Portuguese Journal of Sport Sciences
11 (Suppl. 2), 2011

THE INFLUENCE OF DIFFERENT SPEEDS ON BACKPACKER´S GAIT KINETICS

Marcelo Castro[1,2], Sofia Abreu[1], Helena Sousa[1,2], Cristina Figueiredo[1], Leandro Machado[1,3], Rubim Santos[2] and João Paulo Vilas-Boas[1,3]

CIFI2D, Faculty of Sport, University of Porto, Porto, Portugal[1]
School of Health Technology of Porto, Porto, Portugal [2]
Porto Biomechanics Laboratory, University of Porto, Porto, Portugal [3]

This study analyzed the influence of different speeds on ground reaction force's (GRF), impulses and mean vertical force during gait of people submitted to occasional overload (backpack). A force plate was used to record the GRF data of 60 young adult subjects walking in two different cadences: 69 steps/min (slow gait) and 120 steps/min (fast gait). During the slow gait, the impact and propulsive impulses of vertical GRF, propulsive impulse of anterior-posterior GRF, impulse of medial-lateral GRF and duration of stance phase were larger than during the fast gait; the mean vertical force was the only variable that showed larger values during fast gait. Therefore, slow gait may present a larger possibility of blister development and gait unbalance, while the fast gait, even presenting a small impulse, seems to be more harmful to the musculoskeletal system.

KEY WORDS: backpack, overload, ground reaction force, impulse.

INTRODUCTION: The backpack has been widely used by students, hikers and military as a device to transport load. As a consequence a number of studies have been conducted to identify the biomechanical and physiological impact of this occasional overload on the musculoskeletal system (Birrell et al., 2007; Browing & Kram, 2007; Knapik et al., 1996). Some of the analyzed variables were the impulse or force-time integral of the three components of the ground reaction force (GRF), and mean values of vertical force component (Jordan et al., 2007; Lewek, 2010; Vito et al., 2009). The vertical forces (impulse and mean value) provides information about impact forces, anterior-posterior impulse provides information about impact and blister development and the medial-lateral impulse may be linked to dynamic balance and stability (Birrell, et al., 2007).
Changes in walking speed seem to influence the impulse magnitudes. Previous studies found that as the walking speed increases the vertical GRF impulse decreases (Jordan, et al., 2007; Kimberlee et al., 2007; Vito, et al., 2009), while anterior-posterior GRF impulse increases (Chung & Wang, 2010; Vito, et al., 2009).
The previous studies, however, have not evaluated the effect of gait speed on GRF with additional loading from carrying a backpack. Therefore the purpose of this study was to analyze the influence of different speeds on GRF' impulses and mean vertical force during gait of people under occasional overload (backpack).

METHODS: The study was approved by the local ethical committee and all participants freely signed an informed consent term, based on Helsinki's declaration, which explained the purpose and the procedures of the study.
Participants: The sample was selected by convenience from university students of sport sciences, and was composed by 60 subjects (30 male and 30 female) with a mean age of 23.0 (±3.7) years, mean height of 168.0 (±9.0) cm and mean body mass of 67.8 (±11.2) kg. All participants were physically active and did not present a body mass index (BMI) above 25, didn't have any traumatic-orthopedic dysfunction nor have difficulties on independent gait.
Instruments: A Bertec force plate (model 4060-15, Bertec Corporation, Columbus, USA), operating at 1000 Hz, was used to measure GRF and a Maelzel metronome (Wittner, Germany) to control the step frequency. Three digital non-coplanar video cameras were used for visual inspection, if necessary.

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Experimental Protocol: The participants underwent three phases of testing: preparation, familiarization and testing. In the first phase the procedures to be implemented were explained to the participants and anthropometric data (height and weight) were recorded. A neutral shoe (ballet sneaker) was provided for all participants aiming to minimize the effects of different soles. For each participant the weight to raise their BMI to 30 was calculated; then a backpack was filled with sand and fixed in the central area of each subject's back; the weight placed inside the backpack ranged from 14.1 to 30.1 kg (mean weight 20.3±4.4 kg). This overload was chosen because it is considered to leave the locomotor system more susceptible to injuries (Ko et al., 2010), and the additional upper body mass mimicked obesity, but with the overload in posterior rather than anterior position. In the familiarization process, the participants walked freely over a 6m walkway which had the force plate embedded in the middle; then they trained to walk with two different step frequencies: 69 steps/min (slow gait) and 120 steps/min (fast gait). Participants were asked to try to walk as naturally as possible during these controlled conditions. In this phase the researchers identified the place where the participant should begin the gait to step with his/her right foot in the center of the plate without changing the natural gait pattern. During the test the participants walked three times with a self-selected speed, three times with slow controlled gait, and three times with fast controlled gait. The present study will present data referring to slow and fast gait.

Data analysis: For the acquisition of the force plate data, Acknowledge software (BIOPAC System, California, USA) was used. These data were exported to Matlab® 7.0 (MathWorks, Massachusetts, USA) where a routine was developed to process and calculate the following variables: impact impulse of vertical GRF (Vt_I), propulsive impulse of vertical GRF (Vt_P), braking impulse of anterior-posterior GRF (AP_B), propulsive impulse of anterior-posterior GRF (AP_P), impulse of medial-lateral GRF (ML), mean vertical force (VtF) and duration of stance phase. The events used to calculate impulse variables are illustrated in Figure 1.

Statistical analysis: The mean of the three repetitions performed by each subject was computed and all the statistical procedures were performed with these mean values. The normality of the data was verified using Kolmogorov-Smirnov test and the homogeneity of the variances using Levene´s test. Then seven paired t-tests were used to compare the variables between the groups. The results will be presented as mean and standard deviation and the significance level adopted was α=0.05. All the statistical procedures were conducted using the software SPSS (v.17; SPSS Inc, Chicago, IL).

RESULTS: The data showed a normal distribuition and variances homogenety. Figure 1 shows that the impulse variables Vt_I, Vt_P, AP_P and ML for the slow gait had higher values compared to the fast gait with statistical significant differences. Despite the AP_B mean values obtained for the slow gait tended to be higher than during fast gait, differences were not statistically significant. Table 1 shows the confidence interval and level of significance of the difference between fast and slow gait obtained by statistical test for all variables. As expected, the duration of stance phase was higher at slow gait (1.091 ± 0.009 s) when compared with fast gait (0.677 ± 0.004s). Considering the VtF, this variable presents larger magnitude during fast gait (498.9 ± 76.9 N) with statistical significant differences comparatively to slow gait (475.8 ± 71.7 N).

DISCUSSION: The purpose of this study was to compare the two different gait speeds (slow vs fast) in a severe occasional overloading situation (wearing a backpack), comparable to what a subject of BMI=30 may experience. The results suggest that, in this particular situation, the musculoskeletal system need to manage larger impulses during slow than during fast gait, while the VtF is smaller (see Fig. 1 and results). In the following studies (in non-overload conditions), as in the present study, the vertical impulse of GRF decreases with increasing speed during walking (Jordan, et al., 2007; Vito, et al., 2009), but also during running (Jordan et al., 2007). So, it seems that the influence of speed on the behavior of the vertical impulse of GRF is similar during normal and overloaded gait. However, when analyzing only the propulsive impulse (anterior-posterior GRF), Lewek et al. (2010) found, contrasting with our results, that it increases as gait speed increases in non overloaded conditions. These findings, when compared with the results of the present study indicate a possible difference in the characteristics of a backpacker's gait when compared with normal gait (without overload).

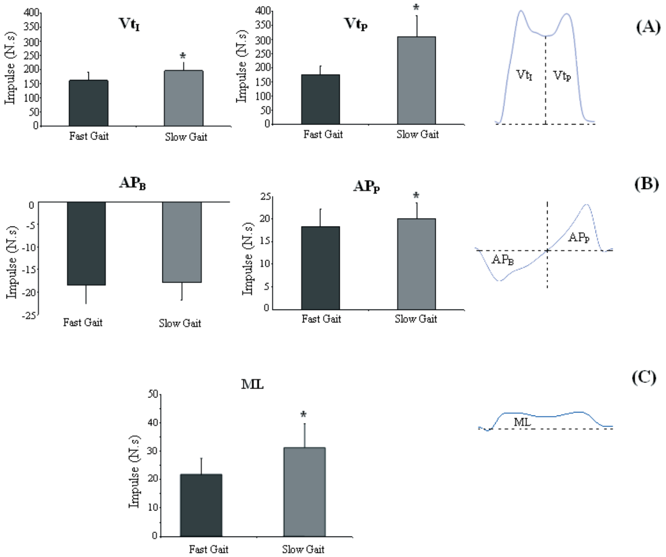

Figure 1: Comparison of impulse variables between fast and slow gait. (A) impulse of vertical GRF; (B) impulse of anterior-posterior GRF and (C) impulse of medial-lateral GRF. Vt_I - impact impulse of vertical GRF; Vt_P - propulsive impulse of vertical GRF; AP_B - braking impulse of anterior-posterior GRF; AP_P - propulsive impulse of anterior-posterior GRF; ML - impulse of medial-lateral GRF; * - statistical significant difference $p \leq 0.05$.

Table 1
Confidence interval and level of significance of the difference between fast and slow gait

Variables	95% Confidence Interval of the Difference		Level of significance (p)
	Lower	Upper	
Duration of stance phase	- 0.434	- 0.394	<0.001
Impact impulse of vertical GRF	- 43.286	- 24.899	<0.001
Propulsive impulse of vertical GRF	-149.146	- 118.050	<0.001
Braking impulse of anteroposterior GRF	- 1.638	0.559	0.329
Propulsive impulse of anteroposterior GRF	- 2.437	- 0.762	<0.001
Impulse of mediolateral GRF	- 12.564	- 9.511	<0.001
Mean vertical force	18.937	27.384	<0.001

Impulses depend on the intensity and duration of the application of force. Previous studies on unloaded subjects indicate that when the speed increases peak vertical (Browing & Kram, 2007; Caravaggi et al., 2010; Grabowski, 2010) and anterior-posterior GRF values increase. On the contrary, the duration of stance phase is reduced at higher gait speeds (Caravaggi, et al., 2010; Grabowski, 2010). Consequently, the amount of variation of these two variables will be responsible for the variation of the impulse. The analysis of the present results suggests that the duration of force application affects more the impulse outcome, being responsible for a significant increase on musculoskeletal load (total load, not peaks) during

slow gait. However, analyzing the VtF, it is possible to observe that, during fast gait, there is less time available for musculoskeletal adaptation which makes this situation potentially more aggressive than slow gait considering the viscoelastic properties of the human body tissues.
Birrel et al. (2007) found an increase of the GRF' medial-lateral impulse during overloaded gait, and stated that this characteristic may be linked to a decrease in stability of gait dynamic balance. In this sense our results seem to point out that the overloaded slow gait situation may be characterized by a decreased stability when compared with fast gait.
One possible limitation of the present study is the utilization of an acoustical pacer to control different gait conditions (slow and fast). However, the subjective analyzes of video images and the differences observed on the duration of stance phase seem to indicate that this methodological option didn't significantly constrain performance.

CONCLUSION: The results of the present study indicate that the backpacker, walking with a slow speed, is submitted to a higher total mechanical load (impulse) and a lesser mean vertical force when compared to fast gait. Therefore, the backpacker has more time (larger duration of stance phase) to force dissipate during slow gait, what seems to be advantageous for the musculoskeletal system, considering their viscoelastic properties. However, during slow gait the backpacker presented larger magnitudes to propulsive anterior-posterior and medial-lateral impulses when compared to fast gait; and since these variables can provide some information about blister development and balance disturbances, respectively, possibly during slow gait these negative aspects are more pronounced. Therefore, each condition (slow and fast gait) seems to have positive and negative aspects considering these kinetic variables. These gait characteristics can be useful in order to achieve adequate preparation and to promote safety during physical activities and sports performance involving load transportation.

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Acknowledgement
The financial support of ADI through Incentive System for Researcher and Technological Developments of the QREN.