Evaluating In Vivo Rotational Knee Kinematics in ACL Ruptured and Healthy Patients Using 3.0 Tesla Magnetic Resonance Imaging

+1Haughom, B; 1Souza, R B; 1Schairer, W; 1Hovis, K; 1Li, X; 1Ma C B  
+1University of California San Francisco, San Francisco, CA,  
MaBen@orthosurg.ucsf.edu

Introduction:
It has long been established that the ACL plays a role in control of anterior-posterior (AP) kinematics of the knee. (1) Reconstructive techniques have been effective at controlling AP translations. (2) However, it has been shown the ACL also plays a role in control of axial rotations about the knee. (3) Abnormal tibial rotation following ACL injury may lead to early cartilage degeneration. (4) Unfortunately, current tools to quantify rotational knee kinematics are limited, as they rely upon indirect measures of joint motion. Magnetic resonance (MR) kinematics is a proven technique that provides a means to quantify in vivo kinematic of the soft tissue as well as the bony structures of the knee. (5) Combining advanced MR kinematic techniques with in-house developed rotational loading device, we have developed a novel way to quantify rotational knee stability. The objective of this study was to evaluate rotational stability of the knee in ACL deficient patients as well as a control cohort. Moreover we aimed to investigate differences in tibial rotation between genders.

Methods:
Sixteen healthy (8 men, 26.8 ± 6.4 years; 8 women, 26.9 ± 3.8 years) and ten ACL deficient (5 men, 33.6 ± 10.5 years; 5 women, 36.3 ± 10.7 years) subjects received bilateral knee MR scans at 15° flexion. Patients were imaged with a 3.0 Tesla MR scanner (GE Healthcare) using an 8-channel knee coil. We utilized a custom built, MR-compatible, device which applied internal/external torques (3.35Nm) as well as an axial compressive load (44N). (Figure 1) The rotational loading device was made from a standard orthopaedic walking boot mounted onto a 30 cm rotating platform. (Figure 2) The rotational loading device was connected to both an axial compressive load as well as the rotational load. Fast spin echo (FSE; TR/TE = 4000 ms / 50.96 ms, FOV = 16cm, 512 x 256 matrix, slice thickness of 1.5 mm) images were acquired in both internal and external rotation positions. Using in-house software, the images were segmented semi-automatically and analyzed in order to calculate the arc of tibial rotation (TR) between the internal and external rotation positions. For reproducibility measurements, six knees were scanned twice on separate days. Group comparisons were made with unpaired t-tests, while intra-subject comparisons were made using paired t-tests.

Results:
Healthy women had more TR than men. Moreover, healthy women had more external rotation than men (8.2° ± 4.6° vs. 2.0° ± 3.57°; p<0.01) while there was no difference observed in internal rotation. ACL deficient knees in men showed more tibial rotation than their contralateral leg and healthy control men. ACL deficient women showed more tibial rotation in their injured leg relative to their contralateral leg, however they did not show more tibial rotation compared to the control women. The intraclass correlation coefficient [ICC(2,1)] of the TR measurement was 0.913 and the SEM=1.1°.

Table 1 An asterisk (*) denotes statistically significant (p < 0.01) differences between men and women in the control group. A cross (†) denotes statistically significant (p < 0.01) differences between the ACL Deficient and contralateral leg in the male patients. Double asterisks (**) denotes statistically significant (p < 0.01) differences between the ACL Deficient and contralateral leg in the female patients, while double crosses (††) denotes statistically significant (p < 0.01) differences between the injured knee in the ACL deficient male cohort compared to the control men.

<table>
<thead>
<tr>
<th>Tibial Rotation (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Men</td>
</tr>
<tr>
<td>Control Women</td>
</tr>
<tr>
<td>ACL Deficient Men</td>
</tr>
<tr>
<td>ACL Deficient Men –Uninjured Leg</td>
</tr>
<tr>
<td>ACL Deficient Women</td>
</tr>
<tr>
<td>ACL Deficient Women –Uninjured Leg</td>
</tr>
</tbody>
</table>

Discussion:
Using MR kinematics in conjunction with our novel rotational loading device, we have developed a unique and reliable method (SEM 1.1°) to quantify in vivo rotational knee kinematics. In a healthy cohort of patients, women appear to have more rotational laxity than men, particularly in the external rotation position. The finding that women have greater external rotation may help explain their increased risk of ACL rupture. Moreover, our data suggests that ACL rupture appears to increase the overall rotational laxity of the knee in both men and women. We feel that this new technique represents an exciting new method of objective evaluation of rotational knee kinematics, which may be applied to clinical evaluations. This technique is currently being applied to the same cohort of patients who have subsequently undergone ACL reconstruction, in order to evaluate the rotational stability following surgery.

References:

Acknowledgement:
This research was supported by NIH/NCRR/OD UCSF-CTSI Grant Number TL1 RR024129 and the UCSF Sports Medicine Research Fund.