Intercondylar Notch Width and ACL Cross-Sectional Area Predict Peak ACL Strain

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INTRODUCTION

Femoral notch morphology has been implicated as an important factor in anterior cruciate ligament (ACL) injury [1]. A smaller intercondylar width has been associated with ACL impingement [2] and smaller ACL size [3]. While ACL cross-sectional area has been correlated with peak ACL strain [4], the relationship between intercondylar width and ACL strain remains unknown. We correlated four measurements of intercondylar notch width, along with ACL cross-sectional area, to peak ACL strain during an in vitro simulated pivot landing. Our hypothesis was that peak ACL strain would be significantly correlated with both intercondylar width and ACL cross-sectional area.

METHODS

Twenty-two cadaveric lower extremities (13 females, mean (SD) age 60(16) yrs; height 171(9) cm; weight 69(6) kg) were acquired and MR scanned (3T Phillips Scanner, T2-weighted; field of view 160 mm; slice thickness: 0.7 mm). The MR scans were reconstructed using OsiriX (version 3.9.1) in order to acquire an oblique-coronal view of the ACL. Four measurements were taken across the femoral notch, at the levels of the superior ACL insertion, mid-ACL insertion, inferior ACL insertion, and anteromedial femoral ridge [5] (Fig. 1). These measurements were aligned parallel to the inferior borders of the femoral condyles. ACL cross-sectional area was measured at 30% ligament length from the tibial insertion, using an oblique axial view of the ligament [4].

Following MR scanning, the knees were dissected, leaving the ligamentous knee structures and the tendons of the quadriceps, hamstrings and gastrocnemius muscles intact. The specimens underwent five simulated pivot landings, consisting of a two body weight impulsive compression, flexion and internal tibial torque, peaking at 60 ms (Fig. 2) [4]. Five pre-baseline and post-baseline trials of 2×BW compression + flexion served as a check on ACL integrity following the simulated pivot landing. The knee had an initial knee flexion angle of 15° prior to each trial. Muscle resistances to stretch were simulated using custom springs. Peak relative strain in the distal 3rd of the anteromedial bundle of the ACL (‘AM-ACL’) was measured using a DVRT (Microstrain, Burlington, VT). A stepwise multiple linear regression compared the peak AM-ACL relative strain during a simulated pivot landing to the four femoral notch width measurements and ACL cross-sectional area. P<0.05 was considered significant.

RESULTS

Inferior ACL insertion intercondylar notch width (mean ± SD: 1.90 ± 0.27 cm; β = -0.378, p = 0.05, Fig. 3) and ACL cross-sectional area (29.7 ± 8.7 mm²; β = -0.457; p = 0.021) were significant predictors of peak AM-ACL relative strain ($R^2 = 0.516$, p = 0.001). Intercondylar notch widths of the superior ACL insertion (2.15 ± 0.16 cm), mid-ACL insertion (2.02 ± 0.16 cm) and anteromedial femoral ridge (1.74 ± 0.47 cm) were excluded from the regression model. Inferior ACL insertion intercondylar notch width explained 47% of the variance in the regression model and ACL cross-sectional area explained 53% of the variance. Inferior ACL insertion intercondylar notch width was correlated with ACL cross-sectional area (p = 0.477, p = 0.025).

DISCUSSION

Patients with ACL injuries have previously shown narrowed intercondylar widths at the level of the anteromedial femoral ridge [5] and the superior ACL insertion [1] when compared to uninjured controls. Our study demonstrates that only the intercondylar width at the level of the inferior ACL femoral insertion has a significant impact on ACL strain. If the narrowed intercondylar width was causing ACL impingement, we would expect to see a significant correlation between ACL strain and intercondylar width at the level of the anteromedial femoral ridge, where the notch is narrowest. The level of the inferior ACL insertion lies close to the midpoint of the femoral notch, suggesting this measurement may be a good surrogate of overall femoral notch size. A smaller inferior ACL insertion notch width may be predicting greater ACL strain due to the presence of a smaller ACL within the notch, rather than ACL impingement within the notch.

SIGNIFICANCE

This is the first study to examine the relationship between intercondylar notch width and ACL strain, and strengthens the use of intercondylar width as a potential screening measurement for ACL injury risk.

ACKNOWLEDGEMENTS

Mrs. Suzan Lowe, Dr. Catherine Brandon, PHS grant R01 AR054821

REFERENCES