LIMITED FEMORAL INTERNAL AXIAL ROTATION INCREASES ACL STRAIN DURING A CADAVER-SIMULATED PIVOT LANDING

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INTRODUCTION

A better understanding of the mechanism of anterior cruciate ligament (ACL) injuries is needed to improve prevention strategies and reduce the enormous health and financial burden of these injuries [1,2]. While many factors contributing to injury risk have been investigated, attention has mostly focused on the knee. However, the mechanics of the hip may also contribute to injury risk. For example, restricted passive range of internal rotation at the hip (e.g., femoroacetabular impingement) has been correlated with ACL ruptures in soccer players [3]. It is unknown, however, how limited hip internal rotation increases ACL injury risk. So, we hypothesized that during ‘risky’ athletic maneuvers, ACL strain increases with the amount of femoral internal axial rotation restriction. We tested this hypothesis in a cadaver model simulating a single-leg pivot landing.

METHODS

Six human knee specimens were harvested from one female and two male donors (age: 55.7 ± 1.4 years; height: 1.70 ± 0.14 m; mass: 73.5 ± 13.0 kg). Each specimen was dissected, leaving the joint capsule, including the ligamentous structures, intact, as well as the tendons of the quadriceps, medial and lateral hamstrings, and medial and lateral gastrocnemii.

Each knee specimen was mounted in a modified version of the Withrow-Oh testing apparatus [4] in 15° of flexion (Fig. 1). As previously described [4], this custom-built apparatus simulates a single-leg pivot landing task by impacting the distal end of the tibia of the inverted knee specimen. An impulsive force induces a compression force, knee flexion moment, and internal tibial torque. A novel addition to the apparatus was a femoral rotation device (‘R’, Fig. 1) able to limit the range of femoral axial rotation. This device comprised a circular plate able to rotate in the transverse plane on a tapered-roller bearing and two pre-tensioned springs attached tangentially to the perimeter of the plate via aircraft cables. Muscles were simulated by pretensioned elastic structures connected to the tendons. Strain of the anteromedial bundle of the ACL (AM-ACL) was recorded with a DVRT (MicroStrain, Burlington, VT) at 2 kHz. An opto-electric imaging system (Optotrak Certus, NDI, Waterloo, ON) recorded tibiofemoral kinematics at 400 Hz via diode triads secured to the femur and the tibia.

In each trial, an impulsive force of two-bodyweights was applied. Each testing session began with five preconditioning trials, followed by five blocks of six trials in an ‘A-B-C-D-A’ design (Table 1).

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Loading Condition</th>
<th>Femoral Rotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>comp + flex m</td>
<td>≈ 0°</td>
</tr>
<tr>
<td>B</td>
<td>comp + flex m + int tib trq</td>
<td>≈ 5°</td>
</tr>
<tr>
<td>C</td>
<td>comp + flex m + int tib trq</td>
<td>≈ 10°</td>
</tr>
<tr>
<td>D</td>
<td>comp + flex m + int tib trq</td>
<td>≈ 15°</td>
</tr>
<tr>
<td>A</td>
<td>comp + flex m</td>
<td>≈ 0°</td>
</tr>
</tbody>
</table>

comp: compression force; flex m: flexion moment; int tib trq: internal tibial torque; R: randomized sequence.
To limit femoral internal axial rotation, the femoral rotation device was either locked (block ‘D’) or resisted by high stiffness (block ‘C’) or low stiffness (block ‘B’) springs.

Peak AM-ACL relative strain and peak relative anterior tibial translation were compared between femoral rotation conditions via two linear mixed models, with femoral internal axial rotation magnitude treated as a fixed effect and knee specimen and donor as random effects. An α < 0.05 was taken to indicate statistical significance.

RESULTS AND DISCUSSION

As the available range of femoral internal axial rotation was decreased, both peak AM-ACL relative strain and peak relative anterior tibial translation increased significantly during the simulated pivot landings (Fig. 2). On average, AM-ACL relative strain increased 36% when the range of femoral internal axial rotation was decreased 10° (from large to small femoral rotation); whereas anterior tibial translation increased 22%. Smaller but significant increases in these variables also occurred with 5° of decreased femoral internal axial rotation.

Differences in peak AM-ACL relative strain between femoral rotation conditions can be explained by the compensatory differences in tibial internal axial rotation. As the range of femoral internal axial rotation was progressively limited, the range of tibial internal axial rotation increased (Fig. 3). Given that tibial internal axial rotation is known to strain the ACL during pivot landings [4], it is likely that this increase in axial rotation at the knee joint caused the increase in ligament strain. These results present a plausible explanation as to why athletes with limited range of hip internal rotation are at greater risk of ACL injuries [3].

CONCLUSIONS

A restriction of femoral internal axial rotation increases peak AM-ACL relative strain and relative anterior tibial translation during simulated pivot landings.

REFERENCES


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