Section: Orthopaedics

Original Research Article

TIBIAL PLATEAU SLOPE MEASURED ON MRI AS A RISK FACTOR FOR ANTERIOR CRUCIATE LIGAMENT INJURY: A RETROSPECTIVE STUDY

Shushrut B Bhavi[1], Manjudev S Nakkaragundi[2], Raju Akkimaradi[1], Chetana S Sultanpuri[3], Lakshminarayana J[4]

[1]Associate Professor, Department of Orthopaedics SN Medical College, Bagalkot, Karnataka, India
[2]Assistant Professor, Department of Orthopaedics SN Medical College, Bagalkot, Karnataka, India
[3]Assistant Professor, Department of Radiology SN Medical College, Bagalkot, Karnataka, India
[4]3rd year Postgraduate, Department of Orthopaedics SN Medical College, Bagalkot, Karnataka, India

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Corresponding Author:
Dr. Manjudev S Nakkaragundi,
Email: manjudev268@gmail.com

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ABSTRACT

Background: The Posterior Tibial Slope (PTS) is an angle formed by the tibial plateau and plays a vital role in the biomechanics of the knee joint. This slope is found to be a factor in differentiating ACL tear injuries. Earlier studies have shown the association of PTS with Anterior Cruciate Ligament (ACL) tears, but failed to evaluate the PTS values for different gradings. Studies reporting tibial plateau slope as a risk factor for anterior cruciate ligament (ACL) injury have been published with greatly increasing frequency. Purpose is studying tibial slope in ACL injured populations who have got MRI knee done at S.Nijalingappa Medical college and Hangal Shri Kumareshwar hospital and research centre from January 2023 to January 2025. Hypothesis is increase in posterior tibial slope is associated with an increased risk of ACL injuries. Study design is a retrospective data analysis from radiological images (MRI knee). **Materials and Methods:** A retrospective data analysis of MRI knee of 40 patients (40 knees) with ACL injury was conducted from January 2023 to January 2025 at the Department of Orthopaedics, S Nijalingappa Medical college and HSK hospital, Bagalkot, Karnataka, India. A total of 40 MRI knees were studied with complete ACL tears, the PTS- Medial PTS (MPTS) and Lateral PTS (LPTS) was evaluated on MRI by using the described method according to Hudek R et.al., study done using the Dicom Software at our radiology department. Student t-test was used to evaluate the mean PTS and the results were then compared with the standard mean PTS. **Result:** Our study demonstrated significant increase in ACL injury for this age group. A total of 40 patients (MRI knee) with ACL tears were analyzed, comprising 32 males (80%) and 8 females (20%). Most patients (82.5%) were aged ≥26 years, and all patients ≤25 years were male. The mean medial tibial slope was significantly higher in females (11.00° ± 2.71°) compared to males (8.59° ± 2.67°) ($p = 0.03$). The lateral tibial slope was slightly higher in females (9.86° ± 4.18°) than males (8.72° ± 2.57°), but this difference was not statistically significant ($p = 0.35$). Overall, ACL tear patients had mean medial and lateral tibial slopes of 9.03° +/- 2.81 degrees and 8.92 degrees+/- 2.89 degrees, respectively. Compared to the controls (medial: 4.8 degrees +/- 0.5 degrees; lateral: 5.0 degrees +/- 3.6 degrees), these differences were highly significant ($p = 0.001$ for both). These findings suggest a strong association between increased posterior tibial slope- particularly medial slope- and the occurrence of ACL tears, with a more pronounced effect observed in female patients. **Conclusion:** We found that tibial slope has a strong linear relationship with the incidence of ACL injuries. A flatter tibial slope had a significantly less incidence of ACL injury, while steeper slope increased the incidence of of ACL injuries.

INTRODUCTION

The day-to-day activities of everyday life are largely dependent on the lower limb. The knee joint, being the master hinge of the lower limb, transforms rigid bones into a symphony of motion that lets us stand, stride, kneel and leap. It has a vital role in weight-bearing and maintaining position, whether standing

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or moving. The tibiofemoral joint is responsible for transmitting the weight of the body from the femur to the tibia and provides a hinge-like sagittal plane joint rotation accompanied by a small degree of tibial axial rotation. The knee joint has various ligaments that provide stability to the joint. The ligaments and menisci are often injured during heavy activities that cause strain to the knee joint. Early diagnosis and treatment are essential to prevent disability of the knee joint.

The Anterior Cruiciate Ligament (ACL) is one of these major knee stabilisers, anchoring stability with every twist and stride, turning chaos into controlled motion in the theater of movement. ACL injury occurs predominantly via noncontact mechanisms. Because of a high incidence of long-term sequelae to ACL injury including pain, instability, and early development of osteoarthritis, a great deal of the sports medicine literature has focused on prevention.[1] Identification of risk factors for ACL injury is an important step in the development of injury prevention algorithms.[2] Currently, it is generally accepted that there are both modifiable and nonmodifiable risk factors that determine how likely a person is to suffer an injury to the ACL. Nonmodifiable risk factors are often inherent to an individual person, such as anatomic, hormonal, and gender based traits. Modifiable risk factors include neuromuscular control patterns, gross biomechanical movement patterns, and environmental factors.[3]

Recently in the literature, there has been a great deal of focus on anatomical risk factors. Most notably, the posterior slope of the tibia has been increasingly studied as a potential risk factor, with increased frequency and widely varied results. The articular surface of the tibial plateau forms posterior and inferior slopes about the longitudinal axis of an axial center and this is known as the Posterior Tibial Slope (PTS).[4] This slope is found to vary in different studies according to age, gender, and ethnicity. Biomechanically, a higher tibial slope in the presence of a compressive load will generate a higher anterior shear component of the tibiofemoral reaction force, resulting in increased anterior motion of the tibia relative to the femur. Because the ACL is the primary restraint against this type of motion in the knee, it logically follows that an increase in posterior tibial slope will generate an increased load in the ACL.

A study done by McLean et al,[5] suggested that axial compression of a knee with a higher lateral tibial plateau slope (LTPS) compared with a medial tibial plateau slope (MTPS) may cause greater anterior motion of the lateral compartment of the tibia compared to its medial counterpartt, creating a net internal rotation of the tibia with respect to the femur, which may increase loading on the ACL.

Another study done by Waiwaiole A et al.,6 in their study found that the mean posterior tibial slope was higher in cases i.e., patients with ACL injury (MTS- 6 and LTS- 7) compared to patients (controls) without ACL injury (mean MTS- 4.8 degrees and LTS- 5.0 degrees) concluding that increased tibial slope lead to higher incidence of ACL injuries.

However, despite several reports relating increased posterior slope of the medial or lateral tibial plateau to ACL injury, the level of risk posed by this intrinsic factor remains unclear.

MATERIALS AND METHODS

The data analysis of 40 knee MRI's with ACL injury was conducted from January 2023 to January 2025 at S Nijalingappa Medical College and HSK hospital, Bagalkot, Karnataka, India. The PTS (Medial PTS and Lateral PTS) was evaluated on MRI, analysed using the method described by Hudek R et al.[7] and by using Dicom Software. Accordingly, Paired t-test was used to evaluate the mean PTS.

Inclusion Criteria

Included patients who were aged between 18 years to 45 years, having ACL injury.

Exclusion Criteria

Included patients whose age was below 18 years and above 45 yrs, with fractures around the knee joint, osteoarthritis knee, inflammatory arthritis & multiligamentous injuries.

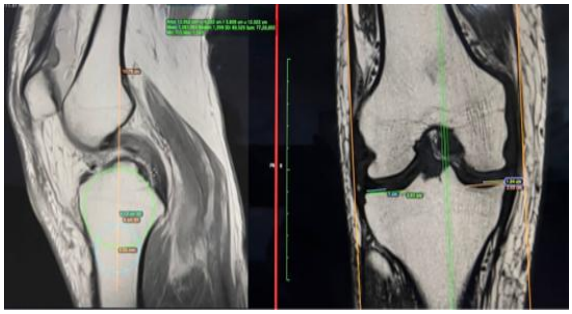
The posterior tibial slope was calculated by reference from Hudek R et al.7 using these 6 steps:

Step 1: Identify the central sagittal MRI slice and choose the central sagittal image where the following structures are clearly visible:

1. Tibial attachment of the posterior cruciate ligament (PCL)
2. Intercondylar eminence
3. Anterior and posterior cortices of the tibia (showing a concave shape)

Step 2: Draw circles to define the tibial longitudinal axis

1. Place a cranial circle in the proximal tibia, ensuring it touches: Anterior cortex, Posterior cortex and the Cranial (top) cortex
2. Place a caudal circle in the tibial shaft, ensuring it touches: Anterior cortex and Posterior cortex
3. In areas where the cortex–medullary transition is unclear, choose the middle of the transition zone (between dark cortex and light medullary canal).
4. Position the center of the caudal circle on the circumference of the cranial circle.
5. Draw a line connecting the centers of both circles — this line defines the MRI-based longitudinal axis of the tibia.



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Step 3: Select the sagittal slice showing the center of the medial plateau

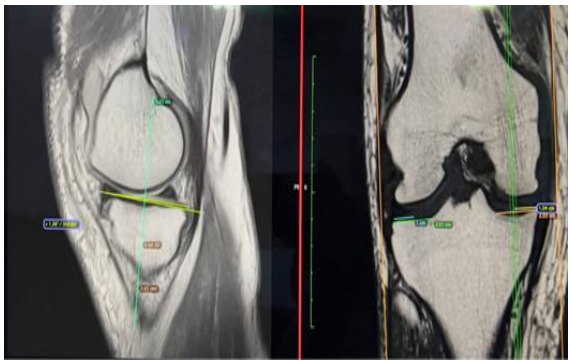
1. Move to the MRI slice that shows the mediolateral center of the medial tibial plateau.
2. Identify the uppermost anterior and posterior edges of the medial plateau cortex.

Step 4: Draw the plateau tangent

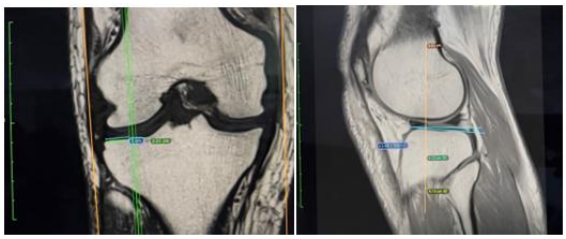
On this medial plateau slice, draw a tangent line connecting the superior anterior and posterior cortices of the plateau surface.

Step 5: Measure the medial tibial slope

1. Draw a line perpendicular to the MRI-defined longitudinal axis.
2. The angle between this perpendicular line and the tangent line to the plateau surface represents the medial posterior tibial slope (PTS).



Step 6: Repeat same for the lateral plateau.



Finally, we compared the results obtained with the findings of Waiwaiole et al.7 (2016) as a reference. Their cross-sectional MRI-based analysis, comparing ACL-injured individuals to controls, provided key comparative data for PTS measurements. This paper was used as a control benchmark to evaluate the relevance of lateral and medial PTS in ACL injury.

RESULTS

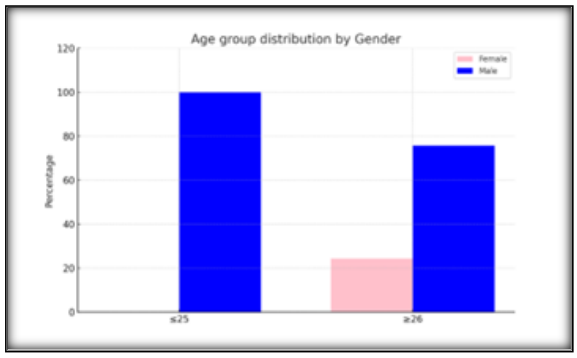


Table 1: Age and Gender Cross-tabulation

Age (Binned) Gender cross tabulation				
		Gender		Total
		Female	Male	
Age (Binned)	<= 25	0	7	7
		0.0 %	100.0 %	100.0 %
	>= 26	8	25	33
		24.5 %	75.75 %	100.0 %
Total		8	32	40
		20 %	80 %	100.0 %

In this study cohort of 40 patients with ACL injury, 80% were male and 20% were female. Among patients ≤25 years old, all were male (100%). In the ≥26 age group, 75.75% were male and 24.25% were female. This suggests that ACL injuries are more frequent in males, particularly in the younger age group. The high proportion of young male patients aligns with the known higher participation of young men in high-risk activities and sports.

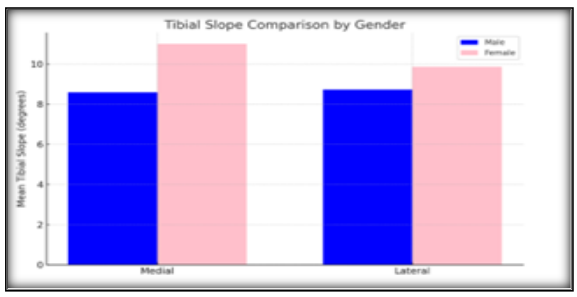


Table 2: Gender-wise Comparison of Tibial Slopes

	Gender	'N'	Mean	Std. Deviation	t	p
Medial tibial	Male	32	8.59	2.674	2.1	0.03
	Female	8	11.00	2.708		
Lateral tibial	Male	32	8.72	2.568	0.94	0.35
	Female	8	9.86	4.180		

Medial Tibial Slope: The mean medial tibial slope in males was 8.59° (SD±2.67), while in females it was significantly higher at 11.00° (SD ±2.71), with a statistically significant p-value of 0.03.

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This indicates that females tend to have a higher medial tibial slope, which may contribute to their higher relative risk of ACL injury despite their lower overall incidence.

Lateral Tibial Slope: The mean lateral tibial slope was 8.72° (SD±2.57) in males and 9.86° (SD ±4.18) in females; however, this difference was not statistically significant (p = 0.35).

This suggests that while lateral tibial slope differences exist between genders, they are not as marked or statistically meaningful as medial slope differences in this cohort.

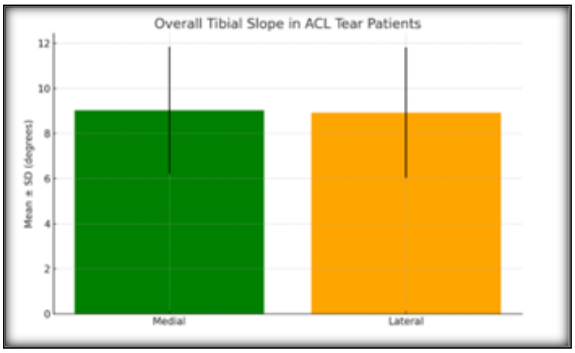

Table 3: Descriptive Statistics of Tibial Slopes in Cases

	N	Minimum	Maximum	Mean	Std. Deviation
Medial tibial	40	3	15	9.03	2.805
Lateral tibial	40	2	14	8.92	2.887

Among the 40 patients with ACL injuries:

- The medial tibial slope ranged from 3° to 15°, with a mean of 9.03° (SD ±2.80).
- The lateral tibial slope ranged from 2° to 14°, with a mean of 8.92° (SD ±2.88).

The wide range, but generally higher mean values of both medial and lateral slopes, reinforce the hypothesis that increased posterior tibial slope may predispose to ACL injury by increasing anterior tibial translation under load.

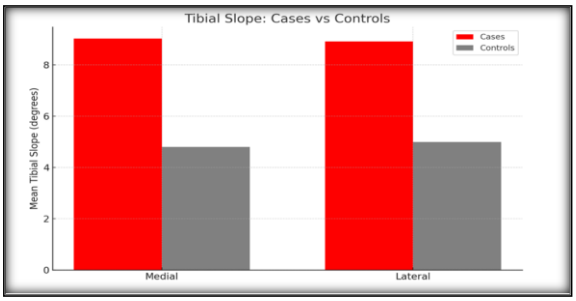

Table 4: Comparison Between Cases and Controls

	Groups	Mean	Std. Deviation	t	p
Medial tibial	Cases	9.03	2.80	9.28	0.001
	Controls	4.8	0.5		
Lateral tibial	Cases	8.92	2.88	5.36	0.001
	Controls	5.0	3.6		

Medial Tibial Slope: Cases had a significantly higher mean slope (9.03° ±2.80) than controls (4.8° ±0.5), with a highly significant p-value (0.001).

Lateral Tibial Slope: Similarly, cases had a mean slope of 8.92° (±2.88), compared to 5.0° (±3.6) in controls, also with a significant p-value (0.001).

This strongly indicates that both medial and lateral posterior tibial slopes are significantly steeper in patients with ACL injuries compared to normal population. Thus, increased tibial slope can be considered a substantial anatomical risk factor contributing to ACL injury.

DISCUSSION

Our findings demonstrate a significant relationship between increased posterior tibial slope and ACL tears, with notable variations based on gender and age. The predominance of male patients (80%) aligns with previously reported higher incidence of ACL injuries in male populations engaged in pivoting sports and contact activities.[8,9] However, the significantly higher medial tibial slope in females supports the biomechanical vulnerability described in female athletes, who are known to have greater dynamic valgus and different neuromuscular control patterns, increasing ACL strain.[10-13]

The mean medial tibial slope in females was significantly higher than in males (11.00° vs. 8.59°), a finding consistent with prior studies that have identified increased posterior tibial slope as an independent risk factor for ACL injury.[14-16] An increased medial slope can contribute to greater anterior tibial translation during dynamic loading, leading to higher stress on the ACL.[17,18]

While the difference in lateral tibial slope was not statistically significant between genders in our cohort, its role should not be underestimated. Previous studies suggest that both medial and lateral slopes influence ACL injury mechanics, but medial slope often has a greater impact on anterior translation.[19,20]

Age-wise, most patients were above 26 years, reflecting possible cumulative microtrauma, changes in activity levels, and potential degenerative changes affecting joint biomechanics.[21] The exclusive occurrence of ACL tears in young male patients ≤25 yearscould reflect higher participation in high-risk sports activities at younger ages.[9,22]

The significant differences in tibial slope between ACL tear patients and controls support the hypothesis that a steeper posterior tibial slope increases ACL rupture risk.

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Limitations

- Further longitudinal studies with larger sample sizes and biomechanical evaluations are needed to validate these findings and explore preventive strategies.
- Our study compares 40 knees of ACL injury with control group.
- We have not studied the normal knees
- Correlation of increased posterior tibial slope and it's effect on other ligamentous injury other than ACL were not considered.

CONCLUSION

Our study supports the hypothesis that an increased posterior tibial slope is associated with a higher risk of anterior cruciate ligament (ACL) injuries. A steeper slope alters knee biomechanics by increasing anterior tibial translation under load, thereby placing greater stress on the ACL. Recognizing posterior tibial slope as a significant anatomical risk factor may help in identifying individuals at increased risk, guiding preventive strategies, and informing surgical decision-making in both primary ACL reconstruction and revision settings.

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