ACL SAGITTAL PLANE ANGLE AND ITS RELATIONSHIP TO GENDER

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**INTRODUCTION**

Anterior cruciate ligament (ACL) injuries are extremely common and result in long-term consequences ranging from lost ability to participate in sports to osteoarthritis [1]. Of particular concern is the significant gender disparity in non-contact ACL injury incidence [2]. Many different factors have been examined to understand the mechanism of injury and difference in injury rates between men and women, including both intrinsic anatomic [3,4] or hormonal factors [5] and extrinsic neuromuscular factors [6,7]. While anatomic gender differences in the ACL length and cross-sectional area have been observed [3], the relationship between the orientation of the ACL itself and gender has not been examined.

The orientation of the ACL may affect the strain and force distribution it experiences when the knee is loaded during movements associated with non-contact ACL injuries such as a single-leg landing or a “plant and cut”. To date, studies reporting the sagittal plane orientation of the ACL have not distinguished male and female subjects, showing an average angle for the general population with respect to horizontal of 52-56° [8,9]. If differences in the orientation of the ACL exist between genders, then the ACL orientation could potentially provide a factor predisposing females involved in sports activities to injury. This study tested the hypothesis that healthy female knees have a different sagittal plane ACL angle than healthy male knees.

**METHODS**

88 subjects participated in this study after providing IRB-approved informed consent. One healthy, uninjured knee was analyzed from 37 female subjects (36.3 ± 12.2 yrs) and 51 male subjects (34.1 ± 9.5 yrs). Sagittal-plane 3D-SPGR MR images were taken with the subjects lying supine and knee fully extended. For each subject, two investigators were averaged together and the averaged orientation angle was calculated. For each subject, two investigators independently measured the angle of the anteromedial bundle of the ACL with respect to the transverse plane (Figure 1). The measurements of the two investigators were averaged together and the averaged measurements were used for statistical analysis.

![Figure 1](Image)

Figure 1. Sagittal plane ACL orientation measurement from 3D-SPGR MRI.

An unbalanced two-sample Student t-test (α=0.05) was used to examine the differences in sagittal plane orientation angle between sexes. Inter-observer reliability was assessed by calculating the correlation coefficient between the investigators’ measurements.

**RESULTS**

The average ACL orientation was 54.9± 4.4° (mean±SD) for females and 50.9 (± 5.3°) for males (Figure 2). The difference in average ACL orientation between females and males was statistically significant (p<0.001). Inter-observer reliability showed good agreement between the two investigators (Average Measure Reliability ICC = 0.92) [10].

![Figure 2](Image)

Figure 2. Box and whisker plots showing the distribution of sagittal plane ACL orientation angles in the female (n=37) and male (n=51) subjects. Females (54.9 ± 4.4°) had a significantly larger average ACL orientation angle than males (50.9 ± 5.3°). Whiskers represent 1.5 x interquartile range (75th percentile – 25th percentile).

**DISCUSSION**

This study has shown that healthy female knees have an intrinsically different anatomic orientation of the ACL in the sagittal plane when compared to healthy male knees. This ACL orientation difference may be an important factor influencing the ligament’s response to tibiofemoral loads and could possibly be a factor in the gender-based injury disparity. The results of this study indicate that women have more vertical orientation of the ACL than men (54.9° vs. 50.9°). One possible consequence of a more vertical ACL orientation is that greater ACL tension is required to constrain anterior tibial translation under an applied anterior tibial load [11]. Thus, a more vertical orientation of the ligament may be less efficient in resisting an anterior tibial load than a more horizontal ACL and could be a risk factor for ACL rupture.

One potential limitation of this study was the fact that ACL orientation was measured relative to the transverse plane rather than relative to the tibial plateau (Figure 1). However, the results for ACL orientation using this technique compared very favorably to those of other studies that examined the sagittal angle of the ACL with respect to the tibial plateau [8,9].

If the injury disparity between sexes is indeed multifactorial as the current literature suggests, the results of this study indicate that the ACL orientation may provide additional insight into the gender differences. Moreover, the current study only measured the sagittal plane angle of the ACL, quantifying the 3-dimensional orientation of the ligament could provide additional information since the ACL resists tibiofemoral loads in all three anatomic planes. Taking these facts into consideration, future observation studies and simulations should investigate the relationship between the differences in ACL orientation and the observed increase in female injury incidence.

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**REFERENCES**