THE EFFECTS OF HAND-HELD LOAD CARRIAGE TECHNIQUES ON LOWER EXTREMITY CONTINUOUS RELATIVE PHASE VARIABILITY

Catherine L.W. Smallman, Ryan B. Graham, Joan M. Stevenson
School of Kinesiology and Health Studies, Queen’s University, Kingston, CA, 9cs68@queensu.ca

INTRODUCTION

Despite the frequency of hand-held load carriage in many industrial settings, most research to date has focused primarily on packs as the means of load carriage. The Mover’s Assistive Device (MAD), developed in 2008 at Queen’s University in conjunction with local moving companies, is an on-body ergonomic aid designed to reduce musculoskeletal effort during hand-held load carriage. The MAD has been found to reduce muscular activity, as well as reduce users’ perceived exertion during loaded walking [1]. Interjoint coordination (quantified as the continuous relative phase (CRP) angle) variability has been used as an indicator of a person’s ability to respond to and recover from perturbations in unfavourable conditions during normal gait [2]. The purpose of this study was to quantify differences in CRP variability during load carriage when: 1) carrying a load anteriorly and posteriorly; and 2) wearing and not wearing the MAD.

METHODS

Kinematic data were collected at 120Hz from six Vicon-512 infrared motion analysis cameras (Oxford Metrics, Oxford, UK). Ten male participants walked 50 steps under each of four carriage conditions: 1) unassisted anterior carriage (UAC), 2) assisted anterior carriage (AAC), 3) unassisted posterior carriage (UPC), and 4) assisted posterior carriage (APC); while carrying a load equivalent to 20% of body mass. Using a three-dimensional Euler rotation sequence, sagittal angles and then velocities of the ankle, knee, hip, and trunk were calculated. Angular positions and velocities were normalized between 0 and 1 (Figure 1 Top), phase angles were calculated using the inverse tangent of angular velocity over angular position (Figure 1 Middle), and CRP angle was calculated by subtracting the distal joint phase angle from the proximal joint phase angle (Figure 1 Bottom). This was done between the knee-ankle, hip-knee and trunk-hip, and CRP variability was calculated as the standard deviation of CRP for each percent of the gait cycle across all strides for each condition. Two-way repeated-measures analysis of variance was used to test for differences between carriage technique and device (p<0.05).

RESULTS

The posterior load carriage technique was found to exhibit significantly greater CRP variability than its respective anterior load carriage technique for all three coordination models. Furthermore, wearing the MAD caused a significantly less variable CRP pattern than not wearing the MAD for the hip-knee and the trunk-hip coordination models (Table 1).

DISCUSSION & CONCLUSIONS

The results from this study provide an initial evaluation of the differences in CRP variability between different types of load carriage. While an increased CRP variability has been associated with an increased ability to recover from external perturbations in normal gait [2], it is unknown whether this applies to hand-held load carriage. In conclusion, different load carriage techniques alter the amount of lower-extremity variability in the sagittal plane; however, the ideal amount of variability is still unknown. Future studies plan to apply stability analyses during similar load carriage conditions to begin testing for an ideal CRP variability during load carriage.

REFERENCES


ACKNOWLEDGEMENTS: WSIB of Ontario

Table 1: Summary of the mean CRP variability (standard deviations of variability) across all subjects for the knee-ankle, hip-knee, and trunk-hip and the analysis of variance (ANOVA) results.

<table>
<thead>
<tr>
<th>Coordination Model</th>
<th>Mean CRP Variability (standard deviation)</th>
<th>Device p value</th>
<th>Technique p value</th>
<th>Device* Technique p value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Anterior Unassisted</td>
<td>Anterior Assisted</td>
<td>Posterior Unassisted</td>
<td>Posterior Assisted</td>
</tr>
<tr>
<td>Knee-Ankle</td>
<td>4.85 (±1.28)</td>
<td>6.14 (±1.33)</td>
<td>4.74 (±0.88)</td>
<td>5.93 (±0.94)</td>
</tr>
<tr>
<td>Hip-Knee</td>
<td>4.94 (±0.97)</td>
<td>6.25 (±1.17)</td>
<td>4.84 (±1.02)</td>
<td>5.32 (±1.18)</td>
</tr>
<tr>
<td>Trunk-Hip</td>
<td>12.03 (±1.87)</td>
<td>20.05 (±2.56)</td>
<td>11.55 (±2.28)</td>
<td>18.34 (±2.96)</td>
</tr>
</tbody>
</table>

Figure 1: Calculation of the CRP during one gait cycle for one participant. Top) The normalized position-velocity curves. Arrow indicates beginning of the cycle. Middle) The phase angle of both the ankle and knee. Bottom) The knee-ankle CRP. The large black dots represent one point at 20% of the gait cycle through each stage of the calculations.