TIBIAL SLOPE CORRELATIONS WITH PEAK KNEE JOINT LOADS AND ANTERIOR CRUCIATE LIGAMENT STRAIN DURING SIMULATIONS OF CONTROLLED ATHLETIC TASKS

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INTRODUCTION

Tibial slope has been identified as a non-modifiable risk factor for anterior cruciate ligament (ACL) injury as ACL injury patients exhibit higher tibial slopes than matched healthy controls.[1,2] Despite these findings, limited work has been done to assess how tibial slope affects ACL strain and joint loading during athletic tasks related to non-contact ACL injury. Recent advancements in robotic simulation have made it possible to create in vitro simulations of knee articulation using in vivo kinematics recorded from athletic tasks.[3] The purpose of this investigation was to quantify the influence of tibial slope on knee mechanics during an in vitro simulated drop vertical jump (DVJ). The primary hypothesis was that increased posterior tibial slope would be associated with increased knee loads in the frontal and sagittal planes.

METHODS

A 6-degree-of-freedom robotic manipulator articulated 18 cadaveric knees from 11 unique donors (age = 47.6 ± 7.3 years; mass = 829 ± 199 N) through simulations of kinematics recorded from in vivo DVJs.[3] DVJs from both male and female subjects were used to articulate separate simulations while forces and torques were recorded by a 6-axis force sensor that was aligned with the long axis of the tibia. A coordinate measuring device was used to digitize landmarks on the articulating surface of the tibial plateau at the anterior and posterior aspects of the midline in the medial tibial compartment as well as the lateral tibial compartment. These landmarks correspond with the points that were selected in previously documented methods of radiographic-based tibial slope calculation.[2] Posterior tibial slope was then calculated via these same previously published techniques using the points specified.[2] Pearson correlations were used to assess the significance of linear relationships between tibial slope and joint forces and torques. All torques are presented as internally-generated within the knee joint.

RESULTS AND DISCUSSION

During the simulated DVJs for both sexes, increased posterior tibial slope in the lateral compartment was significantly correlated with increases in peak knee adduction torque (female: $r = 0.65, P = 0.02$; male: $r = 0.60, P = 0.04$), peak knee flexion torque (female: $r = 0.64, P = 0.03$; male: $r = 0.66, P = 0.02$), and peak lateral knee force (female: $r = 0.69, P = 0.01$; male: $r = 0.57, P = 0.05$). During simulations of male DVJs, increased tibial slope in the lateral compartment corresponded with increased peak external rotation torque ($r = 0.72, P = 0.01$) and decreased peak internal rotation torque ($r = -0.79, P < 0.01$). Across sexes, increased posterior tibial plateau slope in the medial compartment was only correlated with an increase in peak knee flexion torque (male: $r = 0.69, P = 0.01$; female: $r = 0.64, P = 0.02$).

The data confirmed the a priori hypothesis that increased posterior tibial slope was associated with larger magnitudes of knee loading in directions that correspond with larger demand on the ACL. Previous investigations have shown that externally generated knee abduction, extension, and internal rotation torques strain the ACL or are associated with injury risk.[4-5] These degrees of freedom correspond with the internally generated torques documented in the present results. (Figure 1 & 2)
Figure 1: Significant correlations between posterior tibial slope in the lateral compartment and knee loading relative to the male DVJ.

Figure 2: Significant correlations between posterior tibial slope in the lateral compartment and knee loading relative to the female DVJ.

Published literature has traditionally shown that tibial slope in the lateral compartment is more closely related with ACL injury risk than the medial compartment.[1-2] These findings corroborate the present data, as only lateral compartment slope was correlated with the frontal and transverse plane torques most associated with altering ACL strain.

Athletes who land with greater knee extension and greater externally-generated knee extension torques increase strain on the ACL and are therefore more susceptible to injury. [6] The present data indicated that increased posterior tibial slope may drive this kind of loading in the knee as internally-generated flexion torques were moderately correlated with posterior tibial slope angle in both compartments.

It was surprising that tibial slope did not correlate with antero-posterior forces in either the male or female simulation. In vitro studies demonstrate that increased tibial slope generates anterior tibial translation and correspondingly anterior tibial force in the knee. [7] The present in vitro simulations are governed by recorded kinematics and a high-precision robotic arm.[3] Therefore, it is possible that the stiffness and precision of the manipulator only permitted minimal bone bending, despite anatomical differences, and inadvertently inhibited any antero-posterior shift that may otherwise be naturally induced with higher tibial slope.

CONCLUSIONS

Data from this investigation demonstrated that increased posterior tibial slope angle, especially in the lateral compartment, is correlated with increased knee joint loading during simulated landing in degrees of freedom that are known to place additional mechanical demand on the ACL. The mechanical data presented confirms that alterations in tibial slope angle have the potential to influence ligament loading; and thus, may be related to injury risk.

REFERENCES


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