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Short communication

Changes in postural sway as a consequence of wearing a military backpack

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ABSTRACT

Military personnel are often required to carry all of their personal supplies and equipment for long distances during both training and combat situations, creating many biomechanical and postural challenges for these individuals. In addition to other problems such as generalized fatigue and the development of stress fractures, significant external loads may also affect a soldier's postural sway. The purpose of this study was to assess changes in postural sway as a consequence of wearing a military backpack in females. Forty-three female subjects between the ages of 18 and 25 volunteered to participate. There were two conditions: unloaded and while wearing an 18.1 kg military backpack. Each subject stood with two feet on a force platform for 30 s under both conditions while center of pressure (COP) data were collected. COP path length increased 64%, medial–lateral excursion increased 131%, anterior–posterior excursion increased 54%, and COP area increased 229% with addition of the backpack ($p < 0.0001$ for all of these measures). These data show that wearing 18.1 kg of external weight in a military backpack increases the postural sway of females, which may in turn increase the likelihood of falls and injury.

1. Introduction

Much of the literature examining the effects of wearing a backpack on human gait and posture has focused on children wearing school bags [1,2]. However, many adult populations either wear a heavy external load such as a backpack or carry extra weight in their torso due to obesity. Studies have shown changes in gait as a consequence of wearing a heavy backpack in adults [3], but few studies have investigated the postural implications. Increased mass near the torso may increase the risk of injury due to falling within a variety of populations including military recruits, recreational hikers, and overweight individuals. The current study was purposely focused on military personnel because of the high incidence of injury within the first few weeks of military training [4].

Military personnel are required to carry their personal supplies and equipment for long distances during both training and combat, creating many biomechanical and postural challenges for these individuals. The US Army recommends that soldiers carry a maximum of 22 kg during combat and 33 kg while marching [5]. It is important to investigate carrying a heavy load in military backpacks, as the information garnered from such work may contribute to the development of more advanced systems that may lessen injury risk. Design modifications of the backpack, for example altering the stiffness of the backpack suspension system, can change the forces applied to the skeletal system [6].

Female military recruits are twice as likely to be injured during basic training as male recruits [4]. In the military, the same amount of equipment is carried by a female recruit as a male; this load would typically constitute a greater proportion of her body mass compared with her male counterpart. The increase in loading for female personnel should be considered in the context that women are more likely than men to experience musculoskeletal problems, including sprains, strains, and more serious injuries, when participating in sports or other physical activity [7].

The increased mass of a loaded backpack makes it harder to initiate motion and requires greater moments about the axes of rotation to control motion. Load carriage has the potential to alter postural control mechanisms [8], which may in turn alter the risk of falls and injury [9]. A better understanding of the postural perturbations elicited by additional load carriage in specific populations is therefore important. The purpose of this study was to determine changes in postural sway as a consequence of wearing a military backpack in females and to relate these changes to mechanical and/or physiological mechanisms that may be responsible for the differences between the two conditions.

2. Methods

Forty-three female subjects were recruited from the university student population and provided informed consent. All procedures were approved by The Pennsylvania State University Institutional Review Board. The mean age of the

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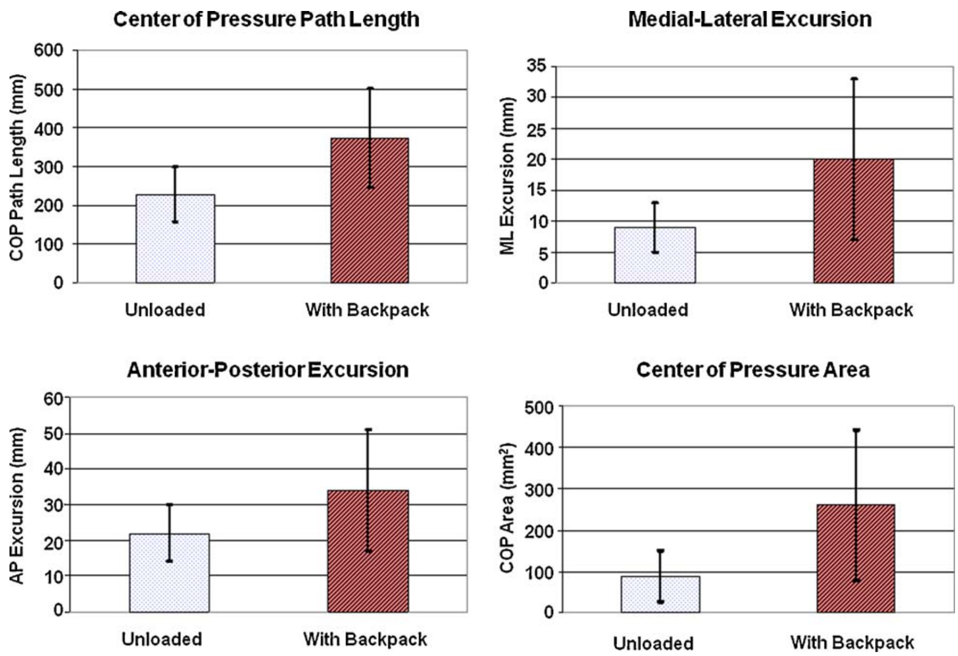

Fig. 1. Center of pressure path length, medial–lateral excursion, anterior–posterior excursion, and center of pressure area with bars indicating the standard deviation of each measure. Addition of the backpack significantly increased all four measures of postural sway ($p < 0.0001$).

subjects was 20.7 years (range 18–25 years), which corresponds to the ages of new military recruits. The subjects had a mean height of 1.64 m (1.54–1.76 m), mean mass of 63.6 kg (46.0–89.5 kg), and a mean body mass index of 23.6 kg m^2 (17.7–35.4 kg m^2). Subjects were excluded from the study if they had any neuromuscular disorders, lower extremity injuries, back problems, or balance problems.

Two conditions were tested: unloaded and with a backpack. Due to the requirements of the overall study, each subject completed the unloaded trial before completing the backpack trial. The backpack was loaded with a bag of rocks with a mass of 11.3 kg, and the remainder was comprised of linens and the mass of the pack itself, resulting in a gross mass of 18.1 kg. The mass was selected to be under the recommended maximum pack mass of 22 kg for recruits during combat to minimize injury risk [10]. For both conditions, the subjects stood quietly on a force plate (Kistler, Model 9287A), with their feet shoulder-width apart and crossed their arms over their chest while looking at an "X" located at eye level 4.7 m from the subject. The position of the subject's feet on the force plate was marked for consistent placement across conditions. Each subject was given as much time as needed (no subject took more than 5 min) to acclimate to the unloaded and backpack conditions. Once the subject indicated she was comfortable and took her position on the force plate, 30 s of data collection (at 1000 Hz) was initiated [11].

The center of pressure (COP) data were analyzed to determine measures of postural sway. These measures were: path length, medial–lateral (ML) and anterior–posterior (AP) excursion, and area of motion. COP path length was computed by calculating the total distance traveled by the COP during the trial. The COP excursion was defined as the maximum displacement of the COP in each direction (i.e., the distance between the furthest points in the AP and ML directions). COP area was calculated by fitting an elipse to the area described by the COP motion [12]. All dependent variables were compared across both conditions using a paired t-test with a conservative α-level of 0.01 to account for the multiple comparisons. Additionally, linear regressions were utilized to investigate the correlation between the measured parameters and body mass, percentage body mass of the external load, and height.

3. Results

COP motion was greater in the backpack condition compared with the unloaded condition (Fig. 1). The path length increased by 64% with the addition of the backpack ($p < 0.0001$). The ML and AP excursions were both greater in the backpack condition compared with the unloaded condition ($p < 0.0001$). Finally, the area encompassed by the COP increased 229% due to the addition of the backpack ($p < 0.0001$). There were no statistically significant correlations between the measured parameters and body mass, percentage body mass of the external load, or height.

4. Discussion

There was greater motion of the COP while wearing a backpack; the subjects moved their COP closer to the boundary of support. Horak and Nashner [13] discussed two strategies by which individuals maintain their upright stance in the AP direction: the ankle strategy and the hip strategy. Visual observation suggested that the ankle strategy was used in this study, although further study would be required to confirm this. Wearing a military backpack challenges this mechanism, as it appears to increase sway in the AP direction. Additionally, Winter [14] described the load-unload strategy, which is used to control an individual's ML sway. Wearing a military backpack also appears to challenge the load-unload strategy, as sway increased in the ML direction. Increased measures of postural sway, especially related to medial–lateral excursion, are correlated to a higher likelihood of falls in elderly adults [9]. In healthy young women, wearing a military backpack increases the four measures of postural sway evaluated in this study and likely makes them more susceptible to losing their balance.

Both mechanical and physiological mechanisms may contribute to increased postural sway while wearing a military backpack, and in this study a specific mechanical factor was manipulated. From a mechanical perspective, upright stance is often modeled as an inverted pendulum, and the mass in the backpack would make such a system less stable. When an individual is "perfectly upright," gravity acts through her center of mass and through the centroid of her base of support, creating a stable system. However, a small departure from this position allows the body to accelerate away from the "perfectly upright" position, and the resulting motion needs to be counterbalanced by one of the aforementioned strategies and will therefore increase postural sway. A physiological mechanism influencing postural sway is that the wearing of a military backpack places higher demands on the cardiovascular system. As the heart rate and respiration change to accommodate the load, there is greater COP motion as a consequence of the increased motion of these internal organs [15]. Another physiological mechanism involved is related to the individual's proprioceptive system, which has been shown to affect postural control

[16]. The backpack changes the muscle activation patterns necessary to maintain upright stance, thereby altering the proprioceptive feedback of the nervous system and the postural sway.

Corbeil et al. [17] investigated the effect of obesity on postural sway and showed that merely adding additional mass to the body made maintaining postural stability more challenging when responding to a minor perturbation. Corbeil's results suggest that under a perturbation, recovery may be more difficult in the backpack condition, and the present study provides evidence that the motion of the COP will be greater even prior to a perturbation. This may be a more of a problem for women who have lower plantarflexion strength than men, even when normalizing for body size [18].

A potential limitation of the current study was that the subjects were not experienced in wearing an 18 kg backpack, but all had worn backpacks before and a common time for injury for military personnel is during the basic training when the recruits would also not be experienced in wearing an 18 kg backpack [4]. The study did not examine the influence of muscle fatigue on postural stability, while in natural conditions this could be an important factor. Future studies could incorporate a fatiguing activity, such as running on a treadmill, into the protocol and measure the COP motion at set time intervals under unloaded and backpack conditions.

The purpose of the current study was to determine how wearing a heavy military backpack affected postural sway in young, healthy females. These effects may have important implications regarding injury rates within this population. It was found that wearing a military backpack altered the postural sway in females, and may therefore increase the likelihood of falls and injury. The findings of increased postural sway as a result of wearing a heavy backpack could be generalized to recreational hikers who carry their camping equipment or to overweight individuals who carry extra weight in their trunk.

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Conflict of interest statement

There are no financial or personal relationships that would create a conflict of interest regarding this work.

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