EFFECTS OF A COMBINED INVERSION AND PLANTARFLEXION SURFACE ON KNEE AND HIP KINEMATICS DURING LANDING

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INTRODUCTION

Landing from a jump is an activity commonly associated with many team sports including basketball, volleyball, and soccer. During the landing, assorted motions at the knee and hip have been associated with increased risk of anterior cruciate ligament (ACL) injury (1, 6). While many ACL injuries are non-contact, sports such as soccer and basketball often require jumping with other people in the vicinity and may result in landing on another competitor’s foot, providing an altered landing surface.

This altered landing surface often manifests into a lateral ankle sprain as a result of excessive inversion and plantarflexion during landing (4). As a result, it is likely that the knee and hip joints are subsequently affected by this altered position. Most research has not examined the affects of the altered landing surface on the knee and hip joints and how it may further predispose athletes to certain knee and hip injuries such as ACL injuries.

ACL injuries during landing often occur due to increased knee abduction motion (7), hip adduction (6), and reduced hip and knee flexion (1, 3). These joint angles may change as a result of the altered landing surface during jumping, which may further predispose these athletes to ACL injury risk during their landings. Therefore the purpose of this investigation was to examine the effects of landing on a combined inversion and plantarflexion surface on knee and hip kinematics during a drop landing.

METHODS

Twelve healthy recreational athletes (age: 24.4 ±4.2 years, height: 1.74 ±0.09 m, mass: 71.4 ±11.6 kg), ten males and two females, participated in this study. Participants did not have a history of major lower extremity injury and had not suffered a lateral ankle sprain within 6 months prior to testing. Subjects performed drop landings from a height of 30cm. Five successful trials were performed in three testing conditions (landing surfaces): a flat surface, a 25° inversion surface, and a 25° inversion and plantarflexion (combined) surface. The landing platform consisted of a movable top surface that was held by one ball-and-sock joint and two releasable ball-and-socket joints, allowing for the tilting of inversion only or a combination inversion and plantarflexion on contact (2). The landing trials were performed with the right leg (perturbed) landing on the modified surfaces while the left leg (non-perturbed) always on a flat surface.

A 9-camera motion analysis system (240 Hz, Vicon Motion Analysis Inc., Oxford, UK) was used to obtain 3D kinematic data during the trials. Anatomical and tracking markers were placed on the pelvis, thighs, shanks, and feet of both legs. Pilot data had shown that landing on the combined surface without practice frequently led to loss of balance after landing, therefore for safety reasons, surface conditions were not randomized. The kinematic data were computed using the Visual3D biomechanics analysis suite (4.0, C-Motion, Inc., Germantown, MD). The right-hand rule was used to establish the conventions of 3D kinematics. Marker trajectories were filtered with a zero-lag fourth order low-pass Butterworth filter at 12 Hz. A 2 x 3 (leg x surface condition) repeated measures analysis of variance (ANOVA) was used to examine the effects of the legs and surface conditions on hip and knee kinematics (SPSS 22.0, SPSS Inc., Chicago, IL). Post hoc comparisons with Bonferroni adjustments were performed using a pairwise t-test (p<0.05).

RESULTS AND DISCUSSION

Significant interactions were seen in peak knee flexion (p<0.001), knee flexion ROM (p<0.001), peak hip flexion (p<0.001) and abduction
(p<0.001), and hip flexion (p=0.001) and abduction ROM (p<0.001). A significant main effect for leg was seen in the peak hip flexion (F=16.765, p=0.002). In addition, a main surface effect was seen for knee abduction ROM (F=8.381, p=0.007), peak hip abduction (F=62.382, p<0.001), and hip abduction ROM (F=72.826, p<0.001). Post-hoc comparisons showed that peak knee and hip flexion was significantly lower and peak knee abduction was significantly higher in the perturbed leg on the combined surface compared to the flat and inverted surfaces (p<0.05, Table 1). Hip abduction ROM was significantly higher in perturbed leg compared to the non-perturbed leg in the inverted condition (p=0.024). On the combined surface, the perturbed leg compared to the non-perturbed leg showed decreased knee flexion ROM, peak knee flexion, hip flexion ROM, and peak hip flexion and increased knee abduction ROM, peak knee abduction, and hip abduction ROM and (Table 1, p<0.05).

Increases in knee abduction have been frequently suggested to place athletes at risk for ACL injury (5, 7). Results from this research suggest that landing on the combined surface may increase the risk of ACL injury due to the increased knee abduction seen in the perturbed limb. This result occurred during double-leg landing with the perturbed leg making contact first. But it is important to note that single-leg landing has been shown to further increase the knee abduction and therefore increase the risk of ACL injury (7). It is common for athletes in competition situations such as basketball, soccer, and volleyball to often land on a single limb which may increase the risk factor during landing on a combined surface. Additionally, our results showed that the perturbed limb landed with a more extended knee, which decreases the ability of the hamstrings to prevent anterior tibial translation and increases ACL injury risk (3). It has also been suggested that hip adduction increases knee abduction. However landing on the tilting surfaces induced hip abduction, which may have been a protective mechanism to limit the amount of knee abduction experienced by the knees during landing.

CONCLUSION

Kinematic differences of the knee and hip between the flat and inverted conditions were few and small. However, when adding the plantarflexion to the inversion tilt, there were many more significant differences which may predispose athletes to ACL injuries during their landings. The increased hip abduction may be a protective mechanism designed to limit the knee abduction occurring during the inverted and plantarflexed landing.

REFERENCES


Table 1. Mean knee and hip kinematic variables (degree): Mean±SD.

<table>
<thead>
<tr>
<th></th>
<th>Perturbed Leg</th>
<th>Non-perturbed Leg</th>
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<tbody>
<tr>
<td></td>
<td>Flat</td>
<td>Inverted</td>
</tr>
<tr>
<td>Knee Flexion ROM</td>
<td>51.3±3.5°</td>
<td>51.5±5.7°</td>
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<tr>
<td>Peak Knee Flexion</td>
<td>73.7±8.9°</td>
<td>72.1±5.6°</td>
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<tr>
<td>Knee Abduction ROM</td>
<td>2.8±3.3°</td>
<td>3.1±2.9°</td>
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<tr>
<td>Peak Knee Abduction</td>
<td>2.9±6.0°</td>
<td>3.3±5.0°</td>
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<tr>
<td>Hip Flexion ROM</td>
<td>28.5±12.7°</td>
<td>26.4±8.2°</td>
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<td>48.1±16.6°</td>
<td>44.8±9.6°</td>
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<tr>
<td>Hip Abduction ROM</td>
<td>3.2±3.5°</td>
<td>9.1±2.6°</td>
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<tr>
<td>Peak Hip Abduction</td>
<td>10.9±6.3°</td>
<td>17.2±4.9°</td>
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Note: All differences are significant (p<0.05). "#": different from Inverted of same leg. "@": different from Combined of same leg. ": different from the non-perturbed leg of same surface condition.