ANALYSIS OF THE BACKPACK LOADING EFECTS ON THE HUMAN GAIT

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INTRODUCTION: Gait is a simple activity of daily life and one of the main abilities of the human being. Often during leisure, labour and sports activities, loads are carried over (e.g. backpack) during gait. These circumstantial loads can generate instability and increase biomechanical stress over the human tissues and systems, especially on the locomotor, balance and postural regulation systems. According to Wearing (2006), subjects that carry a transitory or intermittent load will be able to find relatively efficient solutions to compensate its effects. These are dependent upon the walking distance and of the load characteristics - size, weight and location relatively to the body (Hsiang, 2002).Thus, these solutions should become a concerning factor (Koh, 2009) and a topic of scientific research, particularly in what concerns the inventory of its biomechanical effects and the possible strategies to be developed in order to minimize its effects.
The aim of the present study was to analyze the effects of an occasional dorso-lombar load during the gait through the use of a backpack.

METHOD: Data was collected from forty healthy subjects (twenty males: mean stature 1.75±0.07m and mass 72.01±6.75kg; twenty females: mean stature 1.63±0.06m and mass 59.45±5.71kg), students of Sport Sciences with body mass index (BMI) less than 25, aged between 18 and 45 years and without any dysfunction that affect the independent gait. The subjects were informed of the purpose of study and all signed written informed consent.
Gait characterization was accomplished through ground reaction force (GRF) analysis. To collect the GRF data, a BERTEC force plate (model: 4060-15) was used. A devoted amplifier system (BERTEC AM 6300) and a 16 bits analogical-digital conversion unit (BIOPAC) were also used. The sampling rate was established at 1000 Hz.
Each subject was assessed initially in a normal condition (without load) and then loaded (backpack condition). Data were collected regarding three valid rehearsals of each test on the force plate (right foot). Subjects carried on the backpack, fixed at the dorso-lombar region, a static load that allow the subject + backpack to reach the “total BMI” of 30. Each subject walked three times in each condition, at a self-selected velocity, along the experimental walkway (600 cm × 92 cm × 15 cm) in which the force plate was engraved.
The results for the three components of the GRF (vertical, anterior-posterior and medial-lateral) were expressed as percentages of the total weight, with and without load. The statistical analysis was conducted with SPSS 16.0 software. Data on independent variables studied were statistically analyzed by measures of central tendency (mean) and dispersion (standard deviation), and compared by paired student t-test (with vs. without load), the significance level adopted was α=0.05.

RESULTS: The main results of the study are presented in Table 1. Results include chronometric (temporal) and the dynamometric (GRF) variables. Statistical significant differences ($p < 0.05$) are marked (*). From these we highlight an increase in the stance phase duration and a reduction in the relative magnitude of the first and second peaks of the vertical component in the load condition.

DISCUSSION: During loading, an increase in the two peak values of the vertical GRF component was observed, together with an increase of the stance phase duration. A higher value of the horizontal braking force (anterior-posterior GRF component) was also noted. On the contrary, a reduced maximal value of the latero-medial component was registered. These results showed that even when the weight of the backpack is included in the calculations of GRF as a percentage of total weight (body + pack), the mean values obtained with and without load traduce a relevant disturbance of the dynamometric profile of the gait pattern. These results conflict with previous results from Tilbury-Davis and Hooper (1999), which evaluated the biomechanical effects of load (20 and 40 kg) in military subjects. Nevertheless, those were trained subjects in this particular task.

Table 1. Mean and standard deviation (Std.) values for the studied chronometric and dynamometric variables obtained for unloaded and loaded situations in both genders

Variables	Normal		Loaded		Confidence Interval			
	Mean	Std.	Mean	Std.	Lower	Upper	t	Sig.
Duration stance phase (s)	0.78*	0.06	0.81*	0.07	-0.055	-0.014	-3.36	0.002
First peak - Vertical Component								
(N/BW)	1.03*	0.04	0.99*	0.06	0.021	0.057	4.35	0.000
Time (% stance phase)	25.96	3.09	26.68	3.24	-1.674	0.200	-1.59	0.120
Minimum value between Vertical peaks								
(N/BW)	0.82	0.05	0.82	0.06	-0.016	0.019	0.18	0.859
Time (% stance phase)	46.10	5.95	46.02	4.32	-1.740	1.896	0.09	0.931
Second peak - Vertical Component								
(N/BW)	1.10*	0.05	1.07*	0.06	0.018	0.052	4.20	0.000
Time (% stance phase)	74.64*	2.46	72.64*	3.40	1.139	2.865	4.69	0.000
Braking Force - anteroposterior component								
(N/BW)	-0.14*	0.03	-0.15*	0.03	0.003	0.018	2.93	0.006
Time (% stance phase)	18.12	2.66	17.99	1.87	-0.655	0.956	0.38	0.708
Propulsion Force - anteroposterior component								
(N/BW)	0.19	0.03	0.18	0.03	-0.001	0.014	1.79	0.081
Time (% stance phase)	83.09	1.91	82.99	1.90	-0.473	0.664	0.34	0.736
Peak - mediolateral component								
(N/BW)	0.10*	0.02	0.09*	0.01	0.002	0.012	2.77	0.009
Time (% stance phase)	46.91	21.91	46.32	18.51	-4.898	6.081	0.22	0.829

* Statistical significance $p < 0.05$

Pierrynowski, Norman and Winter (1981) suggested that gait adjustments occurred when loads of 34kg are carried by subjects whose weight was approximately 72kg (47% body weight). The maximal load used in our research for all the studied subjects was lower than the critical absolute value of 30kg proposed by the referred authors, but sometimes higher in relative terms considering the subject's body weight (57%), which suggest the need of a revision of the boundary proposed by the referred authors. Authors also reported an attenuation of the loading and unloading rates when carrying the higher load of 40kg, suggesting a protection of the biomechanical system. This seems to be in agreement with the reduction of the relative values for the first and second peaks of the vertical GRF component for the load condition obtained in our study, combined with the increased stance duration.

CONCLUSION: The present study showed an adaptation of the subjects to the load condition, with: (i) an increase of the stance phase duration; (ii) a significant reduction of the GRF vertical component peaks, and (iii) an increase of the horizontal braking force.

REFERENCES:

Koh, T.S. (2009). Effects of backpack load position on spatiotemporal parameters and trunk forward lean. *Gait & Posture*, 29, 49–53.

Wearing, S. C., E. M. Hennig, et al. (2006). The biomechanics of restricted movement in adult obesity. *Obes Rev*, 7 (Suppl.1), 13-24.

Hsianga,SM & Chang,C. (2002). The effect of gait speed and load carrying on the reliability of ground reaction forces. *Safety Science*, 40, 639–657.

Pierrynowski, M.R., Norman, R.W. and Winter, D.A. (1981). Mechanical energy analyses of the human during load carriage on the a treadmill. *Ergonomisc*, 24, 1-14.

Tilbury-Davis, D.C and Hooper, R.H. (1999) The kinetic and kinematic effects of increasing load carriage upon the lower limb. *Human Movement Science,* 18 (5), 693-700.

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