Hamstring Strength Deficits Three Years after Anterior Cruciate Ligament Reconstruction in Individuals with Hamstring Autografts Alter Knee Mechanics during Gait and Jogging

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INTRODUCTION
Anterior cruciate ligament reconstruction (ACLR) using hamstring tendon autografts may result in hamstring muscle weakness in the involved limb [1]. Altered mechanics are also observed during gait and jogging following ACLR for up to two years [2]; however, to our knowledge, the impact of hamstring strength asymmetry on involved limb gait mechanics has not been reported. The purpose of this preliminary study was to test the hypothesis that individuals with hamstring strength asymmetry would demonstrate altered involved limb knee mechanics during walking and jogging compared to those with symmetric hamstring strength two years after ACLR with hamstring tendon autograft.

METHODS
Participants (n=40; age=22.7; 21F/19M) were a subset of individuals that participated in the Multicenter Orthopaedic Outcomes Network (MOON) ACLR Two-Year Follow-up cohort. All participants had undergone a primary, unilateral ACLR with hamstring tendon autograft at least 2 years prior (mean=34.5mo.; range=27.9-42.7mo.). Hamstring strength was quantified as peak isometric knee flexion torque on an isokinetic dynamometer (Biodex) at 60° knee flexion. Limb-symmetry indices (LSI) were calculated for isometric hamstring strength using: LSI=[involved value/uninvolved value]. Hamstring strength LSI were used to divide the participants into a symmetric hamstring strength (SH) group (LSI≥0.90) and a weak involved limb hamstring (WH) group (LSI<0.85)[3], resulting in 18 participants per group. 4 individuals had LSI from .85-.90 and were not included due to small group size. Involved knee mechanics were quantified by tracking 46 retroreflective markers using a 10-camera three-dimensional motion analysis system (Vicon Nexus; 300 Hz) during walking and jogging across embedded force plates (Bertec; 1500 Hz). Visual3D software was used to calculate peak sagittal, frontal, and transverse plane knee kinematics, moments, and powers during each phase of walking and jogging. Gait phases included initial contact, weight acceptance (initial contact to peak knee flexion), mid-stance (peak knee flexion to peak knee extension), push-off (peak knee extension to toe-off), and toe-off. Jogging phases included initial contact, weight acceptance, push-off (peak knee flexion to toe-off), and toe-off. Marker trajectories and force-plate data were filtered with a low-pass Butterworth filter at 6 Hz. Joint moments and powers were normalized by body mass. Independent samples t-tests were used to compare involved knee kinematic and kinetic variables between the SH and WH groups across each phase of gait and jogging (p<.05; 2-tailed). Given the preliminary nature of this study in guiding future work, multiple comparisons were not controlled for.

RESULTS AND DISCUSSION
There were no differences in sagittal and frontal plane knee kinematics between the WH and SH groups during any phase of gait or jogging. During jogging, the WH group demonstrated increased tibial external rotation at initial contact (p=.02) and during weight acceptance (p=.02) compared to the SH group (Figure 1A). During gait, the WH demonstrated decreased tibial internal rotation during weight acceptance (p=.011) (Figure 1B).

In addition, the WH group demonstrated decreased internal knee flexion moment at initial contact (p=.012) and during weight acceptance (p=.011), decreased internal knee extension moment at toe-off (p=.007), and decreased peak knee power during mid-stance (p=.001), during push-off (p=.026) and at toe-off (p=.005) during gait compared to the SH group. (Table 1).
These preliminary findings demonstrate that decreased involved hamstring strength often persists over two years after ACLR, as nearly half of our sample was in the WH group. These strength deficits may contribute to differences in involved limb knee mechanics, due to persistent morphological deficits from hamstring graft harvest during ACLR [4]. Previous work has illustrated that strength contributions must be increased from the lateral portion of the hamstring to prevent strength loss due to medial hamstring harvest for the graft [5]. This may contribute to altered transverse plane knee kinematics during gait and other functional tasks. Additionally, the findings of increased involved tibial external rotation in the WH group were consistent with previous work comparing the involved limb to the uninvolved limb during gait post-ACLR, regardless of hamstring strength [6]. In addition, the current data demonstrated differences in sagittal plane knee moments and power between the SH and WH groups. This is similar to previous work demonstrating that individuals after ACLR with quadriceps strength deficits also demonstrate reduced sagittal plane knee moments during gait [7].

CONCLUSIONS

Two years after ACLR with hamstring tendon autograft, participants with deficits in involved hamstring strength show altered knee mechanics in the sagittal plane during gait and in the transverse plane during jogging compared with individuals with symmetric hamstring strength. Given these preliminary findings, future work will further examine the impact of persistent hamstring strength deficits on mechanics during functional and dynamic tasks after ACLR.

REFERENCES


Table 1. Involved Sagittal Plane Knee Moments and Knee Powers During Gait

<table>
<thead>
<tr>
<th></th>
<th>SH (n = 18)</th>
<th>WH (n = 18)</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moment at Initial Contact</td>
<td>.351 ± .061</td>
<td>.295 ± .064</td>
<td>.012</td>
</tr>
<tr>
<td>Peak Moment during Weight Acceptance</td>
<td>.359 ± .059</td>
<td>.303 ± .067</td>
<td>.011</td>
</tr>
<tr>
<td>Moment at Toe-Off</td>
<td>-.078 ± .040</td>
<td>-.045 ± .027</td>
<td>.007</td>
</tr>
<tr>
<td>Peak Power during Mid-Stance</td>
<td>-.397 ± .207</td>
<td>-.196 ± .089</td>
<td>.001</td>
</tr>
<tr>
<td>Peak Power during Push-Off</td>
<td>-1.999 ± 494</td>
<td>-1.624 ± .471</td>
<td>.026</td>
</tr>
<tr>
<td>Power at Toe-Off</td>
<td>-.489 ± .258</td>
<td>-.272 ± .166</td>
<td>.005</td>
</tr>
</tbody>
</table>

All values: mean ± SD; All moments and powers normalized to mass in kg (Nm/kg; W/kg, respectively); Positive sagittal plane moment represents internal flexion moment, negative sagittal plane moment represents internal extension moment; Positive power represents power generated, negative power represents power absorbed.