INTRODUCTION

“Excessive” pronation has been associated with a number of lower extremity injuries including anterior knee pain (AKP) [1]. While this injury paradigm is widely accepted, biomechanical studies often fail to demonstrate pronation differences between injured and healthy runners [2]. Conversely, orthotics used to limit pronation have been shown to effectively reduce pain and improve function in those with AKP [3]. This discrepancy indicates that biomechanical studies may not be evaluating pronation in the right context.

The word “excessive” implies that a threshold has been exceeded. Traditionally, this threshold has been calculated using the means and standard deviations reported in the literature [4], not an individual-specific threshold such as the joint’s available range of motion (ROM). For example, a runner displaying 18° of dynamic ankle joint complex (AJC) eversion would likely be classified as having “excessive” pronation using a traditional definition. However, if this runner had 23° of eversion ROM, the AJC would not likely interpret 18° of dynamic eversion as “excessive” because it still has an eversion buffer of 5°. Therefore, from the joint’s perspective it may be more pertinent to define “excessive” using its available ROM.

This theory has been evaluated by Engsberg et al. [5], who compared dynamic AJC eversion in healthy runners to their available active ROM. These authors found that runners displaying greater quantities of dynamic AJC eversion also exceeded their ROM boundary by an average of 8.4°. However, this study is limited in that only active, not passive ROM was measured, and therefore the joint’s full ROM may not have been captured. Additionally, only healthy runners were evaluated, and consequently, the association with injury is unknown. Therefore, the purpose of this study was to 1) evaluate the eversion buffer of injured and healthy runners using the AJC’s passive ROM and 2) to evaluate traditional pronation variables to the eversion buffer. It is hypothesized that injured and healthy runners will demonstrate similar pronation profiles; however, injured runners will exhibit a significantly smaller eversion buffers.

METHODS

Thirteen healthy (6 male, 7 female, 33.2 ± 8.6 years, 1.7 ± 0.1m, 64.9 ± 11.9 kg) and twelve runners with AKP (3 male, 9 female, 30.8 ± 6.0 years, 1.6 ± 0.1m, 61.9 ± 8.1 kg) completed the study. All subjects were running 8+ miles per week for 6 months, utilized a heel-strike foot fall pattern and had no history of lower extremity surgery. Additionally runners were required to be training in neutral shoes and not using orthotics.

Passive eversion ROM was collected using a custom built ROM device (Figure 1) and a motion capture system (Qualisys, Sweden). The AJC was passively everted using a 10 N·m torque in six predefined sagittal plane positions. The joint’s position was captured using retro-reflective markers placed on the lower leg and calcaneus. Three trials in each sagittal plane position were averaged and interpolated to create the eversion ROM boundary.

A barefoot standing calibration was performed to define the thigh, lower leg and calcaneal segments using markers placed on bilateral greater trochanters, medial/lateral knee, medial/lateral malleoli, sustentaculum tali, peroneal tuberacle and a calcaneal tracking cluster. Subjects ran (2.9 m/s) in a neutral running shoe with a modified heel counter to allow the calcaneal tracking cluster to be
directly attached to the calcaneus and remain fixed during both ROM and running trials. Dynamic lower extremity kinematics were captured (200 Hz) using marker clusters attached to the lateral thigh, lateral leg and calcaneus.

Kinematic data were analyzed in Visual 3D (C-Motion, Germantown, MD). Marker trajectories were smoothed using a 12 Hz fourth order low pass Butterworth filter. Right handed local coordinate systems were created for each segment. Joint angles were calculated using Cardan angles with an X-y-z rotation sequence. Angles were analyzed during stance, with touchdown (TD) defined as the minimum vertical position of a marker placed on the posterior lateral aspect of the midsole and push-off at peak knee extension [6]. Traditional pronation variables included the AJC’s position at TD, peak eversion, and eversion ROM. In addition, the minimum distance from the eversion boundary during stance was calculated (eversion buffer). Statistical differences were determined using a one-way ANOVA (α = 0.05).

RESULTS AND DISCUSSION

No significant differences in traditional pronation variables were present between healthy and injured runners (Table 1). Conversely, injured runners had significantly smaller eversion buffers indicating they used a greater percentage of their available passive eversion ROM. This reduced eversion buffer was in large part due to injured runners having less eversion ROM, particularly at 10° and 20° of dorsiflexion (p-value 0.11, 0.06).

Table 1.

<table>
<thead>
<tr>
<th></th>
<th>Ev Buffer</th>
<th>TD</th>
<th>Peak Ev</th>
<th>ROM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthy</td>
<td>-8.83</td>
<td>3.37</td>
<td>-8</td>
<td>11.36</td>
</tr>
<tr>
<td>Injured</td>
<td>-4.15</td>
<td>3.38</td>
<td>-8.14</td>
<td>11.52</td>
</tr>
<tr>
<td>p-value</td>
<td><strong>0.02</strong></td>
<td>0.99</td>
<td>0.99</td>
<td>0.92</td>
</tr>
</tbody>
</table>

These findings suggest that where the AJC functions relative to its available passive ROM may be a better indicator of those at risk for injury than traditional pronation related variables. It is feasible that a smaller buffer could reduce the ability of the AJC to adapt to changes in the running terrain. As a result, proximal joints not designed to accommodate for these terrain changes may be required to, increasing their risk of injury. Additionally, this finding could explain the discrepancies between orthotic and biomechanical studies. While both groups demonstrate a similar amount of eversion, those with AKP had smaller eversion buffers. It is reasonable to assume orthotics increase this buffer by limiting eversion, and subsequently improve AKP.

CONCLUSIONS

The percentage of eversion ROM utilized when running may be a better indicator of those at risk for injury than traditional pronation variables.
