

Femoral Intercondylar Notch Geometry And Anterior Cruciate Ligament Size In Association With Risk Of ACL Injury: A Multivariate Model

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Summary:

In a group of 71 case controlled pairs of ACL injured competitive athletes, notch outlet width (OR=1.37, p=0.0039) and ACL volume (OR=1.18, p=0.0297) were significant independent predictors of ACL injury and furthermore for every 1mm decrease in notch outlet width and 0.1cm³ decrease in ACL volume there is a respective 37% increase and an 18% increase in risk of ACL injury.

Abstract:

Introduction:

Injuries to the anterior cruciate ligament (ACL) of the knee are common and debilitating. Geometric properties of the femoral intercondylar notch and the ACL have been implicated as risk factors for ACL injury. Prior research has produced equivocal results with several studies suggesting a smaller notch is associated with an increased risk of suffering ACL tears (1,2) and others showing no significant association (3,4). Notch width at the anterior-inferior outlet has been consistently shown to be a significant risk factor for ACL injury (1,6). There is also limited evidence that factors such as a small ACL with its paired decrease in structural properties (5,7) as well as the presence of a bony ridge prominence at the anteromedial aspect of the notch wall that borders the medial condylar articular surface, is associated with an increased risk of suffering an ACL tear (6). The objective of this study was to confirm previous results and use multivariate analysis to determine the combined and relative contributions of different geometric risk factors associated with an ACL injury using a matched, case-control study design. We hypothesized that a smaller femoral intercondylar notch width, smaller ACL volume, and larger bony ridge prominence would be independent predictors for ACL injury. Retrospective measures focusing on the ACL and surrounding anatomy must be made using the surrogate uninjured contralateral limb, which we also aimed to validate.

Methods:

This study was approved by the Institutional Review board at the University of Vermont, and all subjects provided signed informed consent. Bilateral knee MRI scans were obtained on 71 case-control pairs (23 male, 48 female) matched for age, sex, and participation on the same sports team. Cases had suffered a grade III first-time, non-contact ACL tear, as diagnosed and confirmed arthroscopically by an orthopaedic surgeon. All images were obtained using the Phillips Achieva 3.0T MRI (Fletcher Allen Healthcare, Burlington, VT) with subjects positioned supine. DICOM images were viewed and digitized using Osirix Software (Pixmeo, version 3.6.1., open source) and manual segmentation was completed using a Cintiq 21UK digitizing tablet (Wacom Tech Corp, Vancouver, WA, USA).

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Using 3D multi-planar reconstruction, sagittal 3D proton density-weighted scans (voxel size: 0.4 x 0.4 x 0.7mm) were reoriented to the coronal oblique plane, parallel to the long axis of the anterior border of the ACL. In the slice containing the length of the ACL, the notch width was measured at the anterior-inferior notch outlet (NOW). The bony ridge prominence was measured as a maximum distance from a line best fit to the medial border of the notch. Sagittal T1-weighted 3D FFE images (voxel size: 0.3 x 0.3 x 1.2mm) were used for segmentation of the ACL. The volume was calculated by taking the sum of these segmented areas multiplied by the sagittal slice thickness (1.2 mm). All measurements were made on the uninjured limb of cases and bilaterally on control subjects.

Using the case uninjured limb and the corresponding side of control subjects, conditional logistic regression was performed to assess the effects of the continuous variables of notch width, ACL volume, and bony ridge prominence, as well as their interactions, on the risk of ACL injury in the pooled male and female population. A paired student's t-test was used to test side-to-side differences in the control subjects.

Results:

Regression analysis revealed that notch outlet width (OR=1.37, p=0.0039) and ACL volume (OR=1.18, p=0.0297) were significant independent predictors of ACL injury, whereas bony ridge prominence (OR=1.20, p=0.3192) was not. Interaction terms between ACL volume/notch width outlet and ACL volume/bony ridge prominence were not statistically significant. There were no side-to-side differences in the control subjects for each measurement.

Discussion:

The results of this study suggest that decreased notch outlet width and decreased ACL volume are both associated with increased risk of suffering an ACL injury. This is in agreement with the previous literature that has identified each of these as intrinsic risk factors for ACL injury with univariate analysis. An important advance made with the current study was application of multivariate analysis and this revealed that notch outlet width and ACL volume are independently associated with the risk of suffering an ACL tear, while the bony ridge prominence does not contribute to overall risk. The lack of significant interaction between ACL volume, notch outlet width and thickness of bony ridge prominence also indicates that their effects are not interdependent. In addition, the absence of side-to-side differences in control subjects validates the use of the uninjured limb as a surrogate for the cases. These results provide evidence that the overall stenosis at the anterior-inferior outlet of the femoral notch is more important to ACL injury risk than the bony prominence on the notch. It can be inferred from our data that for every 1mm decrease in notch outlet width there is a 37% increase in the risk of suffering an ACL tear. Similarly, for every 0.1cm³ decrease in ACL volume there is an 18% increase in risk. In conclusion, a smaller ACL is more likely to be injured, and a narrower notch outlet may increase that risk.

Significance: Individuals with certain anatomic abnormalities may be at increased risk for ACL injuries. Prior to injury, the ACL has been shown to hypertrophy in athletes that undergo extensive training starting at puberty (8), which would increase its volume and decrease its risk of rupturing (5,7). In a clinical context after an initial injury, surgeons may identify notch stenosis (and not simply bony ridge prominence) as a risk factor for future injury or ACL graft failure.

References:

1Simon, 2010; 2Hoteya, 2011; 3Al-Saeed, 2012; 4Van Eck, 2011; 5Chaudhari, 2009; 6Everhart, 2010; 7Hashemi, 2010; 8Grzelak, 2012.

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