FOREFOOT, REARFOOT AND SHANK COUPLING: EFFECT OF VARIATIONS IN FOOT STRIKE PATTERN

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INTRODUCTION

The coupling between movements of the foot and tibia during gait has been suggested to be linked with lower limb overuse injuries. There is growing evidence that motion at the midfoot contributes significantly to overall foot motion during walking and running (Pohl et al., 2006). Despite this, studies examining both midfoot and subtalar joint coupling during gait are rare. Given the potential link between injury and lower extremity coupling, there is a need to investigate normal coupling patterns from which injured populations can then be compared to.

Foot strike pattern can vary between individuals during running and has been shown to significantly affect rearfoot eversion (Stacoff et al., 1989). If changes in rearfoot eversion alter shank and forefoot kinematics in a similar manner, coupling should not be influenced. The aim of this study was to assess the robustness of coupling between the forefoot, rearfoot and shank as foot strike pattern was altered. It was hypothesized that the kinematic coupling between the forefoot, rearfoot and shank would be similar.

METHODS

Twelve injury free subjects participated in over-ground running using three different foot strike patterns: a heel strike condition (HFS) where the heel was the first part of the foot to touchdown; a forefoot strike condition (FFS) where the forefoot was the first part of the foot to touchdown, with the heel subsequently making contact with the ground; and a toe running condition (TFS) where the forefoot was the first part of the foot to touchdown but the heel remained off the floor throughout the whole of stance.

Markers placed on the shank (tibia and fibula), rearfoot (calcaneus) and forefoot (metatarsals) were used to determine 3-D kinematics. Rearfoot motion was expressed relative to the shank (subtalar joint), and the forefoot relative to the rearfoot (midfoot joints). Data were captured using a seven-camera-system (ProReflex).

To examine the continuous coupling between adjacent segments, kinematic data for one segment was compared to kinematic data for the adjacent segment using a cross correlation technique. This approach was used to determine the coupling between the segmental rotations shown in Table 1.

RESULTS AND DISCUSSION

Coupling between rearfoot EVE/INV and shank IR/ER was consistently high regardless of foot strike pattern (Table 1). This was also the case for coupling between rearfoot EVE/INV and both forefoot PF/DF and forefoot ABD/ADD. This suggested a kinematic link between rearfoot frontal
plane motion and motion about the midtarsal joint. In addition, the coordinated sagittal and transverse movements of the forefoot lend support to the proposed oblique axis of the midtarsal joint (Manter, 1941).

The lack of coupling between rearfoot EVE/INV and forefoot EVE/INV across all foot strike patterns indicates that frontal plane motion of the forefoot has limited affect on the rearfoot frontal plane motion and vice versa. However, this may be due to greater degrees of freedom between the articulations of the midfoot and forefoot in the frontal plane.

Overall there were no differences in cross-correlations between foot-strike conditions. However, during HFS running, there was less rearfoot eversion during the initial 15% of stance compared to both FFS and TFS running (Figure 1). This meant that less rearfoot EVE was transferred into shank IR during this period of stance in the HFS condition. There was also reduced forefoot dorsiflexion excursion occurring during the first 15% of stance (Figure 1), which suggested that the midtarsal joint can influence the transfer of movement between the rearfoot and shank. This altered coupling is masked when taking average cross-correlations across the entire stance phase. We are currently in the process of examining coupling in smaller sub-phases of the stance phase to gain a greater understanding of the relationship.

### SUMMARY

Forefoot PF/DF and ABD/ADD were highly coupled with rearfoot EVE/INV regardless of foot strike pattern. This suggests forefoot motion can influence subtalar joint kinematics and vice versa.

### REFERENCES


### Table 1: Mean (SD) coupling (cross-correlation) between rearfoot eversion/inversion and shank internal/external rotation and forefoot motion in each plane.

<table>
<thead>
<tr>
<th>Variables</th>
<th>HFS</th>
<th>FFS</th>
<th>TFS</th>
</tr>
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<tbody>
<tr>
<td>Rearfoot EVE/INV _ Shank IR/ER</td>
<td><strong>0.930</strong> (0.066)</td>
<td><strong>0.918</strong> (0.082)</td>
<td><strong>0.961</strong> (0.027)</td>
</tr>
<tr>
<td>Rearfoot EVE/INV _ Forefoot PF/DF</td>
<td><strong>-0.930</strong> (0.066)</td>
<td><strong>-0.939</strong> (0.043)</td>
<td><strong>-0.853</strong> (0.113)</td>
</tr>
<tr>
<td>Rearfoot EVE/INV _ Forefoot EVE/INV</td>
<td><strong>-0.021</strong> (0.520)</td>
<td><strong>-0.213</strong> (0.452)</td>
<td><strong>0.314</strong> (0.396)</td>
</tr>
<tr>
<td>Rearfoot EVE/INV _ Forefoot ABD/ADD</td>
<td><strong>0.953</strong> (0.039)</td>
<td><strong>0.952</strong> (0.043)</td>
<td><strong>0.947</strong> (0.048)</td>
</tr>
</tbody>
</table>

*Figure 1: Angular displacement curves of rearfoot eversion/ inversion (top) and forefoot plantar/ dorsiflexion (bottom) during heel strike, forefoot strike and toe running conditions. The ensemble means are shown for all subjects.*