KNEE LOADING PATTERNS THAT ENDANGER THE ACL: INSIGHTS FROM EXPERIMENTAL AND SIMULATION STUDIES

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INTRODUCTION

Over the past several decades, *in vivo* research addressing non-contact ACL injury mechanisms has been unable to directly examine motion of the tibiofemoral joint and the strain on the ACL during high-risk activities. Cadaver studies have attempted to identify the loading patterns that strain the ACL during such activity, but these studies are limited by practical considerations such as cadaveric tissue breakdown and experimental setup limitations.

Recent advances in measuring *in vivo* kinematics using the Point Cluster Technique (PCT) [1] now allow much more detailed examinations of the knee loading patterns and tibiofemoral motions that occur *in vivo* during high risk activities [2], and simulations of the tibiofemoral joint can be used to examine consequences of such loading patterns for ACL injury [3]. This talk will discuss the results of these techniques in improving our understanding of the ACL injury mechanism.

METHODS

Using the previously-described PCT we use an opto-electronic motion capture system to measure the 6 degree of freedom motion of the femur with respect to the tibia during activities of daily living. We have observed the anterior-posterior translation, internal-external rotation, and abduction/adduction of the knee joint during 90-degree sidestep cut and single-leg stopping maneuvers [2], as well as the net reaction forces and moments at the knee [4].

In addition, we have developed a specimen-specific simulation model of the knee built from MRI data and validated against experimental loading tests of cadaver specimens [3]. Using this model together with the physiologic loading observed during *in vivo* testing, we can estimate the strain in the bundles of the ACL to examine the relative importance of the different loading modes for the ACL injury [3,5,6].

RESULTS AND DISCUSSION

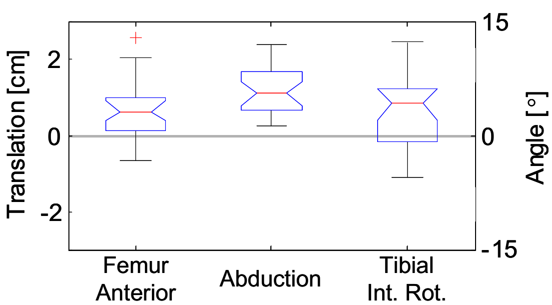

Figure 1. *In vivo* knee tibiofemoral displacement during first 100ms after foot strike during a run-to-stop maneuver.

In vivo testing using the PCT shows that anterior translation of the tibia does not occur in most subjects during single-limb landing. However, abduction and tibial internal rotation do occur in most subjects, suggesting that a mechanism involving abduction and tibial internal rotation may be the most relevant in understanding the ACL injury mechanism during these deceleration and change-of-direction activities. Joint reaction loads at the knee further support these conclusions because the external reaction force at the knee acts to push the proximal tibia in a posterior direction, while the reaction moment acts to push the tibia into abduction and internal rotation.

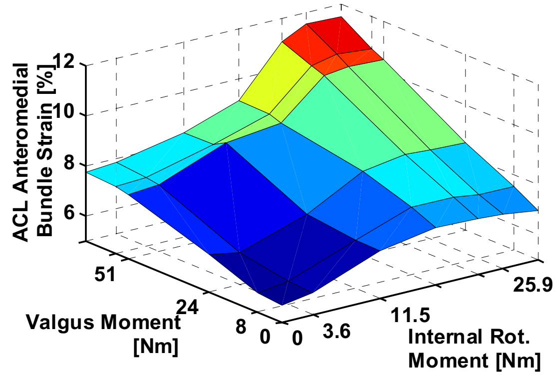

Figure 2. Response of ACL anteromedial bundle strain to applied valgus, internal rotation, and combined moments.

Applying the loading patterns observed *in vivo* to our simulation model shows the direct effects of these loads on ACL strain. Increasing the posterior force from zero to the maximum physiologically observed values reduces ACL strain. **This reduction in strain occurs even while the force in the quadriceps increases, because the force in the quadriceps is merely a reaction to the externally applied force.** In contrast, externally applied abduction and internal rotation moments result in increased ACL strains. The individual moments themselves do not appear large enough to cause rupture of the ACL, but when acting together combined abduction and internal rotation loading cause increased ACL strains that may be large enough to damage the ACL.

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