POSTURAL STABILITY DURING STAIR NEGOTIATION WHILE CARRYING ASYMMETRIC LOADS
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INTRODUCTION

Individuals often carry items in one hand instead of both hands during activities of daily living. Asymmetric load carriage is expected to produce a lateral shift of the center of mass. A laterally displaced center of mass during unilateral load carriage results in a challenge to postural stability during walking. Furthermore, asymmetrical load carriage during stair negotiation results in even higher demands on postural stability.

Previous studies have investigated how load carriage affects the biomechanics of human movement as a function of load magnitude and asymmetry. However, no studies exist that evaluate postural stability of asymmetric load carriage during stair negotiation. Therefore, the purpose of this study was to assess postural stability when carrying symmetric vs. asymmetric loads during stair ascent and stair descent. We hypothesized that: 1) postural stability would be decreased during unilateral load carriage as compared to bilateral load carriage, and 2) postural stability would be decreased during stair descent as compared to stair ascent.

METHODS

Twenty-five young healthy adults (13 males, 12 females; age 24.0 ± 4.2 yr; height 171.3 ± 7.7 cm; mass 68.7 ± 13.3 kg) participated in this research. A three-step staircase (step height 18.5 cm, tread depth 29.5 cm) with force platforms on the two lowest steps was used for stair negotiation. The participants were asked to carry three types of loads: no load, 20% body weight (BW) load on one side of the body, and 20% BW load split between both sides of the body. Two hand-held bags were filled with sealed bags of lead shot to match the two loaded conditions.

An eight-camera Vicon motion analysis system was used to collect three-dimensional kinematic data at a sampling rate of 160 Hz. Five retro-reflective markers were placed on toe, mid-foot, heel, medial malleoli, and lateral malleoli. Force platform data were sampled at 1600 Hz. Kinetic and kinematic data were synchronized using Vicon Nexus.

Center of pressure (COP) based parameters were calculated using custom-made Matlab code. COP velocities were calculated utilizing the first central difference method. Rectangular boundaries of the base of support were modeled from marker data and foot anthropometrics. Anterior-Posterior (AP) and Medial-Lateral (ML) COP position and velocity were then used to estimate Time-to-Boundary (TTB, Figure 1). TTB is the estimated time it takes the COP to reach the boundary of foot [1]. The dependent variables included mean COP AP and ML velocities and minimum AP and ML TTB values during single-leg stance.

Two independent variables were tested: loading conditions (no load, 20% BW bilateral load, 20% BW unilateral load) and stair negotiation (ascent vs. descent). Repeated measures ANOVA with two within factors (3x2) was performed to test the effects of loading conditions and stair negotiation. Holm-Bonferroni post-hoc tests were performed when appropriate. The level of statistical significance for all tests was set at p < 0.05.

RESULTS

For mean AP COP velocity, there were significant main effects of load condition (p = 0.05) and stair ascent vs. descent (p < 0.01, Table 1). Mean AP COP velocity was significantly higher during stair descent as compared to stair ascent, but post-hoc analysis did not detect any significant differences between load conditions (p ≥ 0.11). For mean ML COP velocity, there was a significant main effect of stair ascent vs. descent (p < 0.01). Mean COP ML velocity was significantly higher during stair descent as compared to stair ascent (Table 1).
TTB = \frac{D_{b(i)}}{\text{COPvel}(i)}

DTb = \text{displacement from COP to AP or ML boundary}

\text{COPvel} = \text{AP or ML COP velocity}

i = \text{each data point (1/160s interval)}

Figure 1 Illustration of (a) TTB calculation and (b) the minimum TTB value (in ML direction)

For minimum ML TTB, there were significant main effects of stair ascent vs. descent (p < 0.01) and the interaction between stair ascent vs. descent and load condition (p = 0.01). Minimum ML TTB was significantly lower for stair descent as compared to stair ascent (Table 1). Exploring the interaction effects, minimum ML TTB was significantly lower for stair descent as compared to stair ascent when carrying no load, 20% BW bilateral load, and 20% BW unilateral load. For minimum AP TTB, there were no significant main effects.

Table 1: COP parameters as a function of load condition and ascent vs. descent. Means ± SD are displayed.

<table>
<thead>
<tr>
<th></th>
<th>No Load</th>
<th>20% BW Bilateral</th>
<th>20% BW Unilateral</th>
<th>Ascent</th>
<th>Descent</th>
<th>Load</th>
<th>Ascent vs. Descent</th>
<th>Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP COP vel (cm/s)</td>
<td>19.2 ± 6.9</td>
<td>17.7 ± 5.9</td>
<td>17.9 ± 5.9</td>
<td>16.3 ± 5.6</td>
<td><strong>20.2 ± 6.2</strong></td>
<td>0.05*</td>
<td>&lt; 0.01*</td>
<td>0.08</td>
</tr>
<tr>
<td>ML COP vel (cm/s)</td>
<td>6.5 ± 3.6</td>
<td>6.5 ± 3.3</td>
<td>6.8 ± 3.7</td>
<td>4.6 ± 1.5</td>
<td><strong>8.6 ± 3.8</strong></td>
<td>0.54</td>
<td>&lt; 0.01*</td>
<td>0.06</td>
</tr>
<tr>
<td>AP TTB (s)</td>
<td>0.20 ± 0.10</td>
<td>0.24 ± 0.22</td>
<td>0.21 ± 0.12</td>
<td>0.24 ± 0.20</td>
<td>0.20 ± 0.08</td>
<td>0.27</td>
<td>0.36</td>
<td>0.79</td>
</tr>
<tr>
<td>ML TTB (s)</td>
<td>0.55 ± 0.29</td>
<td>0.54 ± 0.24</td>
<td>0.51 ± 0.26</td>
<td>0.67 ± 0.28</td>
<td><strong>0.39 ± 0.16</strong></td>
<td>0.28</td>
<td>&lt; 0.01*</td>
<td>&lt; 0.01*</td>
</tr>
</tbody>
</table>

DISCUSSION AND CONCLUSIONS

We investigated the effect of different methods for carrying loads on postural stability during stair negotiation in healthy young adults. Our first hypothesis that postural stability would be decreased during unilateral load carriage as compared to bilateral load carriage was not supported. Our second hypothesis that postural stability would be decreased during stair descent as compared to stair ascent was supported for three variables. More specifically, mean AP COP velocity was increased, mean ML COP velocity was increased, and minimum ML TTB was decreased during stair descent.

COP-based parameters measure challenges in postural stability. Specifically, minimum TTB estimates the lowest margin of safety before a postural adjustment is necessary [2-3]. These parameters indicated that stair descent results in decreased postural stability compared to stair ascent, particularly in the ML direction. However, load carriage did not significantly affect these measures of postural stability. Challenges associated with load carriage may be better assessed with musculoskeletal models that estimate structural loading.

REFERENCES