FOOT ORTHOSES’ HARDNESS AND CONTOURING, NOT MIDFOOT MOBILITY, INFLUENCES IMMEDIATE ADAPTATIONS IN LOWER LIMB FUNCTION IN PEOPLE WITH ANTERIOR KNEE PAIN

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INTRODUCTION
There is increasing evidence that the contouring and hardness of in-shoe foot orthoses influence the physiological effect and perceived comfort of the device [1-4]. This research has been conducted in asymptomatic individuals with the inference that results can be directly transferred to clinical populations. However, comparisons of healthy [3] and currently injured [5] cohorts suggest that the direct transference of results, particularly electromyography (EMG), is not appropriate. Anterior knee pain (AKP) is one condition where there is increasing evidence of the efficacy of orthoses [6,7]. Therefore the aims of this study were to investigate the perceptions of comfort of orthoses that differed in contouring and hardness and identify immediate neuromotor and kinematic adaptations in people with clinically diagnosed AKP.

METHODS
Forty participants with clinically diagnosed AKP were recruited. Midfoot mobility of >10.96 mm is 1 of 4 predictor variables (and the only foot measure) recently identified as increasing the likelihood of orthosis success [8]. As such, after a participant was recruited, the difference in their midfoot width from non-weight bearing to weight bearing was measured using a standard protocol [9]. Twenty-seven participants were classified as having a mobile midfoot (table 1).

Table 1: Group demographics (Mean (SD)) defined by foot mobility

<table>
<thead>
<tr>
<th>Mobile (&gt;10.96 mm)</th>
<th>Not mobile (&lt;10.96 mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>27</td>
</tr>
<tr>
<td>Age (years)</td>
<td>28.67 (6.13)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>169.58 (14.94)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>71.03 (11.97)</td>
</tr>
</tbody>
</table>

All participants were fitted with 4 prefabricated orthoses fitted to the length and volume of their usual jogging shoe (Vasyli International). Three orthoses featured identical contouring but differed in hardness: hard (Shore A 75°), medium (Shore A 60°) and soft (Shore A 52°). The fourth orthosis was also soft (Shore A 52°), but was a uniform 3 mm along the length. Participants jogged at self-selected constant speeds, on a treadmill, in 3-minute intervals alternating between their shoe and their shoe with the orthosis inserted until all had been worn. They were blinded to the difference between the orthoses and the order was randomised. Participants were instructed to select a speed that would not provoke their symptoms and were given as much rest as required between intervals. They were permitted to make notes regarding the comfort of each device and at conclusion of the session ranked the orthoses (by the number of the trial) from most to least comfortable (e.g. Orthosis 2 rank 1).

EMG and kinematic data were collected from 10 consecutive strides from the last minute of each interval. Activity of the tibialis anterior (TA), medial gastrocnemius (MG), soleus (SOL), rectus femoris (RF), vastus lateralis (VL), vastus medialis obliquis (VMO), biceps femoris (BF) and gluteus medius (GM) were recorded with circular silver/silver chloride surface electrodes with a fixed intra electrode distance of 20 mm. Skin preparation and electrode placement was in accordance with SENIAM guidelines [10] and innervation zones described by Rainoldi et al [11]. Kinematic data of the lower limbs were captured using a 14-camera system (VICON, Oxford Metrics, Oxford UK) and the plug-in-gait model. The trajectory of the heel marker used to detect gait events [12]. EMG data were sampled at 3000Hz and kinematic at 250Hz. EMG recordings were adjusted for DC offset, full-wave rectified, band-pass filtered between 15 and 400Hz using a Butterworth filter and normalised to maximum voluntary contraction. Kinematic data were filtered with a generalised cross-validatedatory spline filter. All data were time normalised to 100 points.

Comfort ranks of the orthoses were compared using Friedman’s analysis of variance. Two-way multivariate analyses of variance (MANOVAs) followed-up with univariate tests were used to assess the change scores between orthoses and the preceding shoe. Main effects were orthosis design (contouring and hardness) and midfoot mobility. Variables of interest were: Peak amplitude, time to peak, time of onset (>15% of peak amplitude), and time of offset (<15% of peak amplitude) for EMG data and maximum, minimum and total range for kinematic data.

RESULTS AND DISCUSSION
The orthoses were equally spread over the 4 possible comfort rankings (p= 0.451) (Table 2). However, if contouring was discounted, soft orthoses were rated most comfortable (X²(1)=4.033, p=0.0446). The equal spread is in contrast to asymptomatic studies identifying significant comfort difference between orthoses and preference for soft-flat designs [2,13,14]. This re-enforces the notion that asymptomatic results cannot be directly applied to symptomatic populations. However, an overall preference for softer designs has been repeatedly reported [2,14,15] and this study supports this.

We found no effect of orthosis or midfoot mobility on lower limb kinematics.
Table 2: Comfort rankings

<table>
<thead>
<tr>
<th>Rank</th>
<th>Hard</th>
<th>Medium</th>
<th>Soft</th>
<th>Soft-flat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7</td>
<td>7</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>12</td>
<td>12</td>
<td>6</td>
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<td>3</td>
<td>13</td>
<td>9</td>
<td>10</td>
<td>8</td>
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<tr>
<td>4</td>
<td>10</td>
<td>12</td>
<td>6</td>
<td>12</td>
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</table>

No significant MANOVA interactions between orthosis hardness/contouring and midfoot mobility were found for EMG data. This means that an individual’s midfoot mobility did not influence their adaptation to orthoses and is in agreement with the findings of Nawoczenski et al [16].

A significant main effect was found for MG (Pillai’s trace, 0.18, p=0.005) for hardness/contouring. Follow-up univariate analyses showed a significant difference between the orthoses time to peak ($F_{1,35}=2.8$, $p=0.042$) and time of offset ($F_{1,35}=5.57$, $p=0.001$). When individuals wore the soft orthosis, MG reached peak amplitude and offset earlier in the stride than all other orthoses (fig 1). A near significant difference was also found in time of onset with the hard orthosis producing an earlier onset time than the other orthoses.

Interestingly, we observed no effect of orthoses on muscles above the knee when comparisons are based on design. Disruption in neuromotor coordination of the vasti muscles in an observed feature in people with AKP [19] and our results suggest that this is not immediately affected. Asymptomatic studies show significant difference between orthoses and control conditions in BF and quadriceps activity after several weeks of wear [3,5]. This suggests that orthoses’ affect may be time dependent and highlights a possible limitation of our study by investigating immediate effects only.

SUMMARY

Individuals with AKP express a comfort preference for soft orthoses and the mobility of their midfoot does not immediately affect how they physically respond to them. Immediate neuromotor responses to orthoses of different designs are confined to the shank where it appears the hardness of the device has more influence than shape. Midfoot mobility difference affects the timing of offset in MG but this is not influenced by the type of orthosis. Further research should focus on long-term neuromotor adaptations in response to orthoses that differ in hardness.

REFERENCES