PASSIVE KNEE JOINT PROPERTIES IN TIBIAL ROTATION IN MEN AND WOMEN

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INTRODUCTION

The anterior cruciate ligament (ACL) is an important structure for controlling knee joint movement and maintaining stability. The incident rate of ACL injury is two to eight times higher in women than in men [1]. ACL impingement against intercondylar notch during excessive tibial external rotation and abduction has been considered as a main mechanism of ACL injury, especially in women [2]. On one hand, the intercondylar notch geometry ("narrower", loosely speaking) makes it more likely for female knees to have ACL impingement than male knees [2]. On the other hand, women may have larger laxity in tibial rotation and abduction than men, which also makes it more likely for women to have ACL impingement than men under the same knee loading. The purpose of this study was to evaluate passive knee joint properties in tibial rotation in male and female subjects.

METHODS

The subjects (5 men and 5 women) were seated in a custom designed joint driving device (Fig. 1). The knee and hip flexion angles were 60° and 80°, respectively. The ankle was cast in the neutral position and coupled to one end of an L-shaped aluminum angle located distal and posterior to the foot-ankle cast. The L-shaped attachment was mounted onto the motor shaft through a six-axis force sensor.

To measure tibial rotation, LED markers were attached on the bony and flat anteromedial surface of the tibia, and the 3-D movements of the markers were measured by an Optotrak system at 100 Hz. The femur was fixed by clamping the lateral and medial femoral condyles to the seat (Fig. 1).

The zero tibial rotation was taken with the second toe pointing forward. With the position and torque limits set at the internal and external directions, the motor rotated the tibia at the constant speed of 1.5 deg/sec within the limits.

Joint laxity in tibial rotation is measured in two ways: 1) terminal rotation measured at 7Nm torque, and 2) intermediate rotation measured at the slope of 2 deg/Nm [3]. Joint stiffness and energy loss in tibial rotation were measured at 15 degree rotation (shaded area in Fig. 2).

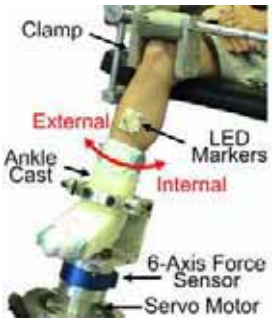

Figure 1: Experimental setup for knee axial rotation. The servo motor rotates the knee about the tibial long axis with the six-axis forces/moments measured by the JR3 force sensor. The ankle was cast for tight coupling. Optotrak markers on the flat tibia surface measure the angle of tibial rotation.

RESULTS AND DISCUSSION

Under the controlled load, women showed significantly higher laxity in tibial external rotation with larger terminal rotation (31.9±4.2° vs 19.5±2.2°, P=0.001) and larger intermediate rotation (28.1±4.2° in women vs 15.5±2.4° in men, P=0.001). Women also showed lower joint stiffness in external rotation (31.9±13.1Nm/rad vs 47.5±6.68Nm/rad in men, P=0.028). In contrast, there was no difference in the passive knee properties in tibial internal rotation between the men and women.

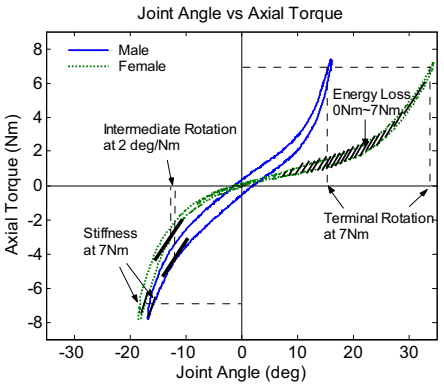

Figure 2. Typical tibial rotation torque-angle relationship in a man (solid blue line) and a woman (dotted green). Intermediate rotation at 2deg/Nm, terminal rotation at 7Nm, stiffness and energy loss at 7Nm are shown.

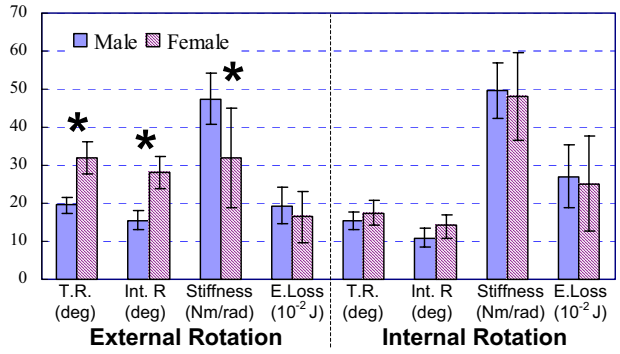

Figure 3.Passive knee joint properties in tibial rotation in men and women.

CONCLUSIONS

With the narrower notch and larger laxity in tibial external rotation, female knees are more prone to having ACL impingement and thus ACL injury. This study presents an in vivo and accurate characterization of knee biomechanical properties in tibial rotation in men and women, which may help us understand the mechanisms underlying the several fold higher ACL injury rate in women than in men. Clinically, rehabilitation protocols may be developed accordingly to strengthen muscles crossing the knee and modify joint properties in tibial external rotation, especially in women, to reduce ACL injuries.

REFERENCES

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