Relationship between Anterior Cruciate Ligament Thickness and Intercondylar Distance in Magnetic Resonance Imaging

Paudel N, Ghimire P, Jha A, Ranabhat R, Jha S, Singh AK, Subedi S

ABSTRACT

Introduction: The anterior cruciate ligament is crucial for maintaining knee biomechanics. It attaches proximally to the posteromedial aspect of the lateral femoral condyle and distally to the anterior intercondylar region. Intrinsic factors such as a narrow femoral intercondylar distance and a small notch width index increase the risk of its injury. A narrow notch often corresponds to a thinner, weaker anterior cruciate ligament, making it more prone to rupture. Identifying individuals with smaller intercondylar distances may help implement preventive strategies during sports and physical activities. **Aims:** To determine the relationship between anterior cruciate ligament thickness and intercondylar distance of the knee on Magnetic Resonance Imaging. **Methods:** This hospital-based, cross-sectional study was conducted with a total of 57 patients undergoing knee Magnetic Resonance Imaging for various indications. Data were analyzed using statistical package for social sciences version 26, applying Pearson's correlation coefficient with a 5% significance level ($p \leq 0.05$). **Results:** Of 57 patients (24 males, 33 females; mean age 40.6 years), 31 were of the right knee and 26 of the left. The mean intercondylar distance was 19.43 mm, while mean mediolateral and anteroposterior anterior cruciate ligament thicknesses were 4.60 mm and 4.76 mm, respectively. Males showed slightly larger values than females, but the differences were not statistically significant. A strong positive correlation was found between intercondylar distance and both mediolateral ($r = 0.79$, $p < 0.001$) and anteroposterior ($r = 0.78$, $p < 0.001$) anterior cruciate ligament thickness. **Conclusion:** The study demonstrated a significant positive correlation between anterior cruciate ligament thickness and intercondylar distance, with no significant gender difference. Wider intercondylar distances are associated with thicker anterior cruciate ligaments, indicating anatomical variation may influence ligament strength and injury risk.

Keywords: Anterior Cruciate Ligament, Intercondylar width, Magnetic Resonance Imaging

Authors:

1. Dr. Nabin Paudel
2. Dr. Prasanna Ghimire
3. Dr. Amit Jha
4. Dr. Roshani Ranabhat
5. Dr. Sushmita Jha
6. Dr. Avinash Kumar Singh
7. Dr. Shreya Subedi

Department of Radiodiagnosis, Nepalgunj Medical College and Teaching Hospital, Banke, Nepal

Address for Correspondence:

Dr. Nabin Paudel
Assistant Professor
Department of Radiodiagnosis
Nepalgunj Medical College and Teaching Hospital
Kohalpur, Banke
Email: nabinpaudel11@gmail.com

INTRODUCTION

The anterior cruciate ligament (ACL) is crucial for knee stability and is the most commonly injured ligament.[1] The intercondylar notch, located between the femoral condyles, houses ACL, posterior cruciate ligament(PCL), the meniscofemoral ligaments, other central fibrous attachments of the menisci and peri cruciate fat.[2,3] Variations in notch width and shape, which differ among ethnic groups, are significant anatomical risk factors for ACL injury along with hormonal, genetic and biomechanical factors.[4,5,6] A narrow or abnormally shaped notch can cause ACL impingement, thinning, and increased rupture risk, and is also linked to degenerative joint diseases and osteochondritis dissecans in children.[3,4,6] As the incidence of ACL) injury continues to rise in children and adolescents, identifying independent risk factors such as narrow intercondylar distance and evaluating ACL morphology in relation to anthropometric data and other knee structures including intercondylar width can help apply preventive strategies and guide the selection of appropriate graft thickness.[7, 8] Since Nepalese individuals gen-

erally have shorter stature and narrower notches than western populations, they may face a higher risk of ACL injury.[4,6] Magnetic Resonance Imaging (MRI) is the preferred tool for accurate ACL morphology assessment as well as in establishment of its relationship with intercondylar width.[8,9] This study was undertaken as a pioneer to evaluate the relationship between anterior cruciate ligament thickness and intercondylar distance of the knee on Magnetic Resonance Imaging in western region of Nepal.

METHODS

This cross-sectional study was carried out in the department of radiology at Nepalgunj Medical College Teaching Hospital, Kohalpur, Banke from February 2025 to October 2025. Ethical clearance was obtained from the Institutional Review Committee, Nepalgunj Medical College and Teaching Hospital. The study included 57 cases with age above 16 years, who came for MRI of knee joint for various indications. Patients with skeletal immaturity, previous surgery or degenerative alterations in the knee, not willing to give consent and those with ACL injury were not included in the study. Age, history of knee disease, and prior surgery were recorded. MRI scans were performed using a 1.5T GE Signa Creator with an eight-channel coil. T2WI and Proton density–weighted sequences in sagittal, coronal, and axial planes (with and without fat saturation) were obtained using TE 1642, TE 30, matrix 512×256, FOV 16×16, slice thickness 3.5 mm, and interval 0.3 mm. Images were analyzed, and each measurement was taken three times, with the average value used for analysis.

The following measurements were obtained from the MRI

• Intercondylar distance which is the distance from the medial articular cartilage margin of the lateral femoral condyle to the lateral articular margin of the medial femoral condyle was obtained from the PD-weighted or T2WI sequences in the axial plane.

• Antero-posterior thickness of the ACL was obtained from the PD or T2WI weighted sequences in the sagittal plane, by means of linear measurement in its middle third, perpendicular to the long axis of the ligament fibers.

• Mediolateral (transverse) thickness of the ACL was obtained from the PD-weighted or T2WI sequences in the axial plane, by means of transverse linear measurements in its middle third, taking the greatest diameter of the ligament fibers.

Data were tabulated in Microsoft Excel and analyzed using SPSS version 26. Descriptive statistics, including mean, standard deviation, minimum, and maximum values, were calculated. Comparisons were made using paired samples t-tests, with a p-value of <0.05 considered statistically significant.

RESULTS

Patient's ages ranged from 16 to 78 years, with a mean of 40.61 ± 13.78 years. Of the 57 patients, 24 (42.1%) were male and 33 (57.9%) were female. Among the 57 knee MRIs, 31 (54.39%) were of the right side and 26 (45.61%) of the left side. Most patients underwent knee MRI due to knee pain (n=37), followed by trauma (n=13), swelling around the knee joint (n=5), and other complaints such as burning or tingling sensations, knee deformity, or tumor around the knee (n=2). The mean mediolateral ACL thickness on the axial plane was 4.60 ± 0.76 mm (range 2.90–5.90 mm), and the mean anteroposterior thickness on the sagittal plane was 4.76 ± 0.93 mm (range 2.18–6.10 mm). The mean axial intercondylar distance was 19.43 ± 2.89 mm (range 14.20–27.00 mm). Among males, the mean mediolateral and anteroposterior ACL thicknesses were 4.73 ± 0.61 mm and 5.01 ± 0.88 mm, respectively, with an intercondylar distance of 20.35 ±2.58mm.Among females, the mean mediolateral and anteroposterior ACL thicknesses were 4.50 ± 0.84 mm and 4.57 ± 0.94 mm, respectively, with an intercondylar distance of 18.77 ± 2.96 mm. Overall, males demonstrated slightly higher ACL thickness and intercondylar distance compared to females.

N=57(M=24, F=33)	ML ACL thickness in axial plane (mm)			AP ACL thickness in sagittal plane(mm)			Axial intercondylar distance (mm)		
	M	F	Total	M	F	Total	M	F	Total
Mean	4.73	4.50	4.60	5.01	4.57	4.76	20.35	18.7	19.43
Std. Deviation	0.61	0.84	0.76	0.88	0.94	0.93	2.58	2.96	2.89
Std.Error of Mean	0.12	0.14	0.10	0.18	0.16	0.12	0.52	0.51	0.38
Minimum	3.80	2.90	2.90	2.18	2.90	2.18	16.3	14.2	14.20
Maximum	5.90	5.90	5.90	6.10	6.0	6.10	27.0	26.0	27.00

Table I: Measurement of Medio-lateral(ML) ACL Thickness (in axial plane), Antero-posterior(AP) ACL thickness (in sagittal plane) and Intercondylar distance

Correlation Analysis of Intercondylar Distance and ACL Thickness

Pearson's correlation analysis demonstrated a strong, positive, and statistically significant relationship between intercondylar distance and both ACL thickness parameters (Table II and III). The correlation between intercondylar distance and mediolateral ACL thickness was r = 0.79 (n = 57, p < 0.001), and between intercondylar distance and anteroposterior ACL thickness was r = 0.78 (n = 57, p < 0.001). Fisher's r-to-z transformation yielded 95% confidence intervals of 0.67–0.87 and 0.65–0.86, respectively. Linear regression analysis further confirmed these findings, showing a statistically significant positive correlation between intercondylar distance and both mediolateral and anteroposterior ACL thickness (Figures 1 and 2)

	Parameter	ML ACL thickness	AP ACL thickness
Intercondylar Distance	Pearson Correlation	0.79	0.78
	Significance(2-tailed)	<0.001	<0.001
	N	57	57

Table II: Correlation of intercondylar distance with mediolateral(ML) and anteroposterior(AP) ACL thickness

	Parameter	ML ACL thickness	AP ACL thickness
Intercondylar Distance	95% confidence intervals(2-tailed)		
		Lower	Upper
	ML ACL thickness	0.67	0.87
	AP ACL thickness	0.65	0.86

Table III: Confidence interval between intercondylar distance and ACL thickness

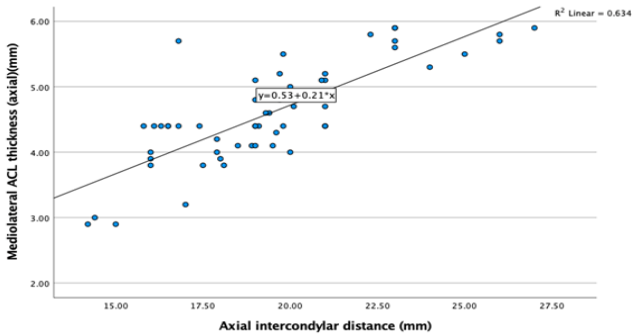

Figure 1: Linear regression analysis of intercondyar distance and mediolateral ACL thickness in axial plane

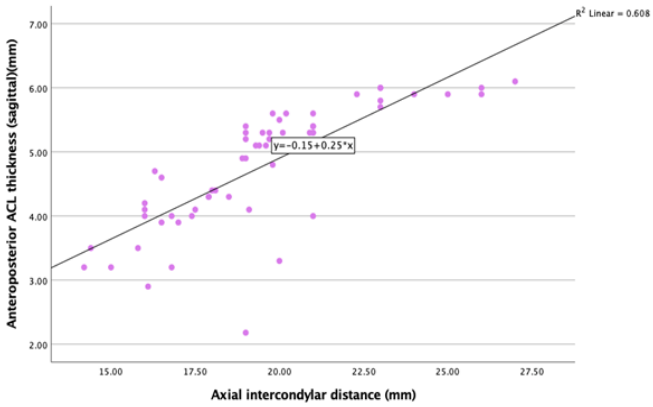

Figure 2: Linear regression analysis of intercondyar distance and anteroposteriro ACL thickness in sagittal plane

CORRELATION BETWEEN TWO GENDERS FOR MEAN INTERCONDYLAR DISTANCE AND ACL THICKNESS

Independent two-sample t-tests (equal variances assumed) showed no significant difference between males and females in mediolateral (p = 0.27, 95% CI: –0.18 to 0.63) and anteroposterior ACL thickness (p=0.80, 95% CI:–0.05 to 0.93). However, a significant difference was observed in intercondylar distance (p = 0.04, 95% CI: 0.67 to 3.09), with males demonstrating higher mean values as shown in table IV.

Parameters	F	Sig	t	df	p (2-tailed)	Mean difference	95 % CI for difference
Mediolateral ACL thickness	1.65	0.20	1.11	55	0.27	0.22	−0.18 to 0.63
Anteroposterior ACL thickness	1.11	0.29	1.78	55	0.80	0.44	−0.05 to 0.93
Intercondylar distance	0.96	0.33	2.09	55	0.04	1.58	0.67 to 3.09

*** Significant at p < 0.05**

Table IV: Independent t-test comparison of ACL thickness and intercondylar distance between genders(equal variance assumed)

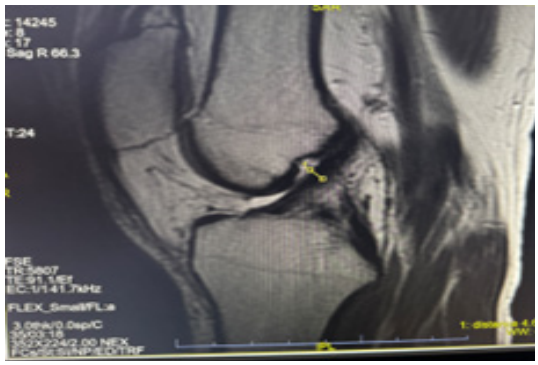

Figure 3: ACL Ligament in Sagittal T2WI

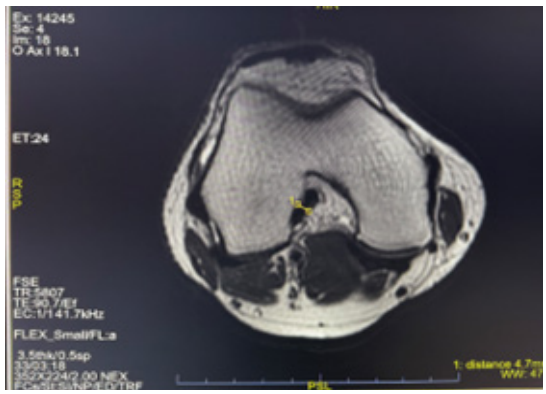

Figure 4: ACL in Axial T2WI

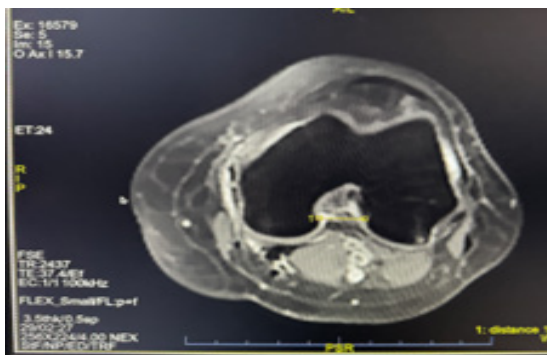

Figure 5: Intercondylar distance in Axial PD

DISCUSSION

MRI is the primary imaging modality for evaluating the knee joint, including ligaments, menisci, and soft tissues. Its superior soft tissue contrast and precise digital measurements allow accurate assessment of bony and ligamentous structures.[10]

Our study analyzed 57 knee MRI scans (mean age 40.6 years; range 16-78), comprising 24 males (42.1%) and 33 females (57.9%). Right knees accounted for 54.4% and left knees for 45.6%. The mean intercondylar distance was 19.43 ± 2.89 mm (range 14.2–27.0 mm), averaging 20.35 ± 2.58 mm in males and 18.77 ± 2.96 mm in females. Study done by De Oliveira VM et al showed mean axial intercondylar distance of 21.7mm (range 15.8 -30.00mm).[8] Hirtler L et al found intercondylar distance ranges from 16.23 ± 2.71 mm before the age of 11 years to 19.38 ± 2.90 mm in middle age and then decreases to 18.6 ± 2.36 mm after the age of 60 years.[3] Shelbourne KD reported significantly wider intercondylar notches in African Americans than in whites, with mean widths of 15.5 ± 2.8 mm vs. 14.1 ± 2.5 mm in women ($p = 0.009$) and 18.0 ± 3.6 mm vs. 16.9 ± 3.1 mm in men ($p = 0.003$).[11]

The mean ACL thickness was 4.60 ± 0.76 mm mediolateral and 4.76 ± 0.93 mm anteroposterior. In males, these measured 4.73 ± 0.61 mm and 5.01 ± 0.88 mm, while in females they were 4.50 ± 0.84 mm and 4.57 ± 0.94 mm, respectively.

Several studies have reported variations in ACL thickness and width measurements. De Oliveira VM et al found a mean mediolateral ACL thickness of 4.3 mm (range 2.9-6.2 mm) and anteroposterior thickness of 4.5 mm (range 3.1-7.2 mm).[8] Kupczik F et al reported a mean ACL width of 4.8 mm (range 3.1-8.3 mm).[12] Anderson AF et al observed mean frontal thicknesses of 4.75 mm in women and 5.6 mm in men, and sagittal thicknesses of 7.6 mm in women and 8.7 mm in men.[13] Marieswaran M et al noted ACL breadth of approximately 10 mm and width ranging from 4–10 mm, comparable to the present study.[14] Ontoh LAP et al found an average ACL width of 9.98 ± 1.5 mm (range 7.59–13.70 mm), with men showing higher values (10.4 ± 1.4 mm) than women (9.1 ± 1.3 mm; $p < 0.0001$).[15] Eleni Triantafyllidi et al reported a midsubstance width of 5 mm in cadaveric ACLs.[16] A Saxena found an average ACL width of 9.38 ± 1.58 mm on MRI, while T.J. Davis et al reported 5.7 ± 1.1 mm in women and 7.1 ± 1.2 mm in men ($p < 0.001$).[17,18]

In our study, a statistically significant linear correlation was found between axial intercondylar distance and mediolateral ACL thickness ($r = 0.796$, $p < 0.001$). De Oliveira VM et al also reported a significant correlation ($r = 0.29$, $p = 0.039$) between these parameters in their study of 48 knee MRIs.[8] Similarly, T.J. Davis et al observed a strong correlation between intercondylar distance and ACL width ($r = 0.87$, $p < 0.001$), consistent with our findings. They also noted smaller intercondylar distances and ACL widths in females (16.2 ± 2.3 mm) compared to males (19.0 ± 2.0 mm).[17] Our study showed a similar trend, with females having a smaller mean intercondylar distance and ACL width than males, though the difference was not statistically significant.

Furthermore, we found a significant correlation between axial intercondylar distance and anteroposterior ACL thickness in the sagittal plane ($r = 0.78$), which contrasts with De Oliveira VM et al, who reported no significant relationship ($r = 0.03$, $p = 0.809$).[8]

Tomas Fernandez et al also found a sex-related difference in notch width (men: 19.3 ± 3.3 mm; women: 17.4 ± 3.1 mm; $p < 0.001$).[20] In contrast, our study also showed a smaller mean intercondylar distance in females than males, but the difference was not statistically significant. Takeshi Muneta et al found results contrary to most studies, showing that both narrow and wide intercondylar notches have ACLs of similar size.[21] Shayan Hosseinzadeh et al reported findings similar to ours, noting smaller ACLs in females.[22] In contrast, M. Rizzo et al, in a cadaveric study of 27 knees, reported significantly larger ACL widths in males (10.59 ± 1.30 mm) than in females (8.09 ± 1.12 mm) ($p < 0.001$). The mean femoral intercondylar notch widths were 20.18 ± 2.20 mm in males and 20.50 ± 1.69 mm in females.[23] Balgovind SR et al reported similar findings, noting that a narrow intercondylar notch often contained a smaller ACL.[4]

LIMITATIONS

The study measured only the axial intercondylar notch distance of the femur, excluding parameters like notch width index and notch angle. MRI was performed in the resting knee position, not in extension or flexion, which might influence ACL width. The study included a heterogeneous population without specific age grouping and did not assess ACL length, focusing instead on the relationship between ACL thickness and intercondylar distance. The small sample size was also a limitation.

CONCLUSION

Our study showed a strong positive correlation between intercondylar distance and ACL thickness indicating that individuals with narrower intercondylar notches tend to have smaller ACLs. Conversely, those with wider intercondylar distances had thicker ACLs. The study also found that ACL size varies significantly among individuals, and axial intercondylar distance can serve as a useful indicator of ACL thickness. Although males generally had larger measurements than females, the differences were not statistically significant.

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