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Carrying heavy asymmetrical loads increases postural sway during quiet standing in older adults

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ABSTRACT

Holding asymmetrical loads in the hands is common during many daily and occupational activities which, depending on the load mass, may alter postural stability. The purpose of this study was to determine the effect of load magnitude held asymmetrically in the hand on postural sway in older people. Eighteen healthy older adults (age, 65.9 ± 5.7 years) were assessed in the following conditions; (1) standing without an external load (0%), (2) standing while holding a grocery bag containing 5%, (3) 10% and (4) 20% body mass in the dominant hand. The total displacement of the centre of pressure (COP) in the anteroposterior and mediolateral directions (cm), mean COP velocity (cm s^{-1}) and COP area (cm^2) were used to indirectly assess postural sway. The COP area (R^2 = 0.96), anteroposterior (R^2 = 0.85) and mediolateral (R^2 = 0.84) COP displacement increased linearly with additional load. The 20% load condition elicited the greatest increase in postural sway (d = 2.1 – 3.6) compared to 0%, while the 5% load had no effects on sway ($P \geq 0.05$). In contrast, the mean COP velocity decreased by similar amounts when holding a load at 5% (d= 1.6), 10% (d= 1.4) and 20% (d= 1.5) body mass, compared to 0% (all $P < 0.001$). The slower COP velocity, combined with greater COP displacements may suggest that postural reactions were restricted and/or delayed. From a fall-prevention perspective, it is advised that older people avoid holding asymmetrical external loads greater than 5% of body mass.

Keywords: Aging, Functional balance, body mass redistribution, stability, grocery shopping

INTRODUCTION

Falling is often the end result of multiple intrinsic factors affecting standing postural stability [1], including aging [2], muscle fatigue [3] and diminished input from one or more sensory system [4]. External loads can also affect postural stability, which is important because holding external loads during standing is an important issue for many daily and occupational activities [5]. Much of the existing literature has shown that holding external loads at or above the centre of mass (COM) (e.g. backpack) increases postural sway in young adults [5-8]. Despite the prevalence of holding or carrying loads in the hands (i.e., grocery bags), few studies have investigated the implications of this type of loading in modifying postural stability.

Carrying external loads (e.g. grocery bags) comprises an important activity of daily living for older adults. Given that older people generally demonstrate increased postural sway [2], examining the effects of holding an asymmetrical external load in the older population has clear relevance. Holding a relatively light load (i.e. ~5% body mass) has no effect on postural sway in older people [9,10]. However, an increase in mediolateral centre of pressure (COP) displacement has been shown when holding heavier loads (i.e. 10% and 20% of body mass) in young adults [11]. Therefore, holding heavy loads may have important implications for older people because mediolateral components of postural sway have predictive value for fall incidence [12]. Within this context, the purpose of the present study was to determine the influence of external load magnitude held asymmetrically in the hand on postural sway in older people. We hypothesised that increasing the load above 5% of body mass would increase postural sway in older people.

2. METHODS

2.1 Participants

Eighteen healthy older adults (female, n = 12; age, 65.9 ± 5.7 years; height, 1.63 ± 0.85 m; mass, 65.4 ± 13.0 kg; BMI, 24.7 ± 4.7; physical activity, 1.1 ± 1.0 hr/week; dominant hand grip strength; 26.2 ± 8.2) volunteered for this study following institutional ethics approval. All participants provided written informed consent as required by the Helsinki declaration (1964). None of the participants had any known neurological, orthopaedic or musculoskeletal problems. All adults were initially screened using a general health screening and physical activity questionnaire (PAR-Q).

2.2 Posturographic assessment

To examine the effects of load magnitude on postural sway each participant performed quiet standing trials on a force platform (AMTI, AccuGait, Watertown, MA) for 30 s. Data were

sampled at 100 Hz (AMTI, Netforce, Watertown, MA) and the total displacement of the COP in the anteroposterior and mediolateral directions (cm), mean COP velocity (cm s^{-1}) and 95% confidence ellipse area (cm^2) were subsequently calculated (AMTI, BioAnalysis, Version 2.2, Watertown, MA). To ensure continuity between trials, foot position was standardised using foot templates at a distance of 3 cm between the medial extremities of the posterior side of the calcaneus. When standing quietly, to gaze ahead at a target which was adjusted to the eye level of each individual. The standing tasks included: (1) bipedal stance without holding a load (0%), (2) bipedal stance while holding a grocery bag containing 5% [3.3 ± 0.6 kg], (3) 10% [6.5 ± 1.3 kg] and (4) 20% [13.1 ± 2.6 kg] body mass in the dominant hand. The order of conditions was randomly assigned for each participant. Each bag was filled with objects of varying dimensions in an attempt to represent the distribution of content in a typical grocery bag. A total of three trials were recorded for each condition and a mean of each sway variable was used in subsequent analysis.

2.3 Data analysis

Data were analysed using IBM version 24.0 (SPSS Inc., Chicago, IL). For all analyses, normality of distribution (Shapiro–Wilk test) and homogeneity of variance/sphericity (Levene's test) were checked prior to parametric tests. Repeated-measures analysis of variance (ANOVA) was used to test the differences in postural sway outcome measures among the various postural conditions (0% × 5% × 10% × 20%). Cohen's *d* effect sizes are reported for significant pairwise comparisons. Statistical significance level was set at $P \leq 0.05$ for all tests.

3. RESULTS

Significant differences were observed between conditions for anteroposterior COP displacement ($F_{(3,51)} = 19.814$, $P \leq 0.001$), mediolateral COP displacement ($F(3,51) = 22.878$, $P \leq 0.001$), mean COP velocity ($F(3,51) = 86.223$, $P \leq 0.001$) and COP area ($F(3,51) = 57.131$, $P \leq 0.001$) (Fig. 1). When compared to 0%, the anteroposterior COP displacement increased with the addition of a 10% ($P = 0.041$, $d = 1.3$) and 20% ($P \leq 0.001$, $d = 2.1$) load. The mediolateral COP displacement also increased with the addition of a 10% ($P = 0.006$, $d = 1.2$) and 20% ($P \leq 0.001$, $d = 2.1$) load. Finally, the COP area increased by 169 ± 153% and 337 ± 223% with the addition of a 10% ($P \leq 0.001$, $d = 1.6$) and 20% ($P \leq 0.001$, $d = 3.6$) load compared to 0%. In contrast, the mean COP velocity decreased when holding a load at 5% ($d = 1.6$), 10% ($d = 1.4$) and 20% ($d = 1.5$) body mass, compared to 0% (all $P \leq 0.001$). There were strong linear relationships between anteroposterior COP displacement ($R^2 = 0.85$), mediolateral COP displacement ($R^2 = 0.84$) and COP area ($R^2 = 0.96$) and load magnitude.

***** FIGURE 1 ABOUT HERE *****

4. DISCUSSION

The results of the present study indicate that older adult's ability to maintain postural stability during quiet standing is reduced by asymmetrical external loading. With the exception of the mean COP velocity, the increase in postural sway was linearly dependent on the size of the load, with a systematic increase in COP measures from 5% to 20% conditions.

In line with the present findings, Zultowski & Aruin [11], reported a systematic increase in mediolateral COP displacement in proportion with increases in briefcase mass (10% and 20% body mass) in young adults. When standing upright without external loading, the line of gravity acts through the COM and centroid of the base of support, creating a relatively stable system [6]. However, holding a heavy asymmetrical load is likely to elicit a lateral displacement in the horizontal position of the COM, which must be counteracted by postural adjustments, thereby increasing postural sway [11]. The linear increases in mediolateral COP displacement with greater asymmetrical loads reported here are disconcerting considering that mediolateral instability has been identified as a predictor for the risk of falling in older people [12].

Interestingly, we found a significant reduction in the mean COP velocity when holding external loads, supporting recent findings using grocery bags [9,10]. An explanation for the slower mean velocity of the COP at all loads is that the greater load mass elicits motor latencies due to increases in the moment of inertia of the body [15]. From this perspective, holding a load in the hand may have restricted and/or delayed postural reactions. Similar reductions in the mean COP velocity across loaded conditions likely reflects a minimum functional level of the COP velocity (i.e., a floor effect) in this older group.

One limitation of the current study was examining quiet standing balance, which can only be applied to stationary conditions (e.g., waiting in a line). Future studies should consider the effects of external loads in more dynamic conditions (e.g., stepping off a kerbside). Additionally, the study is limited by the relatively small sample size that precludes us from generalising our findings to the wider older population and examining gender differences. This is important because older males and females have different postural sway [2]. In addition, although balance deteriorates at 60 years, at higher ages (i.e. > 70 years) there is a further, accelerating decline in postural stability [2]. Therefore, this study does now allow us to make comparative age and/or gender related conclusions. Despite these limitations, the current findings have important implications for older people regarding the risk of fall-related injuries when holding heavy loads during daily activities. From a fall-prevention perspective, it is advised that older people avoid carrying asymmetrical external loads greater than 5% of body mass.

CONFLICT OF INTEREST

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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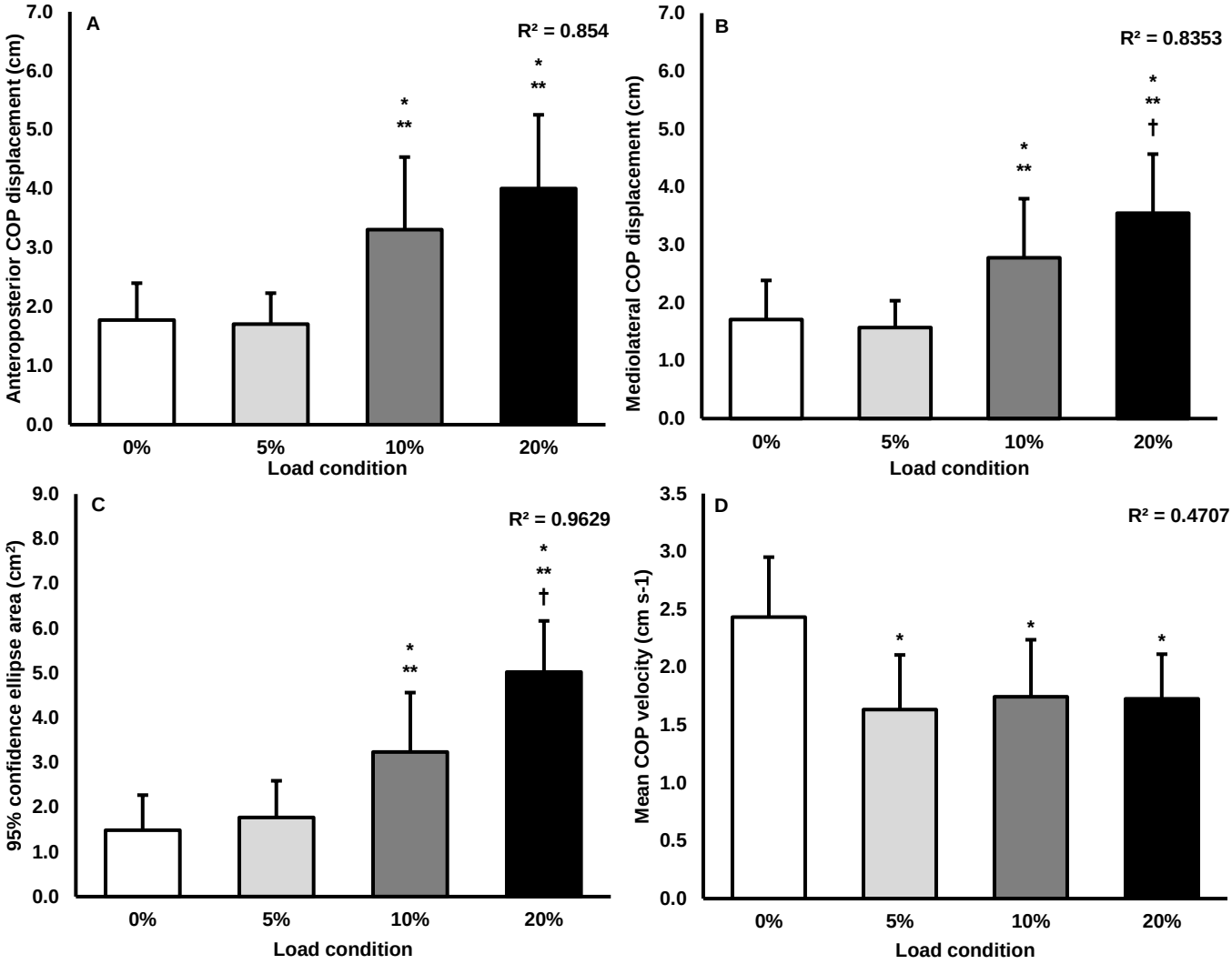

Figure 1: Means and SD for anteroposterior COP displacement (A), mediolateral COP displacement (B), COP area (C) and mean COP velocity (D) when holding a load at 5% (light grey), 10% (dark grey) and 20% (black) body mass compared to 0% (white). * Sig. different to 0% load. ** Sig. different to 5% load. † Sig. different to 10% load.