Predisposing Anatomic Factors for Injury: A Retrospective MRI Analysis of Patients with Anterior Cruciate Ligament Injuries Compared to Matched Controls

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INTRODUCTION:

Anterior cruciate ligament (ACL) tears are one of the most common injuries in cutting and pivoting sports and result in considerable lost to time to play and morbidity related to cartilage injury and posttraumatic arthritis. While female gender and poor neuromuscular and proprioceptive control have been recognized as predisposing risk factors, a number of anatomic variables may also be contributory, including tibial and condylar geometry. Prospective recognition of these risks may be of paramount importance for clinicians to consider extra-articular augmentation or more cautious return to play protocols to prevent recurrent injury. We hypothesized patients' who suffered ACL injury requiring reconstruction will have significant differences in tibial, condylar, and meniscal morphology compared to age-matched controls.

METHODS:

An IRB-approved retrospective case control study was completed with patients who underwent a surgical knee procedure from January 2015 to December 2022. The inclusion criteria were skeletally mature patients (age 15-50 years) with preoperative magnetic resonance imaging (MRI) scans of the knee, patients who underwent ACL reconstruction or arthroscopic, non-ACL surgery (meniscus or patellofemoral instability surgery). Patients were excluded if they had knee arthrosis, ACL revision surgery, or inadequate images. The age and gender matched groups were divided as control group consisting of subjects with non-ACL surgery (n=100) and experimental group consisting of ACL reconstruction group (n=100). Demographics (gender, height, weight, age and body mass index and physical examination findings (sports history, recreational history, knee hyperextension, Knee hyperlaxity, knee alignment and knee stability) were collected.

Two independent reviewers performed the measurements on the MRI of the knee. Morphological measurements included assessment of anterior and posterior tibial slope (medial and lateral side), proximal tibial anterior-posterior distance, tibial depth of the medial plateau, tibial eminence width, meniscus bone angle (medial and lateral side), meniscus cartilage height (medial and lateral side), femoral notch width, notch height, femoral condyle anterior-posterior distance (medial and lateral side), lateral wall angle (axial and coronal). Accuracy of the measurement was confirmed by a fellowship-trained musculoskeletal radiologist and was based on validated techniques published in the literature. Intra- and inter-rater reliability was confirmed using interclass correlation coefficient (ICC (3,1)) with a two-way random effect model for absolute agreement.

Outcomes and patient characteristics in the ACL surgery group were compared against those in the control group. All differences between groups in continuous variables were tested using two sample t-tests. All differences between groups in categorical variables were tested using Chi squared tests. A logistic regression model using group membership as an outcome was performed for multivariate analysis. Statistical significance was defined as $p < 0.05$. All variables collected in this study were used in building a logistic regression model as well as potential interactions with gender and BMI. A backwards selection process was performed to select the final model. All statistical analysis was performed.

RESULTS:

The intra-rater and inter-rater values for the measurements were intra=0.987,0.988 and inter =0.983 respectively.

Significant differences ($p<0.05$) (between experimental vs. control group respectively) was observed for lateral meniscus bone angle (28.3(4.9) vs. 31.4 (5.0)^{o}) (p=0.001), lateral meniscus cartilage height (6.71 (0.87) vs. 7.29 (1.10) mm) (p=0.01), and femoral notch width (17.3 (3.0) vs. 18.3(3.4) mm) (p=0.03).

The anterior tibial slope (ATS) was smaller in experimental group than in control group (4.62 (2.37) vs. 4.78 (2.49)^{o} respectively) whereas posterior tibial slope (PTS) (medial (PTS-M) and lateral (PTS-L) was larger in experimental group than in control group (PTS- M: 6.15(2.49) vs. 5.79 (2.90)^{o} (p=0.4) and PTS- L: 4.62 (2.49) vs. 4.35 (2.40)^{o} respectively. However, these differences did not achieve statistical significance ($p>0.05$).

The logistic regression model for multivariate analysis found that female gender (OR= 3.32, CI (1.24, 8.91)), increased medial meniscus cartilage height (OR=1.62, CI (1.10, 2.41)), and increased coronal lateral wall angle (OR=1.09, CI (1.02,1.18)) increases the odds of belonging to the ACL surgery group.

Increased BMI (OR=0.92, CI (0.86,0.99)), increased lateral meniscus bone angle (OR=0.90, CI (0.83, 0.97)), increased lateral meniscus cartilage height (OR=0.55, CI (0.37, 0.79)), and increased femoral notch width (OR=0.78, CI (0.66,0.91)) decrease the odds of belonging to the ACL surgery group.

DISCUSSION AND CONCLUSION:

There are significant anatomical differences in young patients suffering ACL injury compared to matched controls. Patients with ACL injury have a significantly reduced lateral meniscus cartilage height and bone angle as well as femoral notch width index. Correspondingly, an increased medial meniscus cartilage height and increased coronal lateral wall angle have a 1.62 and 1.09 increased odds ratio of ACL injury compared to matched controls. Increased medial and lateral posterior tibial slope was noted in the ACL tear group, but did not achieve statistical significance. Recognizing these anatomic variations preoperatively may be important to stratify risk for ACL injury before participation in at-risk sports, and prompt consideration for extra-articular augmentation for those patients who undergo ACL reconsideration.