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Effect of the Usual Weight of a Backpack on Body Sway during Quiet Standing

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Abstract. [Purpose] The purpose of this study was to verify the effect on body sway during quiet standing of the habitual weight carried by students in a backpack. [Subjects] Forty-six students between the ages of 8 and 14 years volunteered. [Method] The percentage of body weight (% BW) of each student's backpack was calculated and the students were separated into three groups based on the results: Group A (0–7% BW), Group B (7.01–14% BW) and Group C (14.01–21%BW). [Results] The use of the backpack increased the area of the CoP sway, displacement and mean speed of the CoP data in the antero-posterior and medial-lateral directions in Group C. [Conclusion] Therefore, observed responses in the body posture changes caused by the weight of the backpack were similar to those reported in other studies conducted with different methodos of investigation.
Key words: Posture, Backpack, Stabilogram, Load carriage, Biomechanics

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INTRODUCTION

For many individuals, carrying a backpack begins the moment they start school and continues into their adult life. Load carrying by means of a backpack has been linked to some health alterations such as muscle pain and back tension, many times including pain in the lumbar region, as well as changes in gait and posture[1–4)].

Besides the relation between postural changes and backpack use[5, 6)], excessive weight can also contribute to a greater incidence of spinal column pain in children and adolescents[3)]. Thus, fatigue and body aches in school-age children are the most common manifestations when backpack use is prolonged[1)].

In attempts to minimize the possible effects of the weight of backpacks some studies[3, 7–9)] have suggested that the backpack load should be limited to a backpack weight of between 10 and 15% of body weght (BW).

Bauer and Andris[8)] suggested a limit of 10% BW after using postural evaluation, suface electromyography, cardiac frequency and effort indices as methods to investigate the possible effects of backpack weight on the body.

In fatigue analysis used during transportation of the bag, it was found that backpack loads for children should be restricted to no more than 15% BW for walks of up to 20 min duration to avoid muscle fatigue[7)]. When this limit is calculated in segments, through observation of segment alteration such as angles of the trunk, head and limbs, the suggested limits can range from 5 to 15% BW[9)].

If we consider that the erect posture of man is inherently unstable, and that it is maintained through continuous sensory information from the visual, proprioceptive and vestibular systems[10)], changing the weight of the backpack in an experiment or using as a control individuals who do not wear a backpack may not reflect the real action of the backpack weight on the tonic postural system.

Likewise, questions that should be considered in relation to the results obtained utilizing these experimental indices are: whether the individual's body undergoes postural adjustment due to the carrying of loads to which it is not habituated, and if so whether this interferes with the study results about backpack action on posture control. These observations were not addressed in the studies investigating the action of the backpack weight on posture[3, 7–9)].

Depending on whether the task at hand is static or dynamic in nature, the central nervous system employs different strategies to form the appropriate muscle synergies needed to maintain equilibrium[11)]. In addition to individual perceptual and motor skills, the area of support in terms of foot position, musculoskeletal characteristics and task constraints play an important role in postural stability. These considerations have not been addressed in previous studies[3, 7–9)] and the use of stabilometric parameters can provide the most relevant measures to quantify postural steadiness.

The stabilometric parameters characterized by measurement of forces exerted against the ground from a force plat-

Table 1. Distribution of subjects according to backpack weight in relation to body weight (%BW)

Group	Age (years) (Range)	BW (Kg) (Range)	Height (m) (Range)	BPW (Kg) (Range)	% BW (Kg) (Range)
A	12 (9–14)	47 (27.5–71.7)	1.5 (1.3–1.7)	2.1 (1.3–3.7)	4.6 (2.79–6.31)
B	10.3 (8–14)	39.2 (22.7–62.5)	1.4 (1.3–1.7)	3.6 (1.9–7)	9.5 (7.1–13.2)
C	11 (8 –14)	36.1 (23.1 – 52.5)	1.4(1.2–1.7)	6.2 (4.8–9.1)	17.8 (14–20.8)

BW= Body Weight; BPW= Backpack Weight. Group A (0−7% BW, n=17), Group B (7.01−14% BW, n=17) and Group C (14.01−21% BW, n=12).

form during quiet stance are commonly used to quantify postural steadiness both in research and in the clinic. Typically, stabilometry focuses on the properties of the centre of pressure (CoP) time series, representing the point location of the ground reaction force vector as it evolves in the horizontal plane (2D) or along two orthogonal axes, fixed with the platform (antero-posterior (AP) and medio-lateral (ML))[12].

The purpose of this study was to use stabilometric parameters to verify the effect on the body sway during quiet standing of the weight habitually carried in a backpack by student's.

SUBJECTS AND METHODS

Forty-six subjects (17 females, 29 males) were recruited from the primary and middle school population. Subjects had a mean age of 11.13 years (range 8–14 years), a mean height of 147.1 cm (range 120.2 −170.3 cm) and a mean body weight (BW) of 41.4 Kg (range 22.7–71.3 Kg).

An orthopedic physician examined all subjects before each trial to ensure that they had no musculoskeletal injuries, neuromuscular disorders, lower extremity injuries, back disease, balance problems or pain. The procedures of the whole experiment were presented to the subjects and their parents before the test. Informed consent was obtained from the subjects and their parents. The Nove de Julho University ethics committee approved the study.

Following collection of anthropometric data (stature and BW) the weight of the backpack of each student was measured and calculated as a percentage of body weight (% BW). Subsequently, the subjects were distributed in to three groups according to their backpack weights (Table 1): Group A (0–7% BW; n= 17), Group B (7.01–14% BW; n=17) and Group C (14.01–21% BW; n=12).

Four conditions in quiet standing were tested: (i) eyes open without backpack; (ii) eyes open carrying a backpack (weight carried); (iii) eyes closed without backpack; (iv) eyes closed including backpack . The order of the trials was randomized for each subject. The subjects were asked to select a comfortable position with their feet approximately shoulder width apart, and to stay as still as possible looking straight ahead to a point at eye level. The stabilometric data were recorded with a sampling frequency of 100 Hz for 60 s in each trial, with the feet close together on a force plate BIOMEC 400 (EMG System®). This platform is characterized by load cells with an internal circuit that changes electrical resistance upon the application of a force.

The data analyses were performed using Matlab 7.1 software (The Math Works, Inc. Natick, MA, EUA). The Center of Pressure (CoP) data were low-pass filtered at 30 Hz with a Butterworth filter. After filtering, the first 10 s of the trial, considerd as an adaptation period, were discarded. For the remaining 50 s of CoP data, we computed the area of the CoP sway, displacement, mean speed and frequency of the CoP data in the antero-posterior and medial-lateral direction's.

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 ellipse to the area described by the CoP motion as described by Oliveira et al.[13].

The CoP speed was calculated as the total CoP displacement divided by the measurement time. The frequency of the CoP displacement is the frequency below which 80% of the CoP spectral power occurs[14]. The power spectral density of the detrended CoP data was estimated by the Welch periodogram method with a resolution of 0.039 Hz.

The mean of the two trials in each condition was calculated and used for statistical analyses. The effects of the backpack in the two visual conditions were determined by the two-tailed *t*-test for paired samples with an alpha level of 0.05 using SPSS 16.0 software (Chicago, II, U.S.A).

RESULTS

In the experiment, the effect of the backpack on the CoP sway was observed in Group A and Group C (Table 2). In Group A, it was noted that all significant effects were due to the manipulation of visual information. The results show that postural sway in the AP and ML directions was altered by carrying a backpack in Group C.

DISCUSSION

The possibility that the postural adjustments noted in previous studies[3, 7–9] are related to the experimental conditions in which individuals carried loads different from the backpack weight habitually carried was not confirmed by this study. This is based on the fact that body sway was found in the group of individuals who usually carried backpacks with weights above 14% BW (Group C).

Although significant differences were observed in Group A with the eyes open, these results are not sufficient to confirm the influence of backpack weight of up to 7% BW on corporal stability.

If we consider that somatosensory stimuli also provoke changes in corporal stability[15, 16], it is possible that the lower weight of the backpack in Group A acted as a peripheral stimulus with somatosensory action and not as a mechanical factor capable of provoking changes in postural patterns.

Table 2. Mean and standard deviation (SD) values of the variables CoP area, speed, and frequency of the CoP sway in the anterior–posterior (AP) and medial–lateral (ML) directions. Two visual conditions were tested (with vision and without vision)

		Area (cm^2)	CoP (cm)		Speed (cm/s)		Frequency (Hz)	
			AP	ML	AP	ML	AP	ML
With Vision								
Group A	WhB	1.22 ± 0.79	12.28 ± 5.59	9.88 ± 4.12	0.8 ± 0.17	0.74 ± 0.14	0.52 ± 0.15	0.39 ± 0.14
	WB	2.41 ± 1.87*	11.83 ± 5.23	9.77 ± 3.91	0.89 ± 0.21*	0.83 ± 0.22 *	0.42 ± 0.22	0.35 ± 0.12
Group B	WhB	2.62 ± 2.56	11.21 ± 6.25	9.01 ± 3.86	0.95 ± 0.25	0.89 ± 0.31	0.41 ± 0.15	0.35 ± 0.17
	WB	1.97 ± 1.03	11 ± 6.51	9.54 ± 4.15	0.93 ± 0.16	0.86 ± 0.18	0.43 ± 0.14	0.39 ± 0.18
Group C	WhB	1.72 ± 1.03	9.79 ± 6.67	7.49 ± 3.97	0.86 ± 0.16	0.84 ± 0.17	0.42 ± 0.19	0.37 ± 0.07
	WB	3.45 ± 1.89*	9.6 ± 6.24	7.51 ± 4.62	1.03 ± 0.21 *	0.97 ± 0.16 *	0.35 ± 0.24	0.44 ± 0.18
Without Vision								
Group A	WhB	1.59 ± 0.85	12.01 ± 5.52	9.68 ± 4.01	1.01 ± 0.17	0.89 ± 0.18	0.48 ± 0.21	0.37 ± 0.1
	WB	3.37 ± 2.63	12.12 ± 5.48	9.15 ± 3.62	0.96 ± 0.17	0.86 ± 0.22	0.52 ± 0.25	0.42 ± 0.08
Group B	WhB	4.87 ± 3.83	10.71 ± 6.58	9.32 ± 3.93	1.21 ± 0.26	1.06 ± 0.33	0.40 ± 0.16	0.38 ± 0.13
	WB	3.01 ± 2.13	10.65 ± 6.06	8.79 ± 4.12	1.64 ± 1.66	1.33 ± 1.25	0.49 ± 0.31	0.45 ± 0.46
Group C	WhB	2.82 ± 1.79	9.15 ± 6.55	7.16 ± 4.19	1.13 ± 0.23	0.99 ± 0.17	0.42 ± 0.16	0.39 ± 0.1
	WB	4.77 ± 2.33*	9.64 ± 6.63	8.11 ± 5.36	1.26 ± 0.28*	0.16 ± 0.24*	0.51 ± 0.23	0.42 ± 0.15

*Statically significant differences ($p<0.05$; Pared t-test). WhB: without backpack, WB: with backpack.

Nevertheless, the fact that the same stimulus occurred with the eyes closed should be considered in that no alteration in the oscillation found under this condition.

One possible explanation for this result is the interdependence of vision and somatosensory information when these two stimuli are presented at the same moment[17]. Thus, when the visual stimulus was removed, there was one less demand on the postural system and this, in some way, could have contributed to lessen the body sway.

The absence of body sway in the standing position in Group B also strengthens our hypothesis that the lower backpack weight of Group A acted as a peripheral stimulus capable of influencing the somatosensory system. Goh et al.[18] proposed that backpack carriage would increase stability as the increased mass moment of inertia of the combined body and backpack system would mean that small perturbations of stance would produce less response. In the same way, the absence of significant alterations in the oscillatory responses of Group B may indicate that the greater weight of the backpack in this group eliminated the small oscillations resulting from postural organization, due to a possible somatosensory response, as the Group A results suggest.

However, if the responses of Groups B and C are compared, it is possible to verify that there is a weight limit below which there is no influence on body sway during quiet standing. In this case, taking into consideration the average backpack weight observed in Group C, this limit is below 17% BW, as the area and speed of this group's mean body sway showed significant increases independent of the visual information (see Table 1).

The results of this study are close to the 10–15% BW limits suggested as being the safest limits for backpack carrying[3,7–9]. Furthermore, it is also possible to deduce that the corporal modifications are not related to an adjustment of the postural system to an external condition not yet recognized, and that the weight of the backpack is the principle element with significant influence on body balance.

Another important observation is that the suggested safe limit for backpack transport (10–15% BW) does not differ among the studies carried out with differing methodologies and experimental tests[3, 7–9] including the analysis of body sway during quiet standing as performed in this study. This increases the evidence that the upper limit for backpack weight carrying should be 15% BW.

There is not yet a consensus about the weight limit for backpack carying 10% BW seems to be the safest and most coherent value for to avoiding any type of physical or functional injury to the backpack carrier. The results of the present study indicate that the reliability of traditional stabilometric parameters is acceptable if the purpose of the study is to analyze the influence of the backpack on the postural system.

The postural sway results show that the weight of the backpack on postural balance in the age group studied and that these changes may have important implications for injury rates in this population, as described in previous studies[1–4].

The findings of increased postural sway as a result of carrying a heavy backpack may be generalized for all individuals who are in the same age range of those investigated in this study. So, although there is not yet a consensus about the weight limit for backpack transport, up to 10% BW seems to be the safest and most coherent limit in order to avoid any type of physical or functional injury to the backpack carrier. These results can be used as guideline in relation to the weight limit for safe carrying of a backpack among primary and middle school populations.

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