EFFECT OF MODE OF LOAD CARRIAGE ON POSTURAL SWAY

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People commonly carry external loads for sport and recreational purposes; recently the safety of such practice has come into question. The purpose of this study was to evaluate balance under different load carriage conditions. Fifteen college-age individuals completed three blocks of quiet standing trials: unloaded, wearing a backpack, and wearing a shoulder bag. A-P sway amplitude was greater under the backpack condition than the unloaded condition (P = 0.013); however, A-P sway amplitude did not differ between the backpack and shoulder bag condition, nor did it differ between the unloaded and shoulder bag condition. M-L sway amplitude, sway area, peak sway velocity, and stance width were not dependent on load condition. This evidence suggests a backpack and shoulder bag are equally safe means of load carriage in college-age individuals.

KEY WORDS: load carriage, balance, center of pressure, postural sway.

INTRODUCTION: Individuals of all ages carry external loads in many sport and recreational activities (e.g., backpacking, hiking, and weighted vest resistance training), and on a daily basis to and from school or work. Recently the size of these loads has raised concern for the physical well-being of the individuals frequently carrying these relatively large loads. Backpacks and shoulder style bags (i.e., messenger bags) are common means of carrying such loads. Regardless of the mode of load carriage, maintaining balance under such conditions is believed to be crucial to safe and skillful movement performance.

Despite the growing concern regarding the potential adverse effects of carrying large external loads, scientific evidence does not clearly indicate a cause and effect relationship between load carriage and musculoskeletal injury (Pau & Pau, 2010). However, previous research has indicated that balance may be compromised in the presence of an external load (Pau & Pau, 2010; Schiffman, et al., 2006; Zultowski & Aruin, 2008). Commonly, when carrying a load via backpack individuals exhibit greater center of pressure (COP) sway and sway velocity, indicating that load carriage challenges the stability of the load carrier (Pau & Pau, 2010; Schiffman, et al., 2006). Greater sway velocity and changes in trunk posture have also been reported when individuals carry an asymmetrical load (Lee & Li, 2008; Zultowski & Aruin, 2008). However, at present there is a dearth of knowledge regarding the effects of load carriage via a shoulder bag. Given the prevalence of individuals who frequently carry external loads, it is vital that we explore a variety of means of load carriage in an effort to minimize the risk of injury and enhance performance when carrying an external load.

The purpose of this study was to investigate the effects of different modes of load carriage on static balance, using traditional measures of postural sway. It was hypothesized that postural sway would be greater in the loaded conditions than the unloaded condition. Specifically, it was believed that postural sway in the anterior-posterior (A-P) direction would be greatest in the backpack condition, whereas medio-lateral (M-L) sway would be greatest in the shoulder bag condition due to the asymmetrical positions of the load. Lastly, it was believed that sway velocity would increase when stability was challenged under the loaded conditions.

METHODS: Eight women [mean (SD) age: 22 (1) years; height: 1.58 (0.20) m; mass: 67.0 (8.8) kg] and seven men [mean (SD) age: 23 (2) years; height: 1.80 (0.06) m; mass: 91.9 (24.6) kg] volunteered and provided informed consent prior to participating in the study. Exclusion criteria included any self-reported condition that would make it difficult or painful to stand with a loaded bag and any health condition that could interfere with the ability to maintain balance. All participants wore shoes and tight fitting clothing during data collection.

To assess the effect of load condition on static balance, center of pressure data were recorded during quiet standing under three different load conditions: (1) unloaded (i.e., the participant was not carrying any external weight), (2) wearing a 23.0 liter backpack and (3) wearing a 26.7 liter shoulder bag. The backpack and shoulder bag were loaded with 10% of the participant's measured body weight (BW). The backpack had two shoulder straps and a chest strap. The shoulder bag was a side bag with one strap crossing the body, placing the bag at the hip on the side of the body contralateral to the strap.

After completing a health history questionnaire participants proceeded to the quiet standing trials. Participants completed three randomized blocks of quiet standing trials: 3 unloaded, 3 backpack, and 3 shoulder bag trials. All trials were 30 seconds in duration. During the quiet standing trials participants were asked to stand quietly on the force plate, with their hands at their sides, their feet a comfortable width apart, while looking at an 'X' on the wall at eye level approximately 5 meters in front of them. Prior to beginning the loaded trials participants were allowed to adjust the shoulder bag or backpack so that the respective bag was comfortably positioned. After completing the initial trial in each block, participants were instructed to remain on the force plate while the lateral border of the stance width was measured and marked with tape. For the remaining two trials in the block, participants were instructed to use the same stance width, using the tape as a guide. Between each block of trials the tape was removed. Participants were given approximately twenty seconds of rest between each trial, and approximately one minute of rest between blocks of trials.

Kinetic data were collected using a 400 mm x 700 mm force plate (*Kistler, Amherst, NY, USA)* interfaced with Bioware (3.24, *Kistler, Amherst, NY, USA*) data acquisition software. The COP data were sampled at 1080 Hz and low-pass filtered with a 4^{th}-order, zero-lag Butterworth filter with a cut-off frequency of 15 Hz. The following variables were used to assess postural sway in each of the load conditions:

A-P Sway Amplitude: the maximum range of COP movement in the anterior and posterior direction normalized to participant foot length.

M-L Sway Amplitude: the maximum range of COP movement in the medio-lateral direction normalized to participant stance width.

Sway Area: the smallest ellipse that includes 95% of the COP data points.

A-P Peak Sway Velocity: the peak of the first derivative of the A-P sway amplitude normalized to foot length.

M-L Peak Sway Velocity: the peak of the first derivative of the M-L sway amplitude normalized to stance width.

Repeated measures analysis of variance (ANOVA) was used to examine the effects of load condition on the dependent variables. Values for each variable were averaged across trials of the same type for the statistical analysis. Load condition (unloaded vs. backpack vs. shoulder bag) was the within-subject factor. A one-way ANOVA was used to examine the effects of load condition on stance width. The alpha level was set at 0.05. Significant effects were explored using t-tests. To control the familywise error rate, the alpha level was set at 0.025 for all post-hoc analyses. Statistical analyses were conducted in SPSS 18.0 (SPSS, Chicago, IL, USA).

RESULTS: A-P sway amplitude was dependent on load; however, the remainder of the variables investigated were not dependent on load condition. Post-hoc analysis revealed greater A-P sway amplitude in the backpack condition than in the unloaded condition (P = 0.013) (Figure 1). However, there was no significant difference in A-P sway amplitude when the shoulder bag condition was compared to the unloaded (P = 0.048) or the backpack condition (P = 0.769) (Figure 1). No statistically significant differences in M-L sway amplitude were observed among the three load conditions (P = 0.20) (Figure 1).

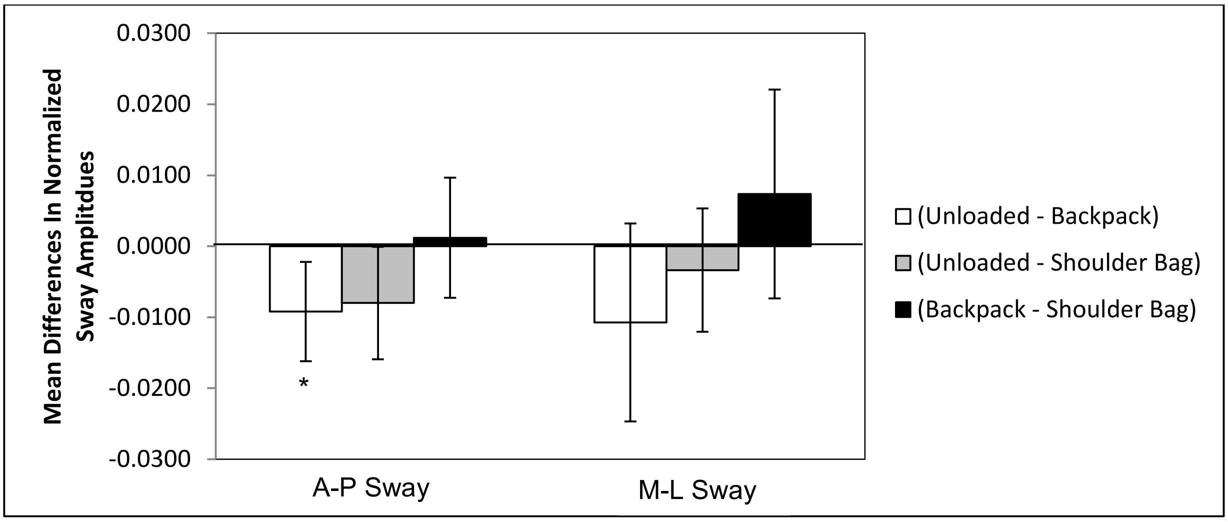

Figure 1: Mean Differences and 95% Confidence Intervals for COP Sway Amplitudes. A-P and M-L sway differences are given relative to foot length and stance width, respectively.
**P* = 0.013 versus unloaded condition

Sway area did not differ with load condition (*P* = 0.091) (Table 1). Load condition had no effect on peak sway velocity in the A-P (*P* = 0.859) or M-L direction (*P* = 0.920) (Table 1). Lastly, stance width was not dependent on load condition (*P* = 0.957) (Table 1).

Table 1
COP Sway Area, Peak COP Sway Velocities, and Stance Width (Mean ± SD).

Measured Variable	Unloaded	Backpack	Shoulder Bag
Sway Area (*Foot Length x Stance Width*)	0.004 ± 0.004	0.005 ± 0.006	0.004 ± 0.002
A-P Peak Sway Velocity (*Foot Length/sec*)	0.33 ± 0.10	0.32 ± 0.12	0.32 ± 0.09
M-L Peak Sway Veolcity (*Stance Width/sec*)	0.24 ± 0.09	0.25 ± 0.13	0.24 ± 0.10
Stance Width (*cm*)	40.4 ± 4.66	40.8 ± 4.68	40.9 ± 5.06

DISCUSSION: Individuals often carry external loads in sport and recreational activities, such as hiking and weighted vest resistance training, which could place unnecessary stress on the body, potentially increase the risk of a fall or injury, and possibly be detrimental to performance. As maintaining stability while carrying a load is crucial to avoiding injury, it is vital that we understand the nuances of balance during load carriage. The present study assessed postural sway during an unloaded condition, and while carrying a load of 10% body weight in a backpack, and a shoulder bag, respectively. The results indicate that postural stability is challenged in the A-P direction when carrying a backpack. However, no other measures of postural stability were dependent upon the load condition, suggesting that in most instances college-age individuals are able to make the necessary adjustments to accommodate an external load and maintain stability.

In the present study, we observed greater A-P sway amplitude in the backpack condition compared to the unloaded and shoulder bag condition. In contrast, M-L sway amplitude and sway area were not dependent on load condition. The greater A-P sway amplitude in the presence of a backpack confirmed the observations of Pau & Pau (2010); this was not unexpected as participants were not allowed to make adjustments to their base of support in the A-P direction to accommodate the posterior load of the backpack. It is possible that in the natural load carriage environment, such as during hiking or backpacking, A-P sway could be reduced with an increase in the A-P base of support. In contrast to previous research we did not see an increase in A-P sway with the shoulder bag (Zultowski & Aruin, 2008). However, this may be explained by the smaller load (e.g., 10% versus 20% BW) and different shoulder bag carriage style in the present study compared to the study of Zultowski & Aruin (2008). In the current study M-L sway amplitude and sway area were not dependent upon load condition; this contradicts previous findings (Pau & Pau, 2010; Zultowski & Aruin, 2008). The discrepancy in findings may be explained by the aforementioned differences in load carriage conditions between the present study and previous work. In addition, Pau & Pau (2010) observed school-age children, without fully developed nervous systems, compared to the college-aged individuals examined in the present study. In general it appears that college-age individuals are able to make the needed adaptations to maintain postural stability in the presence of an external load regardless of the load carriage style. Thus, it appears reasonable to conclude that a backpacker or hiker would be able to make adjustments to preserve movement safety and skill in the presence of an external load of this magnitude. However, it remains to be seen how a larger load or a more dynamic task, such as hiking, would influence the ability of an individual to maintain balance.

A-P peak sway velocity, M-L peak sway velocity, nor stance width, were dependent on load condition. The lack of change in sway velocity is in contrast to the findings of Zultowski & Aruin (2008). Again, this discrepancy in findings may be explained by differences in the load carriage conditions between the present study and the study of Zultowski & Aruin (2008). The fact that stance width was not dependent on load condition confirms the findings of Schiffman et al. (2006). As changes in stance width were not used to accommodate the external loads it is likely that individuals in the present study used other means, such as changes in trunk position, to maintain postural stability.

There are a few limitations to the present study. First, researchers did not control for stance width, rather subjects were allowed to choose a comfortable width in each load condition. Second, participants in the present study completed all trials shod. While we recognize these methodological choices as potential limitations we believe the evaluation of balance under these conditions more closely mimics the natural environment in which load carriage occurs.

CONCLUSION: In many sports activities, such as backpacking and hiking, the ability to maintain balance is vital to safe and skillful performance. The present evidence suggests that in most instances, college-age individuals are able to adapt, and effectively maintain stability, under different load styles. It appears that, in terms of maintaining balance, neither safety nor skill is compromised when college-age individuals carry a backpack or shoulder bag, loaded with 10% BW. It remains to be seen how these individuals were able to adapt to accommodate the different styles of load carriage. Future research should examine postural changes associated with carrying these different style loads under both static and dynamic circumstances and the effects of load magnitude on movement safety and performance so that proper recommendations can be made for sports such as backpacking and hiking.

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Acknowledgement

The authors would like to thank the Office of the Provost at California State University, Chico for the Undergraduate Award for Research and Creativity which funded the present work.