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Investigating the Role of Proximal Femoral Morphology in Noncontact ACL Injuries: A Comparative Study

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Abstract

Background: Non-contact anterior cruciate ligament (ACL) injury is a common and debilitating injury among athletes, with high recurrence rates and long-term consequences. Identifying individuals at risk of ACL injury can help prevent or reduce the severity of these injuries. The present study aimed to assess the alpha angle in ACL rupture patients in both the injured (ipsilateral) and non-affected (contralateral) extremities, compared to a control group.

***Methods and Results*:** This case-control study included 105 subjects (78.1% male and 21.9% female) aged between 15 and 45 years of both sexes involved in sports. The case group consisted of 54 patients with sport-related, noncontact ACL ruptures identified by MRI. Fifty-one patients, 10(19.6%) of whom were female, with no ACL rupture, were included in the study as a control group. Hip radiographs were taken in all the subjects using the modified Dunn View with the patient in the supine position, hip flexed 45° and abducted 20°. OsiriX software was used to obtain the measurements. Most injuries were caused by football (58.1%), followed by jumping sports (23.8%) and skiing (18.1%). The mean alpha angle was 49.27 ° (SD=4.93) for subjects without ACL rupture and 54.84° (SD=6.17) for subjects with ACL rupture, and the difference was statistically significant (P<0.001). Results also showed a statistically significant difference in the alpha angle on the ipsilateral (54.84° [SD=6.17]) and contralateral (49.48° [SD=7.04]) hips of the case subjects (P<0.001). The logistic regression analysis indicated a statistically significant difference in alpha angle between the case and control groups and between hips of the same subject with an OR of 1.12 (P=0.041) and 1.2 (P=0.000), respectively.

***Conclusion*:** Alterations in proximal femur morphology should be considered a potential risk factor for ACL injury, and alpha angle can be a significant predictor of ACL injury. We recommend that young athletes actively participating in sports have their hip alpha angle measured so those with higher alpha angle can follow special prevention programs.(**International Journal of Biomedicine. 2023;13(3):117-122.**)

Keywords: anterior cruciate ligament • alpha angle • femoroacetabular impingement

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Abbreviations

ACL, anterior cruciate ligament; **FAI**, femoroacetabular impingement; **NWI**, notch width index.

Introduction

The anterior cruciate ligament (ACL) constitutes one of the major stabilizers of the knee joint, and it is the most injured ligament of this joint.[(1)] The injury consists of a rupture of the ligament, which usually happens at sports practitioners and, in most cases, is noncontact.[(2)]

Various risk factors that predispose one to an ACL rupture have been described. Multiple studies have reported that sex (female gender is more predisposed to an ACL injury), femoral intercondylar notch width (smaller dimensions), ACL volume, joint laxity, neuromuscular factors, and higher posterior slope of the tibial plateau are risk factors.[2,3]

Different studies indicate that certain individuals are more susceptible to experiencing an ACL rupture.[4,5] Moreover, those who have previously sustained such an injury still have a high risk for re-rupture. While there is a gender bias toward ACL injury, with females having up to an eight times higher risk of sustaining an injury, the number of males affected is higher, mainly due to their greater involvement in sports.[6]

Numerous studies have reported that abnormalities of the joints adjacent to the knee impact the knee and limb kinematics, thus raising the chances for an ACL rupture.[7,8]

In the proximal femur, these bony abnormalities have been found to mostly cause hip impingement. Depending on the cause, hip impingement can be of three types: cam, pincer, and mixed. The pincer type occurs when the bone abnormality is located in the acetabulum, whereas bony abnormalities in the femoral head produce the first type.[9]

In young and active patients, femoroacetabular impingement (FAI) has already been confirmed as a major risk for early osteoarthritis.[10] Furthermore, recent studies suggest a correlation between hip biomechanical alternations and knee injuries, with some reporting the relationship between these radiographic alternations and a higher risk of ACL injury.[11]

The present study aimed to assess the alpha angle in ACL rupture patients in both the injured (ipsilateral) and non-affected (contralateral) extremities, compared to a control group. According to our hypothesis, the affected side of the patients with an ACL tear will have a greater hip alpha angle than both the control group and the contralateral hip. We wish to go deeper into the relationship between ACL tears and hip morphology and offer insights that may have significant clinical implications and could help in the prevention regimens of ACL injuries.

Materials and Methods

This case-control study included 105 subjects (78.1% male and 21.9% female) aged between 15 and 45 years of both sexes involved in sports. The case group consisted of 54 patients with sport-related, noncontact ACL ruptures identified by MRI and verified arthroscopically by the same surgeon. Measurements taken from the same patient's hips are regarded as dependent observations. Fifty-one patients, 10 of whom were female, with no ACL rupture, were included in the study as a control group. Subjects in the control group were matched by age and by the side of the injured knee. Exclusion criteria for both groups were previous hip or knee surgery, previous fractures, developmental hip dysplasia, or other hip issues on either side. Patients were categorized according to the type of sport during the injury: football, skiing, basketball (while falling from a jump), volleyball, or handball.

A priori power analysis was conducted using G*Power v.3.1 (Universitat Düsseldorf, Germany) and determined that at least 51 subjects were required in each case and control group for 80% power based on an effect size of 0.5.

For the dependent observations, a more robust study was desired. Therefore, we computed the effect size based on previous studies.[12] Using the G*Power v.3.1, our effect size was calculated at 0.45, and with 95% power, the total sample size was 54.

For the hip radiographs to be taken, informed consent had to be signed by each patient in the study. In hip X-rays, the alpha angle is assessed to determine the cam impingement. In the case group, the alpha angle was measured in both hips, and the injured side was matched with a hip radiograph in the control group. According to Smith et al.,[13] the modified Dunn View radiograph gives the most sensitive view for assessing the cam morphology by measuring the alpha angle. We took the modified Dunn View radiograph with the patient in the supine position, hip flexed 45^o and abducted 20^o.

We used OsiriX software to obtain the measurements. OsiriX's oval and angle tool was employed to draw a precise circle around the femoral head. This instrument shows two lines that connect at the oval's center, which makes it possible to measure angles precisely. The alpha angle was determined with the lines pointing away from the center of the femoral head, one through the anatomical axis of the femoral neck in the middle of its narrowest part and the other toward the point where the bone margin of the femoral head deviates from the circle.[2,13] This methodology ensured accurate and reliable measurement of the alpha angle for this study (Figure 1).

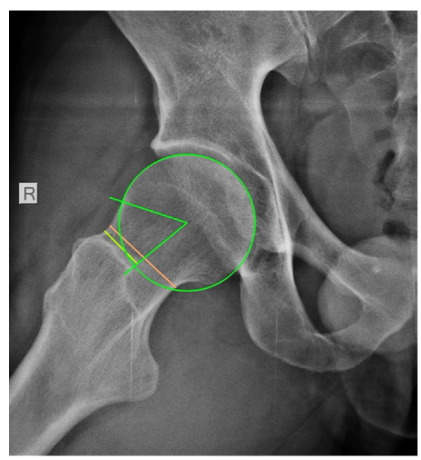

Fig. 1. *The alpha angle measurement on Dunn View hip X-ray, using the oval and angle instrument in OsiriX software.*

One orthopedic surgeon and one radiologist, blinded to the diagnosis of the injured side, evaluated the radiographs and measured the alpha angle.

Statistical analysis was performed using the statistical software package SPSS version 25.0 (SPSS Inc, Armonk, NY: IBM Corp). For the descriptive analysis, results are presented as mean (M) ± standard deviation (SD). To assess the accuracy of the measurements, we used the intraclass correlation coefficient (ICC). The two-sample t-test and paired t-test were used to compare data with normal distribution. The independent samples T-test was used to compare the alpha angle means between the case and control groups, whereas the dependent samples T-test was employed to compare the difference between two dependent means of alpha angle in the hips of case subjects. Group comparisons with respect to categorical variables are performed using chi-square test. Pearson's correlation coefficient (r) was used to determine the strength of the relationship between the two continuous variables. Logistic regression analysis was used to determine the predictive ability of alpha angle on ACL injury. A probability value of $P<0.05$ was considered statistically significant.

Results

Most injuries were caused by football (58.1%), followed by jumping sports (23.8%) and skiing (18.1%). The mean age of all subjects was 27.2 years, with a minimum age of 15.0 years and a maximum age of 45.0 years (Table 1).

Table 1.

Characteristics of subjects.

	Case	Control	*P*-value
N	54	51	
Age	15-45 (mean 23.5)	15-45 (mean 31.01)	<0.001
Gender M/F	40/14	42/9	NS
Mechanism Football	33		NS
Jumping	12		
Skiing	9		

To examine the relationship between alpha angle and ACL injury, we compared the alpha angle of the subjects with and without ACL rupture. Results supported our hypothesis that a higher alpha angle is associated with an increased risk of ACL injury. Specifically, we found that the mean alpha angle was 49.27° for subjects without ACL rupture and 54.84° for subjects with ACL rupture, and the difference was statistically significant ($P<0.001$) (Table 2).

Table 2.

Group statistics between case and control subjects regarding the alpha angle (°).

	ACL Rupture Present	N	Mean	SD	SEM	*P*-value
Alpha angle measurements statistics	Yes (Ipsilateral hip)	54	54.84	6.17	.84	n/a
	No (Control-Group)	51	49.27	4.93	.69	<0.001
	No (Contralateral hip)	54	49.48	7.04	.95	<0.001

Results also showed a statistically significant difference in a paired samples T-test for dependent observations, comparing the alpha angle on the ipsilateral and contralateral hips of the case subjects. ($P<0.001$) (Table 2).

This finding supports our hypothesis that changes in proximal femur morphology, such as higher alpha angle, are associated with an increased risk for an ACL rupture, even between the hips of the same subject. To further explore the relationship between alpha angle and ACL injury, we conducted a two-tailed Pearson correlation analysis at the 0.001 level between the hip alpha angle and ACL injury of the case patients. Results showed a moderately strong relationship between the variables.

We conducted a logistic regression analysis to determine alpha angle's predictive ability on ACL injury (Table 3). Results revealed an OR of 1.2 ($P=0.000$), with a B coefficient of 0.185, indicating that for every degree of increased alpha angle, there is a 20% increase in the risk of an ACL injury.

Table 3.

Logistic Regression – Variables in the equation between case (ipsilateral/contralateral hip alpha angle) and control groups.

	B	S.E	Wald	Df	Sig	OR
Control subjects Alpha Angle	.185	.045	17.067	1	.000	1.20
Contralateral hip Alpha angle	.120	.059	4.162	1	.041	1.12

Interestingly, odds ratio (OR) was positive even when we compared both hips of case subjects, albeit at a slightly lower rate (OR=1.12, $P=0.041$). These findings suggest that alpha angle is a significant predictor of ACL injury even between the extremities of the same patient.

To test for potential confounding factors, we conducted a Kruskal-Wallis test to examine the relationship between the mechanism of injury (football, skiing, jumping) and alpha angle. Results showed no significant differences between the mechanism of injury and alpha angle. Additionally, we tested for a correlation between age and alpha angle, but the results showed a negative correlation that was not statistically significant. In this regard, more data and research are needed to establish significant results.

ICC was calculated to assess the reliability of hip alpha angle measurements made by two observers for three groups: cases, controls, and contralateral hip of the case group. The ICC was calculated using a two-way random effects model and absolute agreement consistency. The ICC values for cases, controls, and contralateral hip of the case group were 0.94 (95% CI = 0.90–0.96), 0.93 (95% CI = 0.88–0.96), and 0.98 (95% CI = 0.997–0.999), respectively, indicating excellent reliability.

Discussion

There are a few previous studies that have taken under consideration the relationship between alpha angle and ACL injury. Our data correspond with these findings. Lopes et al.[2] found that subjects with a noncontact ACL injury had a larger alpha angle in their ipsilateral hip. They also considered hip mobility and found that despite the increase in the alpha angle there was no evidence of decreased hip mobility. Higher alpha angle for the patients with an ACL injury, compared to those in the control group, was reported by Bagherifard et al.[14] But in their study, they reported that the ACL injury group also showed a decrease in the hip range of motion parameters of internal rotation, abduction, and adduction, as well as the sum of internal and external rotation, contrary to what Lopes et al.[2] reported. The study by VandenBerg et al.[15] also supports the idea that restricted hip rotation range of motion (ROM) is associated with an increased risk of ACL injury. These results suggest a correlation between cam and pincer FAI morphology and ACL injury, which correlates with our findings. Another study found that decreased hip flexion and internal rotation can create compensatory knee tensions, increasing the risk of ACL rupture. The changes in hip motion were associated with cam-type impingement or decreased femoral offset.[16]

Furthermore, the results of our study are consistent with those of Philippon et al.[12] that patients with ACL injury had greater hip alpha angle than those with non-ACL injury. Alpha angle larger than 60^o is associated with a decreased hip ROM, particularly internal rotation, and an increased risk of ACL injury. This association was observed in males and females, but the odds were higher in males. Schaver et al.[17] reached similar conclusions, with an association between higher alpha angle and patients undergoing ACL reconstruction. They defined the cam morphology at an alpha angle >60^o.

Contrary to these studies, which described a limitation of their own AP radiographs, we took the radiographs in Dunn View to measure the alpha angle, but the results seem similar.[12,14,17] Our study aimed not to define the cam morphology but to look at proximal femur morphology by investigating the differences between different degrees of alpha angle and the correlation with ACL injury. The mean alpha angle of 54.84^o, as measured in our case subjects, stands between the values reported so far as a definition of cam impingement.[18]

There is an agreement among researchers that alterations in all joints, above and below the knee, play an important role in ACL injury.[12] There have been many reports regarding the distal femur anatomic landmarks and not only their potential impact on ACL injury. Such factors as the intercondylar notch being narrower and the β angle and lateral tibial plateau being larger were described by Shen et al.[19] as associated with a higher risk for ACL injury. The same landmarks, as well as an increased alpha angle, have been studied by Barnum et al.[20] with similar results, resulting in a higher risk for ACL injury. The increased posterior tibial slope may promote ACL injury by increasing anterior tibial motion relative to the femur or by creating torsional loads. The notch width index (NWI) is also linked to ACL injury, with narrower NWI in ACL injury cases, compared to controls. NWI is advantageous in eliminating influences of height, weight, sex, individual differences, and measurement errors.[21]

ACL volume and femoral intercondylar notch width were reported by Whitney et al.[22] to be significant independent predictors of ACL injuries in both the female and male groups. A decrease in each predictor was associated with an increased likelihood of injury in men. In contrast, in females, the thickness of the bony ridge at the anteromedial outlet of the femoral notch was also a significant predictor. Meanwhile, Polamalu et al.,[23] through statistical shape modeling, revealed significant differences in bony morphological features associated with ACL injuries, with variations in the angle between the long axis, condylar axis, and mechanical axis of the distal femur location. A smaller angle between the long and condylar axes may increase contact area and stability, thus reducing the risk of ACL injury. K. Çimen and colleagues[24] compared distal femur and proximal tibia anatomy; even though they didn't find significant differences in the NWI, they found significant differences in the tibial eminence width index when comparing the ACL-injured group to those with an intact ACL. Moreover, Duparc et al.[25] have described the index of cumulative torsions as a regulatory ticket for the limb, with femoral torsion being extremely variable. The increased tibial and femoral torsions have also been described to increase the risk of an ACL injury.[26,27]

Our study's limitation is that we have not considered pincer morphology, and AP radiographs were not taken to limit the patients' exposure. The femoral head-neck offset ratio was not measured and observed since the mean of the alpha angle expressed the degree of femoral deformity. Another limitation may be the small number of subjects, even though the power analysis was done before the study. Furthermore, we did not compare the distal femur morphology, but this should be done in the future to reduce the potential confounding factors and to define even further the role of the alpha angle and proximal femur morphology in ACL rupture.

Conclusion

The present study investigated the relationship between alpha angle and ACL injury in 105 subjects. The results revealed a significant association between a higher alpha angle and increased risk of ACL injury, with the mean alpha angle being significantly higher in subjects with ACL rupture than those without. The logistic regression analysis further supported this finding, indicating a statistically significant difference in alpha angle between the case and control groups and between hips of the same subject with an OR of 1.12 and 1.2, respectively. Overall, our results indicate that alterations in proximal femur morphology should be considered a potential risk factor for ACL injury, and alpha angle can be a significant predictor of ACL injury. We recommend that young athletes actively participating in sports have their hip alpha angle measured so those with higher alpha angle can follow special prevention programs.

Ethical Approval

The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the Faculty of Medicine, University of Prishtina "Hasan Prishtina" of May 18, 2021. All participants provided written informed consent.

Competing Interests

The authors declare that they have no competing interests.

Data availability statements

The data that support the findings of this study are available from the Council of Medical Faculty, University of Prishtina "Hasan Prishtina" upon reasonable request. Contact person: Qerim Kida, E-mail: qerimkida@gmail.com

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