The Effect of Dynamic Valgus Knee Position on ACL Length

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Introduction

Anterior cruciate ligament (ACL) rupture is a common problem in young and active populations. While ACL reconstruction improves knee stability so that patients can return to sport, its ability to mitigate the development of osteoarthritis is less certain. Accordingly, recent studies have focused on reducing the number of ACL injuries by identifying the underlying mechanisms so that appropriate prevention programs can be designed.

Several risk factors have been linked to ACL injury. The most common include cutting and jump landing activities with the knee in or near extension. While there is agreement on this factor, there are conflicting thoughts on the role of the valgus collapse phenomena often visible during videographic analysis. With prevention programs showing varying levels of success and non-contact injury rates remaining high, the role of both ACL injury mechanisms needs to be further evaluated.

The objective of this study was to evaluate the ACL length in a model that mimics low flexion and dynamic valgus positions thought to occur at the time of ACL rupture. Length was measured since it is proportional to strain, a critical parameter for predicting ACL failure.

Materials and Methods

The knees of seven male subjects (27.9 ± 5.4 years) with no history of knee injury were imaged using a 3-T magnet (Trio Tim, Siemens). MR images at 1 mm intervals were acquired using a double-echo steady state sequence (DESS, spatial resolution: 0.3x 0.3x1mm³, flip angle: 25°, TR: 17ms, TE: 6ms). These images were used to trace outlines of the femur and tibia in the sagittal and coronal planes. The outlines were then used to create 3D models of the knee bones and the ACL attachment as described and validated previously. A joint coordinate system was also included on each bone model for later kinematic analysis. Next, each volunteer was imaged with biplanar fluoroscopy (BV Pulsera, Philips). The following knee positions were captured during the test sequence (Figure 1): full extension (FE), 30° of flexion, and 30° of flexion with 10° of external rotation of the tibia and internal rotation at the hip to simulate a dynamic valgus landing position.

The fluoroscopic images were imported into solid modeling software (Rhinoceros, Robert McNeel and Associates) to recreate the test conditions virtually. The 3D knee model was then imported into this virtual test environment and moved until the projections of the model in both orthogonal planes were matched to the fluoroscopic images. For all positions, the ACL length was calculated as the distance between the area centroids of the femoral and tibial ACL attachment sites. Coronal plane angle (CPA) was measured as the angle between the projection of the long axis of the femur onto the long axis of the tibia. Varus-valgus (V/V) was measured as the change in angle between the long axis of tibia and transepicondylar line of the femur, with a right angle between these two axes corresponding to 0° V/V. A repeated measures ANOVA and Student-Newman-Keuls post-hoc test was used to detect statistically significant differences in ACL length at each of the three knee positions.

A paired Student’s t-test was used to detect differences between CPA and V/V angles at 30° of flexion and the dynamic valgus position. Differences were considered statistically significant where p<0.05.

Results

The average flexion angles measured at the three different positions were: -6.4 ± 7.3° (mean ± SD) for FE, 30.5 ± 6.4° for 30° of flexion, and 30.0 ± 6.9° for the dynamic valgus position. The average ACL length significantly decreased from FE to 30° of flexion (Figure 2). In addition, ACL length further decreased in the dynamic valgus position (p<0.05). The CPA and V/V angle were both slightly varus at 30° of flexion (Table 1). The CPA was significantly different (p<0.05) from the V/V angle in the dynamic valgus position, while no significant differences were detected between the CPA and V/V angle at 30° of flexion.

Discussion

Similar to previous studies, this study showed ACL length decreased from FE to 30° of flexion. Interestingly, the ACL further shortened in the dynamic valgus position. This decrease demonstrates that ACL length, and therefore ACL strain, decreases with flexion. These data suggest that, in male athletes, landing in extension is potentially a more important risk factor than landing in a position of dynamic valgus. However, further investigation is needed to confirm these results under dynamic loading conditions. In addition, a significant difference was detected between the CPA and V/V, suggesting that visually determined valgus angles in the coronal plane do not necessarily translate into valgus experienced at the joint level. Future studies will investigate the effects of the dynamic valgus position on ACL length in females to provide insight into the effects of sex differences in ACL injury mechanisms.

Table 1. Mean and standard deviations for coronal plane angle and varus-valgus angle in full extension (FE), 30° of flexion, and in the dynamic valgus position at 30° of flexion. Positive varus-valgus angle indicates a valgus orientation. In the dynamic valgus position, coronal plane angle and varus-valgus angle were significantly different (p<0.05).

References


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