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Changes in postural sway and gait characteristics as a consequence of anterior load carriage

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ABSTRACT

Background: Anterior load carriage represents a common daily and occupational activity. Carrying loads in front of the body could potentially increase instability during standing and walking.

Research question: This study examined the effects of anterior load carriage on postural sway and gait parameters in healthy adults.

Methods: Twenty-nine participants (19 males, 10 females, age = 33.8 ± 12.7 years, height = 1.73 ± 0.07 m, mass = 75.1 ± 13.7 kg) were assessed in four conditions; (1) carrying no load (CON), (2) carrying a load with no added weight (i.e. empty box), (3) carrying a load with 5% body mass, and (4) carrying a load with 10% body mass. Anteroposterior and mediolateral centre of pressure (COP) displacement (cm) and the mean COP velocity (cm s-1) were used to characterise postural sway. Coefficient of variation of the stride length, stride time and double support time were calculated from 1 min of treadmill walking at a preferred pace for gait assessment.

Results: The addition of the 10% load elicited an increase in anteroposterior COP displacement when compared to CON (d = 1.59), 0% (d = 1.50), and 5% (d = 0.75) ($P < 0.001$). The addition of the 10% load increased stride time (d = 1.71) and stride length (d = 1.20) variability when compared to CON ($P < 0.001$).

Significance: In summary, the increase in postural sway and gait variability with added weight is dependent on the magnitude of the load, where the greater the load, the greater the effect on static and dynamic stability. Anterior load carriage potentially increases the risk of fall-related injuries.

1. Introduction

Previous research has indicated that carrying externals loads elicits an increase in centre of pressure (COP) measures of postural sway during quiet standing [1–5] and stride-to-stride gait variability during walking [6,7]. These changes are important as load carriage during standing and walking is a common practice in different occupational and daily tasks [8]. Therefore, further investigation of how postural stability is influenced by external loads is warranted.

To date, the vast majority of research that has investigated the influence of external loading on postural sway and gait parameters has examined posterior (e.g. backpack) [1,4,5,8] or lateral (e.g., grocery bags) load carriage [2,9–11]. Carrying external loads changes the mass-inertia characteristics of the body's centre of mass (COM). For example, when a backpack is added, the combined COM of the backpack and body shifts posteriorly, which is compensated for by a forward trunk lean to maintain the position of the body and load COM over the base of support [11]. Posterior load placement has been shown to elicit an increase in anteroposterior postural sway [1,4,5,8]. Additionally, carrying a backpack induces a slower walking velocity and increases double support time [12,13] and gait variability [7], reflecting reduced gait stability [14]. Accordingly, closer examination of balance and gait characteristics during different load carriage scenarios is essential.

Despite these initial enquires into the effects of carrying external loads on postural stability, little research has examined the effects of anterior load carriage (i.e., carrying loads with the hands and forearms). This gap in the literature is important as many daily (e.g. carrying a laundry basket) and occupational (e.g. courier delivery) activities require loads to be carried in front of the body. To further develop our understanding of the effects of external loads on postural stability, investigation is necessary to determine how anterior loads modulate changes in postural sway and gait characteristics. Only one study has reported the effects of anterior load carriage on postural sway [15]. It was shown that holding a box with 10% body mass in front of the body increased postural sway [15]. However, Shigaki et al. [15] examined only one load (i.e. 10% body mass). Given that impairments in postural

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sway [4] and gait stability [7] are proportional to the mass of the backpack, it seems well justified to investigate increasing anterior load mass on these stability metrics.

Studies examining the interaction between anterior load carriage and gait are scarce, however a study by Perry et al. [16] assessed the effect of anterior load carriage on obstacle-crossing behaviour. The authors reported that participants increased obstacle toe clearance when carrying an anterior load, which may have been influenced by availability of visual information regarding obstacle position. In addition, load carried with both hands removes the option of arm swing to counteract unbalanced loads on the body [17], which is an important restriction as arm swing contributes to overall gait stability [18]. Thus, there is a reasonable theoretical basis for expectation that anterior load carriage involving both arms will impair gait stability.

Within this context, to further develop our understanding of anterior load carriage, this proof of concept study examined the effects of increasing loads carried anteriorly on postural sway and gait parameters in healthy adults. We hypothesised that increases in COP measures of postural sway would be proportional to the load added to a box. Additionally, we also hypothesised that with increasing load, greater gait instability would be observed, characterised by changes in mean gait metrics and an increased gait variability. Understanding changes in postural sway and gait stability with anterior load carriage may contribute to the development of occupational training interventions aimed to mitigate the potentially negative effects of this type of loading on fall-risk. The present findings may also be influential in guiding future efforts to improve ergonomic design, such as on-body assistive devices to reduce both metabolic stress and balance impairments.

2. Methods

2.1. Participants

Twenty-nine healthy participants (19 males, 10 females age; 33.8 ± 12.7 years [18–54 years], height; 1.73 ± 0.07 m, mass; 75.1 ± 13.7 kg) volunteered to participate in this study after providing written, informed consent. Exclusion criteria included: age ≥60 years, a history of lower back pain or lower back injury, and any neurological, musculoskeletal, orthopaedic and/or cardiovascular or pulmonary diseases that might affect balance or gait. The study was carried out in accordance with the guidelines outlined in the declaration of Helsinki (1964) and the study procedures were approved by the institutional ethics committee.

2.2. Procedures

A semi-randomised controlled cross-over study design was employed with each participant visiting the laboratory on two separate occasions in a counterbalanced order; (1) static postural sway assessment and, (2) gait assessment. Participants performed four conditions during each assessment; (1) control with no load (CON), (2) anterior load with no added weight (0%, empty box weight; 1.5 kg), (3) anterior load with 5% body mass (3.75 ± 0.68 kg) and (4) anterior load with 10% body mass (7.51 ± 1.37 kg). The within session order of task conditions were randomly assigned using Research Randomizer (www.randomizer.org). Each box (external dimensions; L 48 cm × W 39 cm × D 20 cm, internal dimensions; L 39.5 cm × W 33.5 cm × D 17 cm, volume; 22.5 L, mass; 1.5 kg) was filled with sealed bags of sand to ensure the distribution of mass was relatively uniform and to prevent excessive movement of the load when walking. During loaded and unloaded conditions, participants were instructed to fix their eyes ahead at a point on the wall and to hold the box against their abdomen with elbows flexed at 90° [16].

2.3. Static postural stability assessment

To examine the effects of load magnitude on postural sway each participant performed quiet stance trials while standing on a force platform (AMTI, AccuGait, Watertown, MA) for 30 s. Data were sampled at 100 Hz (AMTI, Netforce, Watertown, MA) and the maximal displacement of the COP in the anteroposterior and mediolateral directions (cm) and mean COP velocity (cm s^{-1}) were subsequently calculated (AMTI, BioAnalysis, Version 2.2, Watertown, MA). Participants were asked to stand as still as possible on the force platform with their feet together, arms by their sides (CON), while gazing at a target 1.5 m from the force platform. Participants practiced each postural task once prior to recorded trials. A total of three trials were recorded consecutively for each condition and the mean of these trials was used in subsequent analysis.

2.4. Gait assessment

Gait stability determined during steady-state walking on a treadmill (h/p/Cosmos, Gaitway, Traunstein, Germany) using two in-dwelling force platforms (Kistler, Winterthur, Switzerland) (Fig. 1). Participants walked with their own footwear at a self-selected speed (4.21 ± 0.26 km/h). We asked participants to wear comfortable walking shoes, but not shoes with a heel. To habituate participants to walking on the treadmill and to ascertain self-selected walking speed

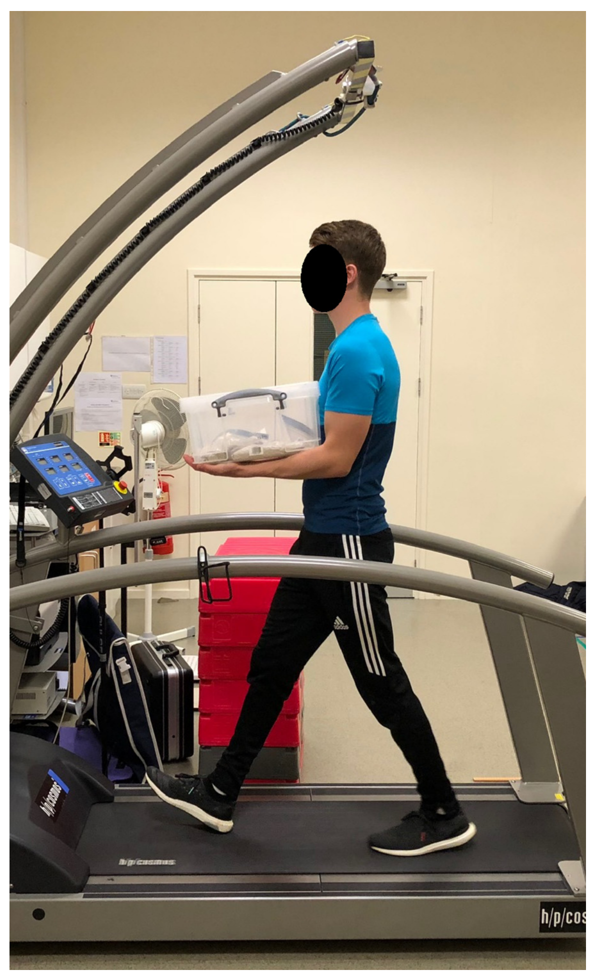

Fig. 1. Participant walking on the treadmill while carrying anterior load.