underwent knee MRI, we observed that the frequency of ACL injuries was 50.5%, with complete tears being more common than partial ones. This is in line with what is observed worldwide, with many ACL injuries making up a substantial share of knee injuries for active young people. The data we obtained suggests that MRI is efficient not only for recognizing ACL injuries but also for analyzing their risk factors. The study found that ACL injuries were more likely for those with a reduced intercondylar notch width (around 13.2 mm compared to those with around 15.1 mm, $p < 0.001$). This backs up the "notch impingement hypothesis," arguing that a narrower notch may cause the ACL to get impinged and injured [12]. The importance of an intercondylar stenosis in causing non-contact ACL injuries was also mentioned by LaPrade et al. (2015) in their research. Also, the angle of the posterior tibial slope was steeper in injured knees (13.9°) than in healthy ones (10.8°) ($p < 0.001$). When the tibia leans more forward, it experiences more force on the ACL during various activities [12]. The knees in the injured group had an average ACL thickness that was 1.4 mm less than those in the non-injured group ($p < 0.001$). Since the tensile strength is not high, a thinner ligament could be torn more easily if pressured. Although the ACL's thickness is rarely measured in common clinical settings, our study suggests it could be a good predictor [13]. Studies, for instance those done by Sturnick et al. (2014), also propose that ligament structure contributes to a person's risk of injury. While the percentage of ACL injuries was slightly higher in females (57.5%), males still reported more of them (45.3%) and this gap was not significant. Yet,

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this study agrees with results from other studies that women tend to experience more ACL tears and this is commonly attributed to how women are made, what they produce and how their nerves and muscles work [14]. No significant correlation was found between the laterality of the knee (right vs. left) and the occurrence of ACL injury. This suggests that side dominance may not play a significant role in injury predisposition in this cohort, which contrasts with some sports medicine studies where dominant limb mechanics are implicated [15]. Moreover, the age-stratified analysis showed that most ACL injuries occurred in the 18–35-year age group, reaffirming that younger adults involved in physically demanding activities are at the greatest risk. This underlines the importance of targeted prevention programs, including strength training and proprioceptive exercises for high-risk populations [16]. The study had several strengths, including the use of standardized MRI protocols and objective morphometric measurements reviewed by experienced radiologists. However, limitations include its single-center design, relatively modest sample size, and lack of clinical correlation such as activity level or mechanism of injury.

Conclusion

It is concluded that anterior cruciate ligament (ACL) injuries are highly prevalent among patients undergoing knee MRI, with complete tears being more common than partial ones. The study highlights a significant association between ACL injury and key morphometric parameters, including narrower intercondylar notch width, increased posterior tibial slope, and reduced ACL thickness. These anatomical variations may serve as predictive indicators of ACL vulnerability, especially in younger, active individuals. Although the difference in injury frequency between genders was not statistically significant, a higher proportion of ACL injuries in female patients supports existing evidence suggesting gender-related anatomical predispositions.

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