FOREFOOT-REARFOOT KINEMATICS IN RECREATIONAL RUNNERS WITH A HISTORY OF TIBIAL STRESS INJURY

Andrew Barnes, Jonathan Wheat and Clare E. Milner
Sheffield Hallam University, Sheffield, UK
University of Tennessee, Knoxville, TN, USA
email: A.Barnes@shu.ac.uk

INTRODUCTION

There is some evidence to support the notion that those with a history of tibial stress injuries exhibit a different loading pattern compared to an uninjured population [1]. Dynamic foot function during loading may be important in determining injury risk. At the rearfoot, greater peak eversion has been reported in female runners with a history of tibial stress fracture, compared to runners without previous bony injury [2]. However, a link between peak rearfoot eversion and risk of stress fracture was not found during a prospective study on military recruits [3]. Given these contrasting findings, peak rearfoot eversion is worthy of further investigation in injured populations. Forefoot motions during gait have not been investigated previously in those with a history of tibial stress injury. Significant motion occurs between the forefoot and rearfoot during early stance [4]. The foot has been suggested to act as a twisted plate model which produces counter rotations of the forefoot with respect to the rearfoot [5]. Rearfoot eversion is accompanied by both forefoot inversion [5] and forefoot abduction [6]. These motions result in separation at the joints of the midfoot. Ligament laxity and muscle function help to govern not only the magnitude of joint separation, but also the rate of rotation. Therefore, peak joint angles and velocities might be important in determining the loading response of the foot.

The purpose of this study was to investigate forefoot-rearfoot kinematics during running as risk factors for tibial stress injury. Specifically, it aimed to establish if differences exist in forefoot-rearfoot mechanics between recreational runners with a history of tibial stress injury (TSI) and a control group with no previous bony injuries (CON). Variables of interest were peak rearfoot eversion, peak forefoot inversion and peak forefoot abduction. It was hypothesised that those with a history of TSI would demonstrate greater peak joint angles than a CON group. Peak joint velocities of the selected rotations were also analysed.

METHODS

After institutional ethics approval, six recreational runners (4 males and 2 females) with a history of TSI were recruited (age 28.0±11.2 years, height 181.2±0.12 cm, mass 77.2±15.1 kg, weekly mileage 12.8±2.6 miles). The TSI group comprised two participants with a previously reported tibial stress fracture, confirmed with bone scans. The remaining four participants were diagnosed as having a TSI by physical assessment. The assessment parameters have been validated previously against diagnostic imaging techniques [7]. The CON group comprised six participants with no history of bone related lower extremity injury (age 27.8±7.4 years, height 173.4±0.03 cm, mass 71.6±8.2 kg, weekly mileage 14.5±4.6 miles). The TSI and CON groups were matched by gender, age and weekly mileage. At the time of testing all participants were free from injury and had been pain free for at least the previous eight weeks.

Participants completed 10 good trials of running (3.5m/s ±5%) wearing gait sandals (Bite, Orca). A three segment model [8] comprising the shank, rearfoot and forefoot was used, with markers fixed directly to the skin. All three dimensional kinematic data were collected using an eight camera motion capture system (Motion Analysis Corporation), sampling at 500Hz. A force platform (Kistler, 9281CA) was sampled simultaneously at 1000Hz. Raw coordinate data were filtered (8 Hz) and cropped to the stance phase of gait using the force data to indicate stance. Rearfoot motion was calculated relative to shank, and forefoot relative to rearfoot, using a joint coordinate system [9]. Peak
rearfoot eversion (RFEV) and peak forefoot abduction (FFABD) were defined as the minimum value during stance, while peak forefoot inversion (FFIN) was defined as the maximum value during stance. Joint velocities were defined as the maximum value between foot strike and peak joint angle, these included peak rearfoot eversion velocity (RFEVv), peak forefoot inversion velocity (FFINv) and peak forefoot abduction velocity (FFABDv). Cohen’s $d$ values were calculated as a measure of effect size (ES). The following thresholds were used to interpret effect size: $ES = .20$ small, $ES = .50$ medium, $ES = .80$ large. Only moderate and large effect sizes were considered to be clinically meaningful.

**RESULTS**

A large effect for greater RFEV in the TSI group compared to the CON group was found (Table 1). Small effects for group were found for RFEVv, FFIN, FFINv and FFABD. FFABDv was greater in the TSI compared to the CON group.

Table 1: Means (SD) of rearfoot and forefoot variables of interest for TSI and CON groups, plus effect sizes (ES).

<table>
<thead>
<tr>
<th>Variables</th>
<th>CON ($n=6$)</th>
<th>TSI ($n=6$)</th>
<th>ES</th>
</tr>
</thead>
<tbody>
<tr>
<td>RFEV (°)</td>
<td>4.4 (2.9)</td>
<td>6.3 (1.3)</td>
<td>0.85</td>
</tr>
<tr>
<td>RFEVv (°/s)</td>
<td>224.0 (96.4)</td>
<td>245.0 (45.3)</td>
<td>0.28</td>
</tr>
<tr>
<td>FFIN (°)</td>
<td>8.6 (2.6)</td>
<td>7.5 (3.3)</td>
<td>0.38</td>
</tr>
<tr>
<td>FFINv (°/s)</td>
<td>88.1 (29.0)</td>
<td>82.1 (11.3)</td>
<td>0.27</td>
</tr>
<tr>
<td>FFABD (°)</td>
<td>11.5 (5.8)</td>
<td>13.7 (5.3)</td>
<td>0.38</td>
</tr>
<tr>
<td>FFABDv (°/s)</td>
<td>71.2 (10.8)</td>
<td>103.6 (25.6)</td>
<td>1.60</td>
</tr>
</tbody>
</table>

**DISCUSSION**

The purpose of this study was to compare forefoot-rearfoot kinematics in recreational runners with a history of TSI and a matched CON group. Key differences were found in peak rearfoot eversion angle and peak forefoot abduction velocity between groups, these group differences may provide some insight into potential injury mechanisms. It was hypothesised that individuals with a history of TSI would exhibit greater peak joint angles compared to CON. This hypothesis was supported at the rearfoot, with 1.9° greater peak eversion in the TSI group than the CON group. This finding supports previous research which found 2.7° greater peak rearfoot eversion in female runners with a history of tibial stress fracture compared to controls [2]. The hypothesis was not supported for peak forefoot inversion and peak forefoot abduction. Both variables were similar between groups. These data do not support the notion of greater separation of the joints of the midfoot in those with a history of TSI.

Both forefoot inversion velocity and rearfoot eversion velocity were similar between groups. Similar finding have been reported previously for the rearfoot [3]. In the present study, greater forefoot abduction velocity was observed in those with a history of TSI compared to a CON group. Similar peak forefoot abduction was found in both groups. However, a greater abduction excursion over a shorter time period in the TSI group resulted in the higher peak forefoot abduction velocity compared to CON. A reduced forefoot abduction excursion time in the TSI group may allow less time for the body’s momentum to be reduced and result in higher average forces exerted on the skeletal structures of the lower extremity [3].

**CONCLUSIONS**

Peak rearfoot eversion angle and peak forefoot abduction velocity were greater in those with a TSI compared to a CON group. These differences may be important in relation to understanding TSI risk. Findings represent an initial insight into forefoot-rearfoot kinematics in runners with a history of TSI, further investigation in larger scale studies is needed to establish a specific link to TSI risk.

**REFERENCES**

5. Sarrafian SK. Foot Ankle Int 8, 4-18, 1987.