Association of Tibia Eminence Width Index and Intercondylar Notch Angle with Risk of Anterior Cruciate Ligament Injury in an African Population

Oladimeji Ranti Babalola[1], Ukamaka Jane Igwillo[2], Ijoukhumo Ethel Egbekun[1], Kehinde Sunday Oluwadiya[3]

[1]Department of Orthopaedics and Trauma, Division of Arthroscopy and Sports Medicine, National Orthopaedic Hospital, [2]Department of Radiology and Radio-Diagnosis, National Orthopaedic Hospital, Igbobi, Lagos, [3]Department of Orthopaedics and Trauma, Ekiti State University Teaching Hospital, Ekiti, Nigeria

Abstract

Background: Certain modifiable and nonmodifiable risk factors have been associated with the risk of suffering an anterior cruciate ligament (ACL) rupture. The goal of this study was to determine the relationship between the intercondylar notch angle (INA) and the tibia eminence width index (TEWI), with the risk of ACL injury. **Materials and Methods:** Consecutive patients with ACL injury presenting over a 3-year period were recruited. A control group with no complaints related to cruciate and collateral knee ligament injuries was also recruited. **Results:** The mean values of each of these variables were compared between the groups. The body mass index, height, and weight were correlated with TEWI and INA in each group. A total of 30 each of ACL injured cases and controls were recruited for the study. The mean values of the TEWI for the ACL group were 0.20 and 0.19 for the control group ($P = 0.553$). The mean INA for ACL is 43.37° and 42.43° for control ($P = 0.969$). **Conclusion:** The INA and TEWI are not predictive of the risk of ACL injury.

Keywords: Angle, anterior cruciate ligament, correlation, index, intercondylar angle, tibia eminence

Introduction

Anterior cruciate ligament (ACL) injuries can be a functionally limiting injury to the involved individual. The socioeconomic cost of care is far-reaching and the long-term effect on knee health has been a source of concern to orthopaedic surgeons. In a bid to understand the etiology of this injury and possibly formulate injury prevention programs, risk factors associated with ACL injuries have been a research focus of late.

Broadly speaking, these risk factors may be divided into anatomical, physiological, and environmental factors. Anatomic risk factors are the focus of injury prevention programs in patients with noncontact injuries. Anatomic risk factors that have been noted include the notch width (NW) and NW index (NWI).[1-7] Other anatomic factors worthy of note include a small-sized ACL and the intercondylar notch angle (INA). The INA can determine if there would be an impingement of the ACL on the roof of the femoral notch and the consequent risk of ACL rupture.[8] In a study by Huang *et al.*,[9] they observed a significantly smaller INA in ACL injured patients as compared to patients with intact ACL. Certain sporting activities such as basketball, soccer, and lawn tennis that entail undercutting and pivoting movements have also been noted to be predisposing factors.[10] Furthermore, a narrow tibia eminence has been described as giving rise to a smaller diameter ACL with the attendant increased risk of ACL rupture.[11]

The goal of this study is to attempt to characterize the TEWI) and INA (alpha angle) in our population of patients using case and control groups. The null hypothesis was that there was no significant difference in the mean INA and TEWI between the

Access this article online	
Quick Response Code:	Website: www.njmonline.org
	DOI: 10.4103/NJM.NJM_45_22

Address for correspondence: Dr. Oladimeji Ranti Babalola, Division of Arthroscopy and Sports Medicine, Department of Orthopaedics and Trauma, National Orthopaedic Hospital, Igbobi, PMB 2009, Yaba, Lagos, Nigeria.
E-mail: ladibabalola28@gmail.com

How to cite this article: Babalola OR, Igwillo UJ, Egbekun IE, Oluwadiya KS. Association of tibia eminence width index and intercondylar notch angle with risk of anterior cruciate ligament injury in an african population. Niger J Med 2022;31:323-7.

Submitted: 27-Mar-2022 **Revised:** 01-May-2022
Accepted: 14-May-2022 **Published:** 24-Jun-2022

ACL injury and control groups. The alternative hypothesis was that there is a significant difference between these parameters in the injury and control groups.

Materials and Methods

This was a case–control study involving patients between the ages of 15–50 years with ACL injury and controls with no such injury. The study was conducted between January 2016 and August 2020. Approval for the study was obtained from the institutional health research and ethics committee. Consent was obtained from patients for the study. The cases were patients with noncontact ACL injury, who consented to the study and who had no associated fractures of the distal femur or proximal tibia. The controls were patients diagnosed with early degenerative knee joint disease (Kellgren I or II), intra-articular loose bodies in the knee, patellofemoral instability, or isolated meniscal injuries presenting within the study period. This category of control groups was selected among patients visiting the hospital and not from the general population because the INA and tibial eminence width index have not be established as risk factors for meniscal injuries, degenerative joint disease, or intra-articular loose bodies. Furthermore, the risk of undue exposure of the general population to radiation is avoided by this. These patients were matched for gender and age with the patients with noncontact ACL injury. The patients who did not consent to the study and who did not have the appropriate radiographs of the knee were excluded from the study. Furthermore, excluded from the control population were the patients with fractures around the knee. In recruiting patients for the control group, consecutive patients diagnosed with noncontact ACL injury clinically and confirmed with magnetic resonance imaging (MRI) in the orthopaedic outpatient clinic of the hospital, and who consented to the study were recruited. A history of a noncontact injury to the knee, the presence of instability particularly with pivoting and undercutting movements consequent to this injury was noted. Clinical examination was done to help establish a positive Lachman's, anterior Drawer, and pivot shift tests. As part of the preoperative workup of the patients for ACL reconstruction, plain radiographs of the knee were requested. The lateral image of the knee was made with the patient in the supine position with the knee flexed to 30°. The X-ray beam was made to pass through the knee joint from the medial-to-lateral side. For the tunnel view X-ray, an axial view of the knee was made with the patient positioned supine and the knee flexed between 40° and 45°. The X-ray beam was made to pass through the knee from the anterior to posterior at a 90° angle to the lower leg to obtain a tunnel view. Two of the authors then measured the tibia condyle width and the tibia eminence width using the tunnel view radiograph mounted on an X-ray viewing box. The INA of the distal femur was measured using a lateral radiograph of the knee. Both measurements were taken on two separate occasions 3 months apart, independently. The tibia eminence width was measured using the method described by Uhorchak *et al*.[12] A line was drawn from the lateral to the medial border of the tibia [Figure 1; A and B], parallel to the tibia plateau. This represented the tibia condyle width. Subsequently, two lines perpendicular to this line and bisecting the tibia eminence peaks were drawn [Figure 1; C and D]. The distance between these two bisecting lines (CD) was taken as the tibia eminence width and this approximates the ACL diameter at its origin from the tibia. The TEWI is the tibia eminence width(CD) divided by the tibia condyle width (AB) [Figure 1]. For the measurement of the INA the principle in the method described by Bouras *et al*.[13] was applied. However, this was done using plain radiographs. The use of plain radiographs is supported by a study by Kosy and Mandalia,[14] in which plain radiographs were used in measuring ACL tunnel placements. The study lends support to the fact that plain radiographs may be adequate in the measurement of parameters related to the ACL such as tunnel position despite the extra detail three-dimensional imaging such as computed tomography (CT) and MRI may afford. In addition, plain radiographs are part of the routine investigations usually requested for the clinical conditions in the case and control groups. MRI and CT are not usually routine investigations for early degenerative joint disease or intra-articular loose bodies. The authors also considered the undue high radiation dose, these patients might be exposed to if a CT scan of the knee were requested for patients recruited for the study. These observations informed the use of plain radiographs by the authors in this study.

To measure the intercondylar angle, the lateral radiograph of the knee was mounted on a viewing box and two points, 3 cm–5 cm apart were located along the posterior cortex of the shaft of the femur and away from the supracondylar region [Figure 2; A and B]. From these two points, a line perpendicular to the posterior cortex of the femur was drawn and continued to the anterior cortex [Figure 2; A' and B']. The length of these two lines was measured and the midpoints were noted on the plain radiograph. A line joining these two midpoints and continued distally into the knee joint area was drawn. This line represents the anatomic axis of the shaft of

Figure 1: Tunnel view plane radiograph showing measurement of the tibia eminence width index

Figure 2: Lateral radiograph showing measurement of intercondylar notch angle

the femur. Next, a line running parallel along the cortex of the roof of the intercondylar notch (Blumensaat line) was also drawn to intersect the original line drawn along the long axis of the femur. The acute angle formed posteriorly between these two lines was represented the INA [Figure 2; ά angle]. A similar number of patients presenting with complaints of the lower limb not related to ACL tear, who consented to the study were recruited as controls. Such lower limb injuries included early degenerative joint disease (Kellgren I or II), loose bodies in the knee, patellofemoral instability, and meniscal injuries. These patients were matched for sex and age with the patients with ACL injury. Tunnel view and lateral radiographs of the knee were also requested for these patients. Measurements of the TEW and INA were made for those with ACL injury. The body mass indices of the cases and controls were also documented.

Statistical method

Statistical analysis was performed using SPSS Statistics v. 22 for Windows software (IBM). Continuous variables were expressed as the mean (± standard deviation). The measurements were taken independently by two of the authors. Reliability in measurement was determined by intraclass correlation coefficient (ICC). Intra-rater reliability was estimated by measurements taken independently by the first author and inter-rater reliability was determined by comparing with measurements taken by the second author who was blinded to the readings of the first author. The mean values for the TEWI and INA for the cases and controls were compared using the independent *t*-test. The level of significance was taken as $P < 0.05$.

Results

A total of 102 ACL injured cases were seen during the study period. Thirty of these had their injury by noncontact mechanism and were recruited for the study. Thirty age- and gender-matched controls were also recruited for the study. There were 18 males and 12 females. The mean values of the age, body mass index, Tibial eminence width index and Intercondylar notch angle of the case and control groups are as displayed in [Table 1], and this revealed no statistically significant difference between the groups. Also, no statistically significant correlation was found between the body mass index (BMI) and the INA and TEWI in both the case and control groups [Table 2]. The ICC was calculated using SPSS Statistics v. 22 for Windows software (IBM) (SPSS Inc., Chicago, IL, USA.) using an absolute-agreement and mixed-effects model. An excellent correlation was found between the measurement with an ICC value of 0.95 at 95% confidence interval ($P < 0.01$).

Table 1: The mean values for age, body mass index, tibia eminence width index, and intercondylar notch angle

	Mean±SD		*P*
	Cases	Controls	
Age (years)	31.53±11.37	32.37±10.36	0.53
BMI (kg/m^2)	25.53±2.90	25.19±3.35	0.38
TEWI	0.20±0.65	0.19±0.27	0.553
INA (°)	43.37±5.64	42.35±6.51	0.970

SD: Standard deviation, BMI: Body mass index, TEWI: Tibia eminence width index, INA: Intercondylar notch angle

Table 2: Correlation of body mass index with intercondylar notch angle and tibia eminence width index

	r (*P*)			
	Case (INA)	Control (INA)	Case (TEWI)	Control (TEWI)
BMI (kg/m^2)	0.13 (0.72)	0.05 (0.80)	−0.186 (0.37)	0.25 (0.45)

BMI: Body mass index, TEWI: Tibial eminence width index, INA: Intercondylar notch angle

Discussion

Our study revealed that there was no significant difference in the mean values of the INA and TEWI between the ACL injured group and age and gender-matched controls. Furthermore, there was no correlation between the BMI of the case and control groups and each of the TEWI and the INA.

The NWI, TEWI, and (INA/α angle) represent nonmodifiable factors for ACL injury. The NWI and INA have been noted to be weak indicators of ACL injury outcome.[13] In a comparative study by Alentorn-Geli *et al*.[15] on INA in male patients with noncontact ACL injury, they found no significant difference between the injured group and controls. They used MRI in measuring the INA. However, in another study by Fernández-Jaén *et al*.,[8] they found a higher INA in patients with a torn ACL than in those with an intact one. The study by Huang *et al*.[10] revealed that ACL injured patients tend to have a smaller INA angle compared to controls. These series of results appear contradictory. Bouras *et al*.[13] in their study measured the INA in female patients but found no significant difference between the ACL-injured and-uninjured groups. Similar to the finding of Bouras *et al*.,[13] the study by Lombardo *et al*.[16] involving 305 patients, and using plain radiographs found that the NWI was not predictive of ACL injury and concluded that ACL injury could not be predicted by the absolute measurement of the femoral intercondylar notch.

Our study revealed no significant difference between the injury and control groups despite the fact that our sample population unlike those of Bouras *et al*.[13] had both gender represented. However, a meta-analysis by Zeng *et al*.[17] concluded that a narrow intercondylar NW and a lower NWI were risk factors associated with ACL injury.

Our result represents the first report in an exclusively black patient population and appears to add to the argument that the INA may not be a risk factor in the etiology of noncontact ACL injury.

The TEWI is also a nonmodifiable risk factor noted to be associated with ACL injury. The TEWI is said to represent the size of the ACL at its tibia attachment. A small TEW and TEWI would mean a small ACL and a small ACL has been noted to be an added risk factor for ACL injury.[18] Our study revealed no significant difference between the two groups in terms of the TEWI. In a comparative study of 73 patients by Xiao *et al*.,[11] the ACL group had a TEWI that was significantly lower in the ACL group compared with the control group both in the total sample population and when compared between the gender subgroups. Similar observations were noted by Uhorchak *et al*.[12] in their study of 895 military cadets. Our observation may be related to the small sample size of our study as these other studies had a larger sample size.

The findings in relation to the INA and risk of ACL injury remain largely inconsistent. As previously documented, the possibility exists that the risk factors for ACL injury act in combination rather than as isolated risk factors.[5] Further research would be needed along this line to corroborate that. Previous research have suggested that a smaller TEWI is related to a higher risk of ACL injury. This was not the finding in our study. These other studies were conducted in a different population from ours. The possibility of race playing a role in this risk factor also leaves room for further research.

Study limitations

The limitations of this study include the fact that the sample size was small both in terms of the total sample size and the sample size on a gender basis. Second, other anatomic factors such as the femoral notch shape, femoral notch size, femoral NWI, and posterior tibia slope which may all act in combination to predispose an individual to ACL injury were not included in this study. Third, the anatomic measurements were done in two-dimensional radiographic images only which may be a cause for inaccuracy in measurements taken. However, studies have shown that while CT scan may be the most accurate modality for anatomic measurements in the knee, plain radiographs offer a cost-effective alternative to CT scan when CT scan cannot be used.[14,19]

Conclusion

The authors conclude that there is no significant difference in the mean values of the INA and TEWI between the ACL injured group and age and gender-matched controls.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Dienst M, Schneider G, Altmeyer K, Voelkering K, Georg T, Kramann B, *et al.* Correlation of intercondylar notch cross sections to the ACL size: A high resolution MR tomographic *in vivo* analysis. Arch Orthop Trauma Surg 2007;127:253-60.
2. Domzalski M, Grzelak P, Gabos P. Risk factors for anterior cruciate ligament injury in skeletally immature patients: Analysis of intercondylar notch width using magnetic resonance imaging. Int Orthop 2010;34:703-7.
3. Padua DA, DiStefano LJ, Hewett TE, Garrett WE, Marshall SW, Golden GM, *et al.* National Athletic Trainers' Association Position Statement: Prevention of Anterior Cruciate Ligament Injury. J Athl Train. 2018;53:5-19.
4. Stijak L, Nikolić V, Blagojević Z, Radonjić V, Santrac-Stijak G, Stanković G, *et al.* Influence of morphometric intercondylar notch parameters in ACL ruptures. Acta Chir Iugosl 2006;53:79-83.
5. Smith HC, Vacek P, Johnson RJ, Slauterbeck JR, Hashemi J, Shultz S, *et al.* Risk factors for anterior cruciate ligament injury: A review of the literature – Part 1: Neuromuscular and anatomic risk. Sports Health 2012;4:69-78.
6. Hernigou P, Garabedian JM. Intercondylar notch width and the risk for anterior cruciate ligament rupture in the osteoarthritic knee: Evaluation by plain radiography and CT scan. Knee 2002;9:313-6.
7. Myklebust G, Engebretsen L, Braekken IH, Skjølberg A, Olsen OE, Bahr R. Prevention of anterior cruciate ligament injuries in female team handball players: A prospective intervention study over three seasons. Clin J Sport Med 2003;13:71-8.
8. Fernández-Jaén T, López-Alcorocho JM, Rodriguez-Iñigo E, Castellán F, Hernández JC, Guillén-García P. The importance of the intercondylar notch in anterior cruciate ligament tears. Orthop J Sports Med 2015;3:1-6.
9. Huang M, Li Y, Guo N, Liao C, Yu B. Relationship between intercondylar notch angle and anterior cruciate ligament injury: A magnetic resonance imaging analysis. J Int Med Res 2019;47:1602-9.
10. Huang M, Li Y, Guo N, Liao C, Yu B. Relationship between intercondylar notch angle and anterior cruciate ligament injury: a magnetic resonance imaging analysis.Journal of International Medical Research 2019;47:1602-9.
11. Xiao WF, Yang T, Cui Y, Zeng C, Wu S, Wang YL, *et al.* Risk factors for noncontact anterior cruciate ligament injury: Analysis of parameters in proximal tibia using anteroposterior radiography. J Int Med Res 2016;44:157-63.
12. Uhorchak JM, Scoville CR, Williams GN, Arciero RA, St Pierre P, Taylor DC. Risk factors associated with noncontact injury of the anterior cruciate ligament: A prospective four-year evaluation of 859 West Point cadets. Am J Sports Med 2003;31:831-42.
13. Bouras T, Fennema P, Burke S, Bosman H. Stenotic intercondylar notch type is correlated with anterior cruciate ligament injury in female patients using magnetic resonance imaging. Knee Surg Sports Traumatol Arthrosc 2018;26:1252-7.
14. Kosy JD, Mandalia VI. Plain radiographs can be used for routine assessment of ACL reconstruction tunnel position with three-dimensional

imaging reserved for research and revision surgery. Knee Surg Sports Traumatol Arthrosc 2018;26:534-49.

15. Alentorn-Geli E, Pelfort X, Mingo F, Lizano-Díez X, Leal-Blanquet J, Torres-Claramunt R, *et al.* An evaluation of the association between radiographic intercondylar notch narrowing and anterior cruciate ligament injury in men: The notch angle is a better parameter than notch width. Arthroscopy 2015;31:2004-13.
16. Lombardo S, Sethi PM, Starkey C. Intercondylar notch stenosis is not a risk factor for anterior cruciate ligament tears in professional male basketball players: An 11-year prospective study. Am J Sports Med 2005;33:29-34.
17. Zeng C, Gao SG, Wei J, Yang TB, Cheng L, Luo W, *et al.* The influence of the intercondylar notch dimensions on injury of the anterior cruciate ligament: A meta-analysis. Knee Surg Sports Traumatol Arthrosc 2013;21:804-15.
18. Bayer S, Meredith SJ, Wilson KW, de Sa D, Pauyo T, Byrne K, *et al.* Knee morphological risk factors for anterior cruciate ligament injury: A systematic review. J Bone Joint Surg Am 2020;102:703-18.
19. Webster KE, Feller JA, Elliott J, Hutchison A, Payne R. A comparison of bone tunnel measurements made using computed tomography and digital plain radiography after anterior cruciate ligament reconstruction. Arthroscopy 2004;20:946-50.