SAGITTAL PLANE BIOMECHANICS DURING SPORT MOVEMENTS DOES NOT EXPLAIN HIGHER INCIDENCE OF ACL INJURY IN FEMALES

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INTRODUCTION

Anterior cruciate ligament (ACL) injury is a common and traumatic sports injury, particularly for females. Female neuromuscular control patterns can contribute to their increased risk of ACL injury. For example, women tend to land in a more extended (hip and knee) position than men (e.g. Malinzak et al., 2001). This places the patellar tendon in a more anterior orientation (Herzog and Read, 1993), which is theorized to increase the amount of quadriceps-induced ACL force, and thus contribute to ACL injury (DeMorat et al., 2004). During athletic movements, however, the quadriceps and ground reaction forces are not independent of flexion angle, or of each other, which is ignored in this theory. The current study quantified the contributions of gender specific sagittal plane knee biomechanics to the force in the ACL during an athletic movement linked to ACL injury.

METHODS

Ten male and ten female NCAA basketball players had lower limb 3D kinematics and kinetics quantified during the stance phase of ten sidestep cutting maneuvers. A dynamic model of the pelvis and lower extremity was generated for each subject as described previously (McLean et al. 2003). Joint angles were obtained from Mocap Solver (Motion Analysis Corporation, Santa Rosa, CA) and intersegmental 3-D forces and moments at the knee were solved using standard inverse dynamics. Intersegmental loads were defined as components of external load on the joint, expressed in a joint coordinate system. Anterior tibial shear force (F_{ant}), external flexion (M_{flex}), valgus (M_{val}), and internal rotation moments (M_{int}) were used for further analysis. ACL force (F_{ACLsag}) due to the sagittal plane joint loading mechanism was estimated as:

$$F_{\mathrm{ACLsag}} = F_{\mathrm{ant}} + \left(\frac{M_{\mathrm{flex}}}{d(\theta)} \right) \times \sin \alpha(\theta) ,$$

where d is the moment arm of the patellar tendon as a function of knee flexion angle θ, and α represents the angle between the patellar tendon and the long axis of the tibia in degrees, also a function of knee flexion (Herzog and Read, 1993). This equation does not incorporate hamstring force contributions, and thus represents a worst-case scenario in terms of ACL injury risk during sidestepping. Peak joint loads, F_{ACLsag} and initial contact knee flexion data were obtained from each trial, averaged for each subject, and compared between genders using a Student t-test ($p<0.01$ after Bonferroni correction).

RESULTS AND DISCUSSION

Women landed with less initial knee flexion (Table 1), similar to previous observations (Malinzak et al., 2001). Significant gender differences were found in peak valgus moment only (Figure 2), which is consistent with data obtained via gender specific forward dynamic simulations of sidestepping movements (McLean et al., 2004). The sagittal plane loading mechanism failed to significantly load the ACL for either gender (Figure 1). In fact, the joint forces were mainly posterior, loading the PCL rather than the ACL. Females loaded the ACL during early stance, but the magnitude was much smaller than known failure loads. The closed-chain relationship between flexion angle, external ground reaction force, and quadriceps force appears to protect the ACL from excessive sagittal plane loading. Specifically, during early stance, the ground reaction force acts posteriorly on the tibia, protecting the ACL. Quadriceps force does not become large until later in stance, when the flexion angle is such that the patellar tendon orientation is no longer harmful.

Table 1: Peak load comparisons across gender (*p<0.01).

Variable	Male	Female
θ_{init} (deg)*	30.4 ± 3.6	24.0 ± 1.3
F_{ant} (N)	294.2 ± 126.3	194 ± 85
M_{flex} (Nm)	311.4 ± 84.4	282 ± 60
M_{val} (Nm)*	36.6 ± 12.2	70.0 ± 19.8
M_{int} (Nm)	31.7 ± 14.3	20.0 ± 16.2
F_{ACLsag} (N)	378 ± 173	287 ± 110

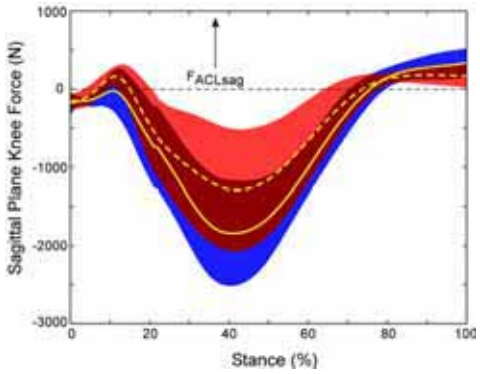

Figure 1: Male and female sagittal plane ACL force.

CONCLUSIONS

Gender differences in sagittal knee biomechanics do not alone explain the higher incidence of ACL injury in women. Gender differences observed in peak valgus moment add further support the evolving hypothesis that knee valgus is the primary extrinsic contributor to the female injury mechanism.

REFERENCES

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