Alterations in Rearfoot Motion Across Locomotor Speeds

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Introduction
Excessive rearfoot motion during the support phase of gait has been described as a contributor to chronic lower extremity pain and injury (Clement et al., 1981). This motion is estimated by measuring movement of the calcaneous with respect to the leg. Currently a range from +11.80° of supination at foot strike to –13.50° of pronation is defined as “normal” (Clarke et al, 1984; Kernozek and Ricard, 1990). Generally, most studies have utilized a limited sample size and a single or few locomotor speeds. Without a large, representative population of subjects it is difficult to predict with any confidence what rearfoot motion parameters are normal and what are excessive. Therefore, the purpose of this study was to develop normative measures of rearfoot motion in a large female subject sample over a range of locomotor speeds. These data are part of a larger study where data on males were also collected, however, only the female data are presented here.

Methods
Forty-seven healthy females between the ages of 18 to 30 years served as subjects. The subjects were all recreational runners. All subjects walked at 1.03, 1.52 and 2.01 m·s⁻¹ and ran at 2.68, 3.35 and 4.03 m·s⁻¹ on a motorized treadmill while rearfoot motion data were collected. A rearfoot electrogoniometer was used to collect rearfoot motion at 1 kHz. The static arm of the electrogoniometer was attached adhesively to the estimated midline of the heel counter of the shoe, while the moveable arm was attached via a mechanical guide to the estimated midline of the leg. Foot strike was detected using an accelerometer mounted under the belt of the treadmill from which data were also collected at 1 kHz. Prior to the initiation of data collection, a standing calibration trial was collected. Rearfoot data was then calculated relative to the standing trial. Maximum calcaneal eversion (MP) and touchdown angle (TA) were extracted from the raw data for eight footfalls for each subject at each speed. Figure 1 graphically illustrates the rearfoot parameters.

Results and Discussion
The foot landed in a more supinated position during running, and the foot was significantly more supinated at the fastest speed (Table 1). Also, maximum pronation was least at the slowest walking speed. Maximum pronation was greater for running than walking, but there were no differences between running speeds. Maximum velocity of pronation increased systematically with increased speed. The distributions of maximum pronation at each speed are shown in Figure 1.

Table 1 – Mean (+SD) for all parameters. Like letters indicate values that are not different.

<table>
<thead>
<tr>
<th>Speed (m·s⁻¹)</th>
<th>TA (°)</th>
<th>MP (°)</th>
<th>MV (°·s⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.03</td>
<td>2.0 (4.5)</td>
<td>-5.7 (3.4)</td>
<td>-181 (96)</td>
</tr>
<tr>
<td>1.52</td>
<td>2.4 (4.9)</td>
<td>-7.0 (3.6)</td>
<td>-240 (112)</td>
</tr>
<tr>
<td>2.01</td>
<td>3.3 (5.2)</td>
<td>-7.6 (3.9)</td>
<td>-292 (131)</td>
</tr>
<tr>
<td>2.68</td>
<td>4.1 (5.9)</td>
<td>-10.5 (4.8)</td>
<td>-369 (187)</td>
</tr>
<tr>
<td>3.35</td>
<td>4.1 (6.4)</td>
<td>-11.0 (5.1)</td>
<td>-431 (2.2)</td>
</tr>
<tr>
<td>4.03</td>
<td>5.5 (6.4)</td>
<td>-11.5 (5.1)</td>
<td>-517 (211)</td>
</tr>
</tbody>
</table>
Figure 1a-g. The distribution of maximum pronation values at each speed. The vertical line represents the mean and the arrows represent one standard deviation.
The increased supination from walking to running and the fact that MP is not significantly different for the running conditions suggest a change in kinematic strategy between the two types of gait. The fact that MP did not change significantly with changes in speed of locomotion suggests that maximum pronation may not be directly dependent upon speed. Perhaps the subtalar joint allows a certain maximum pronation that is achieved at all speeds of locomotion.

Although the maximum pronation did not increase with increases in speed, touchdown angle did increase from walking to running gait. Consequently, the range of rearfoot motion (angular distance travelled from foot strike until maximum pronation) also increased. Since MV increases with increases in speed, it follows that either the time to MP will decrease or the range of motion over which the pronation occurs with increase. Thus it is possible that the kinematic strategy adopted when changing from walking to running gait prioritizes the intact timing of events in the gait cycle such as maximum pronation.

Since a substantial number of subjects were used in this study, it was expected that the data would be normally distributed. This is approximately true for maximum pronation in the walking trials (Figure 1a-c). However the running data displayed a bimodal distribution with two peaks, each approximately 1 standard deviation away from the mean (Figure 1c-f). The mean MP in walking conditions is from $-6$ to $-8^\circ$, and one of the two peaks in the running conditions is about $-6^\circ$. It appears that while running resulted in greater pronation for some subjects, others remained fairly constant from walking to running. Figure 1g combines all of the data from the six speeds and shows an overall normal distribution. Although not presented here, neither the distribution of the touchdown angle nor the maximum velocity of pronation exhibited this bimodal distribution.

This study documented the changes in not only the mean values in rearfoot kinematic parameters, but also the changes in the distribution of the data. This has implications in making statements about the general population. It appears there were two distinct kinematic effects that are produced by changing speed within our subject population.

References