Sex Differences in Unconstrained Transverse Plane Kinematic Response Under Compression and Simulated Muscle Forces

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ABSTRACT

In vitro biomechanical experiments provide valuable insight into the responses of biological structures to applied loads and motions. In the human knee, a number of researchers have employed cadaveric techniques to elucidate the roles of passive and active restraints under simple and complex conditions. Several researchers have espoused the theory that increased posterior slope on the medial and lateral tibial plateau in females contributes to increased risk of anterior cruciate ligament injury. However, few in vitro biomechanical studies take the differences between male and female bone geometry into consideration when selecting specimens and reporting results. The purpose of this study was to examine sex differences in unconstrained kinematic response to simulated muscle forces and compressive loads. We hypothesized that the transverse plane kinematic response between males and females would differ as a compressive load across the knee joint was added to simulated muscle forces. Sixteen cadaveric limbs (10 female age 45.7±9.3, 6 male age 41.5±7.1) were sectioned at the femoral midshaft and the proximal end of the femur was potted in a polyester resin. The potted end was rigidly fixed in a custom 6 axis load cell, inside of a force couple testing system (FCTS). Tibiofemoral and patellofemoral kinematics were captured using an OptoTrak 3020 System (Northern Digital, Waterloo, Ontario, Canada). After capturing the neutral position, simulated muscle loads were applied to the hamstrings and quadriceps tendons. Limbs were tested through 90 degrees of flexion under simulated muscle load, and under simulated muscle load with an added 134 Newton compressive joint force applied. Significant sex by knee flexion angles were observed for both the simulated muscle condition ($p=0.024$) and the muscle + compression condition ($p=0.007$). Figure 1a shows that for the muscle load only condition, males and females progressed from a neutral transverse plane alignment toward greater internal rotation for the first 45 degrees of flexion. From 45 to 90 degrees of flexion the degree of internal rotation reduced, with males exhibiting primarily external rotation at high flexion. In the compression condition (Figure 1b), males moved from a neutral condition to internal rotation from 0 to 20 degrees of flexion, after which internal rotation decreased until 50 degrees of flexion where external rotation was observed. Females however, continued to exhibit greater internal rotation angles until 35 degrees of flexion after which they gradually returned to a neutral rotation angle at 90 degrees of flexion. The current study demonstrates that the unconstrained kinematics differ between sexes under identical loading. Interestingly, males reached their peak internal rotation at lower flexion angles and demonstrated less peak internal rotation than females. Furthermore, this data shows that joint compression and knee flexion angle affect the transverse plane response of cadavers. This may impact the strains and loads in soft tissue knee structures such as the anterior cruciate ligament (ACL) during simulated injury studies. The interactions observed indicate that sex effects multiplanar unconstrained kinematics. Future research should consider the inherent effects of sex on kinematic response when designing in vitro biomechanical studies.