THE INFLUENCE OF INTERNAL AND EXTERNAL TIBIAL ROTATION OFFSETS ON KNEE JOINT AND LIGAMENT BIOMECHANICS DURING SIMULATED ATHLETIC TASKS

Nathaniel A. Bates\textsuperscript{a,b,c}, Rebecca J. Nesbitt\textsuperscript{b}, Jason T. Shearn\textsuperscript{b}, Gregory D. Myer\textsuperscript{a,c}, Timothy E. Hewett\textsuperscript{a,b,c}

\textsuperscript{a}OSU Sports Medicine Sports Health & Performance Institute, Ohio State University, Columbus, OH, USA
\textsuperscript{b}University of Cincinnati, Cincinnati, OH, USA
\textsuperscript{c}Cincinnati Children’s Hospital Medical Center, Cincinnati, OH, USA

email: batesna@gmail.com  website: http://sportsmedicine.osu.edu/

INTRODUCTION

Following anterior cruciate ligament (ACL) injury, transverse plane tibiofemoral rotation becomes underconstrained, while subsequent reconstruction leaves it overconstrained.[1,2,3] That ligament deficiency and repair cause alterations in the transverse-plane orientation of the tibiofemoral joint would suggest that the ACL is a mechanical restraint to knee motion within this plane. However, the effect of isolated internal tibial torques on knee loading has been evaluated via biomechanical testing and the current literature is conflicted.[1] The objective of this investigation was to determine the mechanical effects of transverse plane tibial rotation offsets on knee kinetics and ligament strains during in vitro simulations of in vivo kinematics recorded from athletic tasks.

METHODS

\textit{In vivo} kinematics were recorded for male and female athletic tasks using 3D motion capture. \textit{In vivo} kinematics were filtered and processed to be usable in robotic simulation.[4] 11 cadaveric lower extremities from 9 unique donors were obtained from an anatomical donations program and accepted for use in this study (age = 46.1 ± 7.7 years; mass = 861 ± 203 N). A six-degree-of-freedom robotic arm and custom mechanical fixtures were used to articulate each specimen through male- and female-specific simulations of recorded drop vertical jump (DVJ) and sidestep cutting tasks. The robotic manipulator then applied isolated ±4° rotational offsets to the tibia in the transverse plane and rearticulated the same kinematic simulations. Throughout each simulated articulation, joint forces and torques were recorded by a six-axis load cell aligned with the long axis of the tibia and ligament strains were recorded by differential variable force transducers implanted on the ACL and MCL. Each motion condition was analyzed individually with a 3x1 ANOVA with Bonferroni post-hoc analysis was used to determine significantly different (\(\alpha < 0.05\)) forces, torques, and strains between each of the three simulation offset conditions.

RESULTS AND DISCUSSION

Transverse plane rotational offsets had a significant effect on peak posterior force for female motion simulations (\(P < 0.01\)), on peak lateral force for most simulated tasks (\(P < 0.01\)), and on peak anterior force, internal torque, and flexion torque for sidestep cutting tasks (\(P \leq 0.01\)). Rotational offsets did not influence significant differences on peak ACL strain (\(P > 0.05\)) or MCL strain (\(P > 0.05\)) for any task (Figure 1). With that consideration, during the sidestep cutting tasks, the peak magnitude of ACL strain did increase linearly as the initial orientation offset orientation shifted from and externally rotated to internally rotated position. A similar linear, but non-significant, change in peak MCL magnitude was noted. Transverse plane rotational offsets comparable to those observed in ACL deficient and reconstructed patients alter knee kinetics without significantly altering ACL strain.

Internal and external tibial rotation offsets were able to effect significant changes on the loading profile at the knee joint without effecting significant changes on ACL strains. A 4° internal offset did generally increase the peak ligament strain; however, the magnitude of this change was not great enough to be statistically significant.
Kinematic changes following ACL-deficiency and ACL-reconstruction imply that the ACL has an important role in transverse plane stabilization of the knee.[2,3] However, the present results indicate that the role of the ACL in this regard is limited. Not only did magnitude changes in ACL strain lack statistical significance (1.1% mean increase for internal offset; -1.9% mean decrease for external offset), but the peak strains achieved were approximately half of previously reported failure values in the ACL.[5]

ACL reconstructions may overconstrain the joint as reconstructed patients have demonstrated 4° greater external tibial rotation during gait than healthy controls.[3] Similarly, the magnitude of mean ligament force in reconstructed ACLs can often exceed that of the native ligament tissue. [1] In the present study, ACL strain magnitudes were generally smaller in the 4° externally rotated offset condition. Therefore, it is conceivable that this external offset induced by ACL reconstructions would stress shield native ACLs from natural loading.

CONCLUSIONS

As knee degeneration is attributed to abnormal loading profiles, altered transverse plane kinematics may contribute to this. However, the data demonstrated that transverse plane perturbations on the magnitude of those applied in the present investigation likely play a limited role in ACL loading. These physiologic offsets failed to significantly influence ACL strain during tasks commonly associated with ligament loading.

REFERENCES


ACKNOWLEDGEMENTS

Funding from NIH Grants R01-AR049735, R01-AR05563, R01-AR056660, and R01-AR056259.