Analysis of Posterior Tibial Slope as Risk Factor to Anterior Cruciate Ligament Tear

Análise da inclinação tibial posterior como fator de risco para lesão do ligamento cruzado anterior

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Abstract

Objective The objective of the present study was to evaluate the relationship between patients with anterior cruciate ligament (ACL) injury by indirect trauma and increased posterior tibial inclination.

Methods Retrospective study, performed by analysis of medical records and digital radiographs of patients, present in a database of a tertiary orthopedic hospital. The sample consisted of two groups, the first group consisting of patients diagnosed with ACL injury by indirect trauma, and a control group matched by age.

Results Each group consisted of 275 patients, whose measurements of posterior tibial inclination were measured by three specialists. It was observed that the group of patients with ACL lesion presented a significantly higher tibial slope (in degrees) than the control group in the total sample and in the subsamples stratified by gender. The best cutoff point for the first group was identified as a posterior tibial inclination $\geq 8°$, achieving a sensitivity of 63.3% and a specificity of 62.5%. The first group also had a tibial slope ratio $\geq 8°$ (63.3%), significantly higher than the control group (37.5%), with an odds ratio of 2.8.

Conclusion It was concluded that the increase of the posterior tibial inclination is associated with an increased risk for injury of the ACL by indirect trauma, mainly for values $\geq 8°$.

Keywords
- anterior cruciate ligament
- ligaments
- knee injuries
- tibia

Resumo

Objetivo O objetivo do presente estudo foi avaliar a relação entre pacientes com lesão do ligamento cruzado anterior (LCA) por trauma indireto e o aumento da inclinação posterior da tíbia.

Métodos Estudo retrospectivo, realizado por análise de prontuários e radiografias digitais de pacientes, presentes em banco de dados de um hospital terciário de

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ortopedia e traumatologia. A amostra foi composta por dois grupos, sendo o primeiro formado por pacientes com diagnóstico de lesão do LCA, por trauma indireto, e um grupo controle pareado por idade.

Resultados Cada grupo foi formado por 275 pacientes, cujas medidas de inclinação tibial posterior foram aferidas por 3 especialistas. Observou-se que o grupo dos pacientes com lesão do LCA apresentou slope tibial (em graus) significativamente maior que o grupo controle na amostra total e nas subamostras estratificadas por gênero. Identificou-se como o melhor ponto de corte (*cutoff*) para o primeiro grupo uma inclinação tibial posterior $\geq 8°$, atingindo uma sensibilidade de 63,3% e uma especificidade de 62,5%. O primeiro grupo também apresentou proporção de slope tibial $\geq 8°$ (63,3%), significativamente maior que o grupo controle (37,5%), com razão de chances de 2,8.

Conclusão Concluiu-se que o aumento da inclinação tibial posterior está associado com um maior risco para lesão do LCA por trauma indireto, principalmente para valores $\geq 8°$,

Palavras-chave
- ligamento cruzado anterior
- ligamentos
- traumatismos do joelho
- tíbia

Introduction

The anterior cruciate ligament (ACL) is the main restrictor of the anterior translation of the tibia over the femur, being responsible for 85% of the anterior knee stabilization.[1,2] It also acts by limiting internal rotation and secondarily restricting valgus and varus stresses.[2–4]

Anterior cruciate ligament injury is one of the most common ligament injuries of the knee, with increasing incidence due to the rising number of individuals involved with the practice of sports activities.[2,4] It occurs predominantly secondary to indirect trauma, with an association between knee valgus stress and internal tibial rotation.[2,4,5] Failure to properly treat previous instability can lead to injuries to other structures or long-term degenerative changes. Its surgical treatment has good results, although the patient is not always able to return to sports activities with the same performance as before the injury.[5–7]

The identification of risk factors for ACL injuries during physical and sports activities has become a focus of musculoskeletal research. Understanding the mechanisms that produce this instability allows the identification of people at increased risk so that preventive interventions can be applied.[6,7]

The posterior tibial slope has been increasingly studied as a potential risk factor for ACL injury, showing quite varied results between its increase and ligament injury.[6,8,9]

Some biomechanical studies of the knee joint verify that, during an axial compression load, the posterior tibial slope acts producing a force component that leads to the anteriorization of the tibia in relation to the femur.[8–12] It is known that the ACL is the primary retention system against this type of knee movement, that is, an increase in the posterior tibial slope will generate a stress increase in this ligament.[1,11,12] Although some studies suggest the relationship between the posterior slope of the tibial plateau and the ACL injury, the level of risk presented by this intrinsic factor remains unclear.[6,8,9]

Reducing the occurrence of ACL injuries in young active individuals remains an important goal in sports medicine. The objective of the present study is to evaluate, in the Brazilian population, the relationship between patients with ACL injury due to indirect trauma and the increase in posterior tibial slope.

Material and Methods

This is a retrospective study, conducted through the analysis of medical records and digital radiographs of patients present in the database of a tertiary hospital for orthopedics and traumatology in Brazil, from January 2014 to January 2016.

The sample consisted of two groups, with Group I formed by patients diagnosed with ACL injuries due to indirect trauma. During the study period, 643 patients with ACL injury were identified. To form group I, patients who did not have medical records clearly showing the trauma mechanism as indirect were excluded. Other exclusion criteria were radiographs of the knee that prevented reliable measurement of posterior tibial slope (poor quality, radiological changes due to previous surgery or osteoarthritis).

A control group (Group II) was formed from a database of knee radiographs, paired by age with Group I. Any patient with evolution of the medical record showing knee ligament injury was excluded. Research subjects with images that prevented reliable measurement of the tibial slope were also excluded, as described for group I. After analyzing the exclusion criteria, each group was composed of 275 patients. The sample age ranged from 16 to 55 years old. ►**Table 1** provides data on age and gender distribution.

All of the patients underwent a radiographic study according to the routine recommended by the institution. The 500 mA Shimadzu (RADspeed MF, Shimadzu, Kyoto, Japão) X-ray machine was used with a 50 KV and 25 mA technique. A 30×40 cm film was placed at one meter from the ampoule of the digital radiographic apparatus. Then, images in lateral view (profile) with a 30° semiflexion were obtained.

The patients had their knee profile radiographs analyzed, and their posterior tibial slope measured by three orthopedics specialists who were unaware of which group each patient belonged to. This measurement was performed by

Table 1 Sample characterization regarding age and gender

Variable	ACL injury due to indirect trauma ($n = 275$)	Control group ($n = 275$)	Total ($n = 550$)
Age (years)			
Mean (SD)	33.0 (8.8)	38.4 (9.7)	35.7 (9.7)
Sex (N)			
Male	241 (87.6%)	212 (77.1%)	453 (82.4%)
Female	34 (12.4%)	63 (22.9%)	97 (17.6%)

Abbreviation: ACL, anterior cruciate ligament; SD, standard deviation.

drawing a line on the posterior tibial cortical and another on the proximal articular surface of the tibia. The angle formed between the perpendicular to the posterior cortical line and the line of the articular surface corresponded to the measurement of the posterior tibial slope, as described in ►**Figure 1** and determined by the technique of Hohmann et al.[13]

The statistical analysis was composed by the Student t test for independent samples in the comparison of continuous data between the group with ACL injury by indirect mechanism and the control group, and by the chi-squared test ($\chi 2$) when comparing categorical data. In the association between continuous variables, the Pearson correlation coefficient was used.

A Receiver Operating Characteristic (ROC) curve was built to identify the best cutoff point for posterior tibial slope for indirect trauma. The strength of the association between elevated posterior tibial slope and indirect trauma was measured by odds ratio (OR) and its respective 95% confidence interval (CI).

The normality of data distribution was assessed using the Kolmogorov-Smirnov test and graphical analysis of the histogram. The significance determination criterion adopted was the level of 5%. The statistical analysis was processed using IBM SPSS Statistics for Windows, Version 20.0 (IBM Corp., Armonk, NY, USA). The study was previously approved by the research ethics committee of the hospital where the study was carried out under the number CAAE 79853617.0.0000.5273.

Fig. 1 Demonstration of measurement of posterior tibial inclination.

Results

The values of the posterior tibial slope ranged from 2.6° to 18.1° in the first group, with an average of 9.1°, and from 0 to 17.6° in the second, with an average value of 7.3°. Evaluating the variables posterior tibial slope and gender as a whole, according to the Student's *t* test, we verified that there was no significant association ($p = 0.66$), that is, men did not present a medium tibial slope (8.2 ± 2.9 degrees) significantly different from women (8.1 ± 2.8 degrees).

When we performed the association between tibial slope and the two groups under study, we observed that the group of patients with ACL injury due to indirect trauma presented a tibial slope (in degrees) significantly greater than the control group in the total sample and in the subsamples stratified by gender. ►**Table 2** provides the descriptive of the tibial slope (mean, standard deviation [SD], minimum and maximum, in degrees) according to the groups and the corresponding descriptive level (*p-value*) of the Student *t* test for independent samples, in the total sample and stratified by gender (men and women).

►**Figure 2** illustrates the ROC curve of posterior tibial slope for the group with ACL injury due to indirect trauma in the total sample. The overall accuracy of a test can be

Table 2 Tibial slope (in degrees) according to groups and stratified by gender. Student *t* test for independent samples

Sample	ACL injury due to indirect trauma	Control group	*p-value*
All ($n = 275 \times 275$)			
Mean (SD)	9.1 (2.9)	7.3 (2.6)	< 0.0001
Minimum–maximum	2.6–18.1	0–17.6	
Men ($n = 241 \times 212$)			
Mean (SD)	9.0 (2.9)	7.3 (2.6)	< 0.0001
Minimum–maximum	2.6–18.1	0.10–17.6	
Women ($n = 34 \times 63$)			
Mean (SD)	9.3 (3.0)	7.4 (2.5)	0.001
Minimum–maximum	3.1–14.6	0–12.5	

Abbreviation: ACL, anterior cruciate ligament; SD, standard deviation.

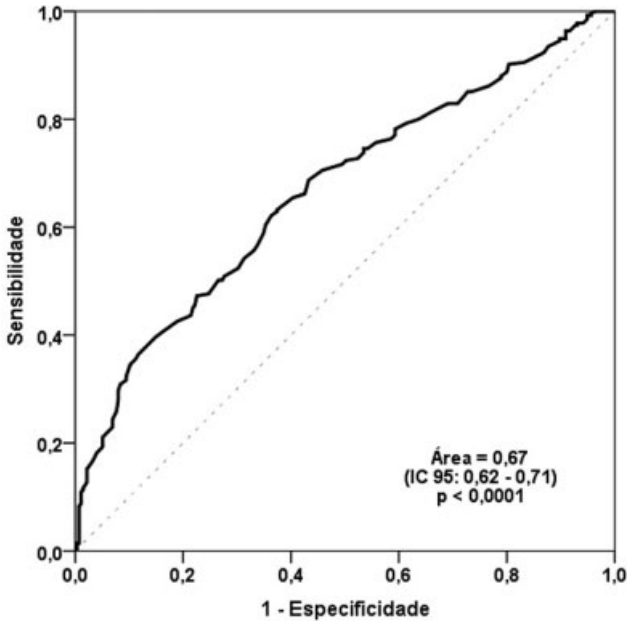

Fig. 2 ROC curve of the tibial slope (in degrees) for patients with ACL injury from indirect trauma.

described as the area under the ROC curve, and the larger the area, that is, the closer to 1, the better the test.

An area of 0.67 was observed with a 95%CI of 0.62 to 0.71, expressing a "moderate/regular" discriminatory power with a significant value ($p < 0.0001$). In addition, considering the control group as a reference category, the best cutoff point for the first group can be identified, which was, according to the ROC curve in the present study sample, a posterior tibial slope $\geq 8°$, reaching a sensitivity of 63.3% and a specificity of 62.5%.

►**Table 3** provides the frequency (n) and percentage (%) of the tibial slope $\geq 8°$ according to the groups under analysis, the corresponding descriptive level (*p-value*) and the odds ratio (OR) for ACL injury due to indirect trauma with the respective 95%CI in the total sample. It was observed, in the total sample, that the group with ACL injury due to indirect trauma presented a proportion of tibial slope $\geq 8°$ (63.3%) significantly higher than the control group (37.5%), with an OR of 2.8 (95%CI: 2.04–4.07) (►**Figure 3**).

However, in ►**Table 4**, it was observed that group I presented a proportion of posterior tibial slope $\geq 8°$ significantly higher than the control group by stratifying into subsamples according to gender, with an OR of ~ 3 for ACL injury from indirect trauma.

Discussion

The association between ACL injury and posterior tibial slope is well-documented in the literature, even though there is still not a consolidated consensus on the level of risk that such an association may have. The present study specifically sought to assess the importance of the degree of posterior tibial slope in patients with ACL injuries originating from indirect trauma. In view of the results found, there is no association between the gender of the patient and the intensity of the posterior tibial slope, differently from what was found by Hohmann et al.,[13] who found greater angulations among females. In the face of equal exposure conditions, it is known that females have a greater risk of ACL injury than males;[7,14] however, the posterior tibial slope could not be considered, according to the results found, one of the reasons for this increased risk.

The relationship between posterior tibial slope and patients with ACL injury due to indirect trauma showed that an increase in angulation would represent an increased risk to the ACL structure when compared to a control group, proving an important interference of the anatomy and biomechanics of the knee in the stability of the joint.

This relationship has been previously described by some authors[9,15–18] who demonstrated that posterior tibial slope has an adverse effect on knee kinematics. On a cadaveric model, Dejour et al.[15] showed a 6 mm increase in anterior tibial translocation for each 10° increase in posterior tibial slope. Similarly, Giffin et al.[16] demonstrated a significant increase in anterior tibial translocation if the posterior slope was increased by 4.4° after a high tibial osteotomy in the opening wedge. Fening et al.[9] performed high tibial osteotomies in the opening wedge and reported an increase in anterior tibial translocation with an increase in tibial slope.

McLean et al.[19] suggested that axial compression of a knee with a greater slope of the lateral tibial plateau, compared to that of the medial tibial plateau, may cause greater anterior movement of the lateral tibial compartment, compared to the other, generating stress in internal rotation of the tibia in relation to the femur, further increasing the load on the ACL.

The statistical analysis of the present study found that patients with an angle $\geq 8°$ are 3 times more likely to damage the ACL through indirect trauma than patients with an angle $< 8°$, regardless of gender.

Some authors advocate the performance of deflection osteotomy as a surgical treatment for patients with excessive posterior tibial slope associated with ACL rupture.[20,21] Dejour et al.[20] evaluated retrospectively a series of patients with tibial slope $> 12°$ who underwent a second ACL

Table 3 Distribution of patients with posterior tibial slope $\geq 8°$ according to groups

Tibial slope	ACL injury due to indirect trauma	Control group	*p value*	OR	CI 95%
$\geq 8°$	174 (63.3%)	103 (37.5%)	< 0.0001	2.87	2.04–4.07
$< 8°$	101 (36.7%)	172 (62.5%)			

Abbreviations: ACL, anterior cruciate ligament; CI, confidence interval; OR, odds ratio.
χ^2 test.

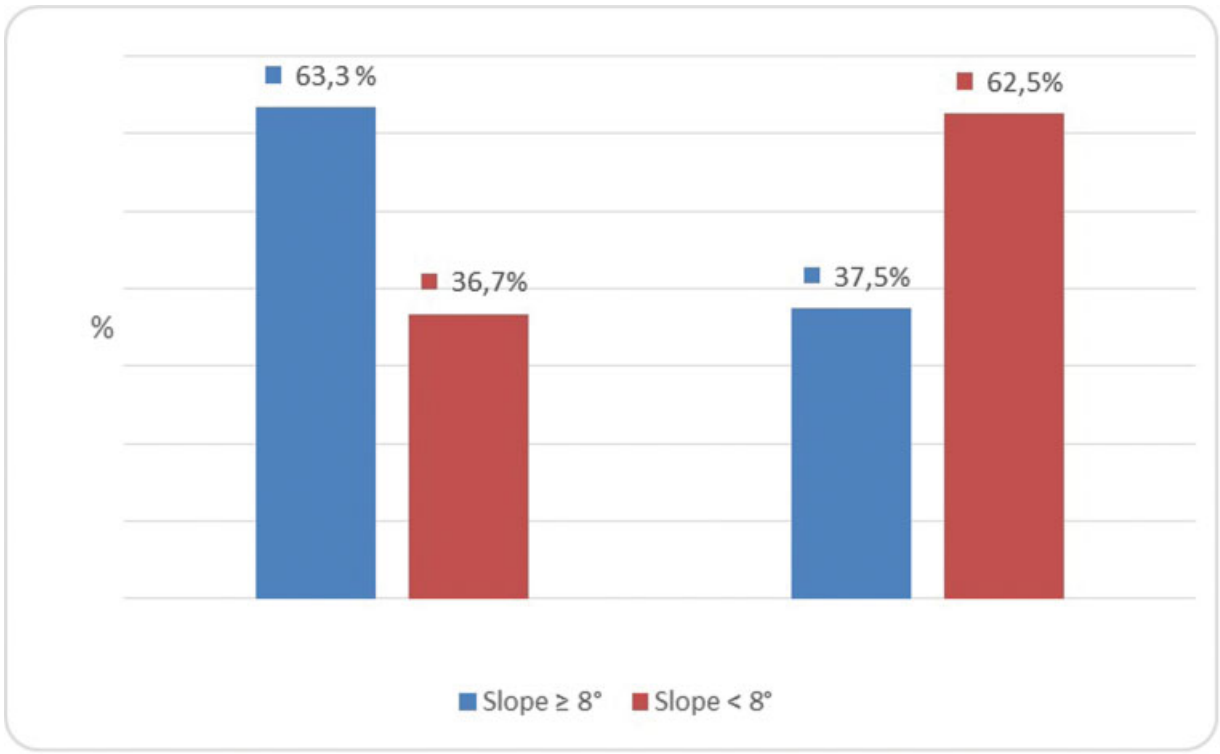

Fig. 3 Tibial slope ≥ 8° according to the groups under study.

Table 4 Tibial slope ≥ 8 degrees according to the type of trauma in the total sample and stratified by gender and age group

Tibial slope	ACL injury due to indirect trauma	Control group	*p-value*	OR	CI 95%
All *(n = 275 × 275)*					
≥ 8 degrees	174 (63.3%)	103 (37.5%)	< 0.0001	2.87	2.04–4.07
< 8 degrees	101 (36.7%)	172 (62.5%)			
Men *(n = 241 × 212)*					
≥ 8 degrees	149 (61.8%)	74 (34.9%)	0.011	3.02	2.05–4.43
< 8 degrees	92 (38.2%)	138 (65.1%)			
Women *(n = 34 × 63)*					
≥ 8 degrees	25 (73.5%)	29 (46.0%)	< 0.0001	3.25	1.31–8.08
< 8 degrees	9 (26.5%)	34 (54.0%)			

Abbreviations: ACL, anterior cruciate ligament; CI, confidence interval; OR, odds ratio.
χ^2 test.

reconstruction review associated with deflection osteotomy. After a minimum follow-up of 2 years, the 9 patients in the study, who met the adopted criteria, were free of complications and with satisfactory functional scores, justifying the procedure for selected cases.

The present study had limitations because it was retrospective. This led to the exclusion of research subjects, due to incomplete information in the medical records, in addition to making it difficult to match the groups on other important criteria, such as the level of sports activity performed or on other associated risk factors for ACL injuries, such as angular deformities.

Conclusion

It is concluded that the increase in posterior tibial slope is associated with a greater risk of ACL injury due to indirect trauma, regardless of gender. Thus, corrective measures should be considered, particularly for those who present excessive tibial slope associated with anterior knee instability.

Conflict of Interests

The authors have no conflict of interests to declare.

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