HOP PERFORMANCE IN INDIVIDUALS WITH ANTERIOR CRUCIATE LIGAMENT INJURIES

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INTRODUCTION

ACL injury can have two major impacts; failure to return to pre-injury activity levels and future predisposition to osteoarthritis [1,2]. Rehabilitation is recommended to help individuals maximize their recovery and performance. Single leg hop is an exercise used in late stage rehabilitation and a tool to evaluate recovery and inform treatment selection [1] but there is insufficient biomechanical understanding of this activity.

The aims of this study were to investigate 1) if hop performance is altered in individuals with Anterior Cruciate Ligament (ACL) injury and 2) identify how kinematics and kinetics determine hop performance.

METHODS

19 individuals with ACL rupture (ACLD; height: 1.77±0.08 m, mass: 83.2±14.0 kg, age: 32±9 years, gender: 2 female, 17 male) and 19 individuals with ACL reconstruction (ACLR; height: 1.75±0.06 m, mass: 80.3±9.9 kg, age: 28±9 years, gender: 4 female, 16 male) were compared to 20 healthy controls (CONT; height: 1.74±0.11 m, mass: 74.8±16.5 kg, age: 29±8 years, gender: 8 female, 12 male). Individuals were asked to hop their maximum single leg hop distance and regain balance after landing. All ACL subjects hopped using their injured leg and the controls their dominant leg. Analysis focused on the landing phase. Ethical approval was obtained from South East Wales Local Research Ethics Committee.

Kinematic data were collected using a VICON motion analysis system (Oxford Metrics Group Ltd., UK) at 250 Hz. Reflective markers were placed using the ‘Plug-in-Gait’ full body marker set. Ground reaction force data were collected using a Kistler force plate (Kistler Instruments Ltd., Switzerland) at 1,000 Hz. Inverse dynamics calculations were performed within VICON Nexus software and data were processed and analyzed in Matlab R2010b (The Mathworks Inc., USA).

To investigate the kinematics and kinetics a telescopic inverted pendulum (TIP) model approach was used (Fig. 1). Hopping can be simulated by an inverted pendulum model where the stance limb is modeled as a rigid segment that rotates around the ankle. The TIP model approach will show whether ACL injured individuals use a predominantly telescopic motion (large change in stance leg length) or predominately pendular motion (large change of the approach angle of the stance leg). Statistical differences for the output variables between the ACL and control groups were analyzed using a general linear model univariate analysis. Centre of mass (COM) velocity prior to landing was used as a co-variant.

Figure 1: Schematic overview TIP model, with the COM angle (θCOM), knee angle (θknee), and distance ankle to COM (L_COM).
RESULTS AND DISCUSSION

ACLR had a similar hop distance ($D_{\text{hop}}$) to CONT but ACLD hopped significantly shorter. Recovered hop distance for ACLR was achieved by a different kinematic/kinetic strategy compared to CONT. Both ACL groups had reduced range of knee motion ($\text{ROM}_{\text{knee}}$), reduced peak extensor moments ($M_{\text{knee(max)}}$), reduced knee angle at peak knee extensor moment and increased peak hip flexor moments ($M_{\text{hip}}$) during the landing phase compared to CONT. ACLD also had increased plantar flexion moments ($M_{\text{ankle}}$). The angle of the COM ($\theta_{\text{COM}}$) and trunk lean ($\theta_{\text{trunk}}$) at peak knee moment were not significantly different from CONT (Table 1).

<table>
<thead>
<tr>
<th></th>
<th>$D_{\text{hop}}$ (m)</th>
<th>$M_{\text{knee(max)}}$ (N.m/body weight.m)</th>
<th>ROM$_{\text{knee}}$</th>
<th>$\theta_{\text{knee at M_{knee(max)}}}$</th>
<th>$\theta_{\text{COM at M_{knee(max)}}}$</th>
<th>$M_{\text{hip(max)}}$ (N.m/body weight.m)</th>
<th>$M_{\text{ankle(max)}}$ (N.m/body weight.m)</th>
<th>$\theta_{\text{trunk at M_{knee(max)}}}$</th>
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</thead>
<tbody>
<tr>
<td>CONT</td>
<td>$1.34\pm0.04$</td>
<td>$0.41\pm0.02$</td>
<td>$70^\circ \pm 2$</td>
<td>$39^\circ \pm 1$</td>
<td>$82^\circ \pm 0.4$</td>
<td>$0.46\pm0.02$</td>
<td>$0.29\pm0.01$</td>
<td>$18^\circ \pm 1$</td>
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<tr>
<td>ACLD</td>
<td>$1.05\pm0.04^*$</td>
<td>$0.33\pm0.02^*$</td>
<td>$58^\circ \pm 2^*$</td>
<td>$35^\circ \pm 1^*$</td>
<td>$83^\circ \pm 0.5$</td>
<td>$0.61\pm0.03^*$</td>
<td>$0.38\pm0.02^*$</td>
<td>$17^\circ \pm 1$</td>
</tr>
<tr>
<td>ACLR</td>
<td>$1.33\pm0.04$</td>
<td>$0.29\pm0.02^*$</td>
<td>$61^\circ \pm 2^*$</td>
<td>$35^\circ \pm 1^*$</td>
<td>$83^\circ \pm 0.4$</td>
<td>$0.60\pm0.02^*$</td>
<td>$0.31\pm0.01$</td>
<td>$18^\circ \pm 1$</td>
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Table 1: Mean hop output variables with standard errors. *: significant difference from CONT (p<0.025).

Figure 2: TIP model analysis with distance ankle to COM as percentage of body height ($L_{\text{COM}}$) against angle of the COM ($\theta_{\text{COM}}$); black line is average data for CONT; red line for ACLR; blue line for ACLD. Stars indicate peak knee extensor moments. The arrow is the direction of movement.

TIP model analysis (Fig. 2) indicates that the ACL groups used a reduced range of flexion/extension at the knee throughout landing. The peak knee moment also occurred with the knee in a more extended position. This suggests that the ACL groups were in a more upright position throughout the landing phase and therefore used more of a pendular deceleration strategy. Whereas CONT flexed their knee through a greater range, had larger knee extensor moments and therefore used a more telescopic strategy. The ACL pendular strategy was further confirmed by their decreased knee extensor moments and increased $M_{\text{hip}}$. ACLD also had increased $M_{\text{ankle}}$. Pendular deceleration requires higher hip flexor and plantar flexor moments to decelerate and regain single leg balance.

CONCLUSIONS

Hop performance was reduced in ACLD but not in ACLR. However kinematics and kinetics of ACLR were very similar to ACLD. We suggest that the ACL groups used a more pendular deceleration strategy during landing. Therefore this shows that both ACL groups had not fully rehabilitated. Consequently hop distance may not be a good criterion for full recovery. Translation of these biomechanical results to clinical practice would indicate that training of soft landing techniques should be used to optimize control of knee joint loading. The challenge is to do this in an understandable and user-friendly manner.

REFERENCES


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