Neural Control of Movement

Kinematic analysis and self-perceived exertion during the walking gait with a backpack in Brazilian scholars

Bruna Felix Apoloni[1], Cecília Segabinazi Peserico[1], Pedro Paulo Deprá[1]

[1]*Universidade Estadual de Maringá, Departamento de Educação Física, Maringá, PR, Brazil.*

Associate Editor: Giordano Marcio Gatinho Bonuzzi, [1]Universidade Estadual do Piaui, Picos, PI, Brazil. [2]Graduate Program in Kinesiology, Universidade Federal do Vale do São Francisco, Petrolina, PE. Brazil. E-mail: giordanomgb@gmail.com.

Abstract - Aim: The present study aimed to investigate the effects of different backpack loads on the walking gait kinematics and ratings of perceived exertion (RPE) in Brazilian scholars. **Methods:** The sample was composed of 25 male children and adolescents, from 10 to 14 years. The mean body mass and height were 45.3 kg ± 10.6 kg and 1.51 m ± 0.08 m, respectively. For the walking gait assessment, a tridimensional analysis system was used. In the backpack conditions, loads of 5%, 10%, 15%, and 20% were applied according to the body weight of everyone. Kinematic variables and angular amplitudes of head, shoulders, thorax, pelvis, and knees in the sagittal plane were collected. The OMNI scale was used to assess the RPE. **Results:** The loads of 5%, 10%, 15%, and 20% promoted postural adjustments and alterations in the walking gait, in which the RPE presented a correlation with those alterations. The step in the left cycle altered from the baseline in the 5% ($p = 0.006$). The stride length altered from baseline in the 5% ($p = 0.030$) and 10% ($p < 0.001$) load conditions. The single support time was different from baseline in all conditions ($p = 0.003$; $p = 0.012$; $p = 0.005$; $p = 0.006$). The walking gait cadence was different in the comparison between baseline in the 5% ($p = 0.003$). Thorax amplitude altered in the 10% ($p = 0.023$), 15% ($p = 0.033$) and 20% ($p = 0.005$) load conditions in the left cycle. **Conclusion:** We concluded that the posture, RPE, and the gait kinematic altered according to the increase in the backpack load.

Keywords: posture, gait, backpack, children, ratings of perceived exertion.

Introduction

The use of backpacks represents a daily practice of scholars for carrying their study materials[1-3]. However, the use of backpacks with excessive loads can induce compensatory adjustments in the posture, inappropriate spine alignment, and consequently, modifications in the gait pattern that are associated with balance loss and fatigue, increasing the risk of falls[4-6]. Furthermore, children and adolescents often report back pain because of the aspects related to school backpack; the main probable causes are related to the biomechanical adaptations that cause the static and dynamic posture[3].

Studies have been conducted comparing loads magnitudes of 10, 15, and 20% of the body weight. The objective is to suggest an appropriate load limit in relation to the subject-specific body weight[3,7-9]. This is essential to advise and prevent children and adolescents from developing postural and biomechanical complications related to excessive weight carriage. Nevertheless, the load limit scholars can safely carry in their backpacks is still unclear, and no guideline has been consistently established so far, based on literature evidence.

In this sense, studies have already demonstrated that the backpack load can modify the kinematic pattern of walking gait, in which the increased load on the backpack promotes biomechanical compensations, such as the posterior displacement of the center of gravity, increased pelvic tilt, or anterior tilt to keep the individual in an upright position, and increased pressure on the intervertebral discs[9], thus leading to adaptations in space-time parameters and joint amplitudes during walking gait[3].

Chen and Mu[10] investigated 12 scholars during the walking gait with a backpack in a treadmill, carrying loads of 5%, 10%, and 15% of their total body weight. The highest values regarding the head and thorax flexion were identified in the 15% load condition. In the time-space variables such as single support time, double support time, velocity, and stride time, no significant differences were found among the load conditions. Paez-Moguer et al.[11] described a linear increase in the double support time according to the increase in the backpack load (5%, 10%, 15%, and 20%). The authors indicated that the most evident differences in the space-time parameters of walking gait occurred between the 15% and 20% loads.

Despite the alterations in the kinematic parameters, the ratings of perceived exertion (RPE) is another parameter influenced by the backpack load[5,12-13]. The RPE aids in the understanding of how the individual perceives the effort related to the backpack load[14], allowing the identification of an excessive load carriage, low muscle resistance (mainly in the thorax), and if this could represent a risk factor for back pain[15-17].

Orantes-Gonzalez and Heredia-Jimenez[5] compared the walking gait kinematic and RPE of scholars when carrying two shoulder straps and trolley (e.g., carrying the back with the hand) backpack models. The loads used were no load, 10%, 15%, and 20% of body weight. The authors identified higher RPE values in the conditions with the load when compared with the condition with no load. However, the increase was only significant when comparing the control condition with the 20% load condition, and between the 10% and 20% load conditions. Similar outcomes were reported by Devroey et al.[12], in which an increase in the RPE values in the 10% and 15% load conditions were verified in comparison with the control condition and the 5% load condition. Nonetheless, the authors used the scale for different body parts, in the particular head, shoulders, and upper back. Instead, Chen and Mu[10] have identified a higher discomfort, described through a subjective scale, in the 15% load condition, as well as an increase in the head and thorax flexion. These findings suggest that the limit load of 10% is the most adequate.

As concerns the literature, we noted the necessity of research describing the time spacewalking gait and joint variables, as well as RPE during the backpack carriage with all the aforementioned loads (0%, 5%, 10%, 15%, and 20%), considering the reality of Brazilian scholars, in order to assist the revision of the guideline for the backpack load carriage. Furthermore, it is important to mention that, to the best of our knowledge, no study investigated time-space and joint variables (*e.g.,* kinematic analysis) and their relationship with the RPE during walking gait with different backpack loads.

Thus, the present study aimed to investigate the effects of different backpack loads on the kinematic walking gait and RPE in Brazilian scholars. We hypothesized that an increase in load would promote a change in the space-time parameters and joint amplitudes, besides an increase in the RPE.

Methods

Participants

Twenty-five male scholars from a Southern Brazilian school participated in the present study. The mean age was 12.00 ± 0.58 years, with the mean body mass of 45.3 ± 10.6 kg, the height of 1.51 ± 0.08 m, and body mass index (BMI) of 19.60 ± 3.29 kg/m^2. The sample was selected by convenience through a list containing all male students that were enrolled in the selected school. The inclusion criteria adopted for the sample selection were children and adolescents aged between 10 and 14 years, have the consent of parents and/or guardians to participate in the study, consent of the volunteer, present independent walking gait, and can carry a backpack on their shoulders. The exclusion criteria were not completing all the proposed tasks, not delivering the informed consent signed, presenting severe postural deviation, having any joint or musculoskeletal limitation that compromises the execution of the walking gait safely, or presenting a BMI equal or above 30 kg/m^2.

This research was previously approved by the local Ethics Committee (number 852.213). The participants did not report a history of orthopedic trauma or neurologic issues. All the volunteers as well as their guardians provided the Informed Consent Form before the beginning of the study.

Experimental procedures

The crossover randomized design was chosen for the current study. The backpack weight and body mass were measured with a scale, and the height was assessed with a stadiometer (Welmy®). The room temperature was controlled, remaining at 24 °C.

The backpack model was traditional, only size, with two adjustable and padded straps. The backpack positioning in the back considered the T8 and T9 thoracic vertebrae as the medium point.

Following the familiarization with the apparatus and procedures, the students performed six conditions for the kinematic analysis of the walking gait and the postural adjustments during the school backpack transportation: 1) control condition (with no backpack); 2) with a backpack and additional loads of 5%, 10%, 15% and 20% relative to the body weight of each student.

The order of the conditions was defined by drawing lots. The volunteers assigned the RPE on a 0-10 scale after the performance of each condition[18].

Task

The task consisted of walking at a self-selected velocity using a school backpack in a three meters length space. For data collection, three valid gait cycle were considered. The gait cycle considered the right and left feet consecutive touch on the ground and the register of the displacement of all body joint makers during the cycle, enabling, therefore, the tridimensional reconstruction of the movements[19].

Kinematic analysis

As regards the walking gait kinematic analysis, six infrared cameras with an image acquisition frequency of

100 Hz, properly calibrated and synchronized by the Vicon® system were used. Accordingly, 42 retroreflective markers were positioned in previously determined body sites by the biomechanical model Plug-in Gait full-body (Figure 1), with some adaptations such as the removal and the positioning of extra markers, which allowed the positioning of the school backpack in the volunteer's back. Sequentially, the register of the static position was performed. It was necessary for modeling the body segments during the execution of the dynamic analysis conditions.

During the adaptation session, the scholars performed the gait on flat ground, using the backpack with or without load and not exceeding five minutes of warming-up[20]. For the load magnitudes inside the backpack, a metal prototype measuring 35.5 cm x 27 cm x 5 cm, with a homogeneous distribution of iron plates with different weights was placed inside the backpack.

Time-space parameters were obtained from the kinematic analysis (e.g., step and stride length, cadence, single and double support time, step and stride time, and velocity), as well as angular amplitudes of body segments (head and thorax) and joints (shoulder, pelvis, and knee) of gait referred to the gait cycle performed with both right and left feet. The first gait cycle of each attempt began with the right foot.

Ratings of perceived exertion (RPE)

After each experimental condition performance, the following question was asked: "How tired did you feel during the exercise?". The OMNI scale for walking/running was used for this RPE assessment[18]. The RPE was related to the load magnitude carried in the backpack. The instructions were given verbally, and the OMNI scale remained visible for the volunteers during the performance of all conditions. The scale score varies from 0 (not tired at all) to 10 (exhausted).

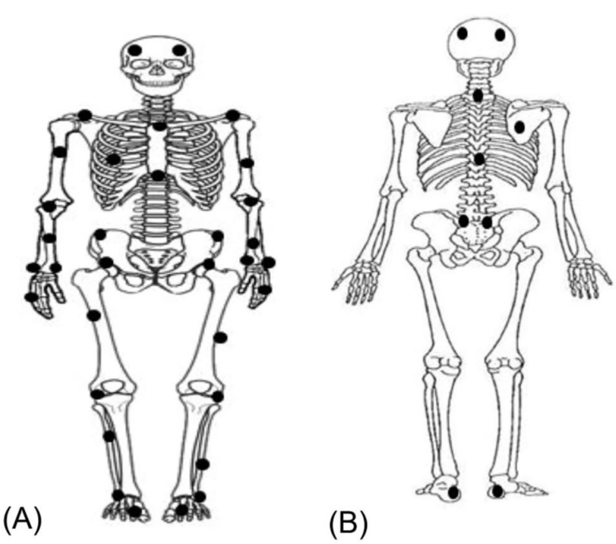

Figure 1 - Positioning of body markers following the Plug-in-gait full-body model (Vicon® system) – Anterior (A) and posterior (B) views.

Statistical analysis

Data distribution was verified by the Shapiro-Wilk test and described as mean and standard deviation. The repeated measures analysis of variance (ANOVA) followed by the Bonferroni correction and the Friedman test was used to compare the gait kinematic variables and the angular amplitudes in relation to the load magnitudes. The Spearman and Pearson tests were applied to verify possible correlations between the gait kinematic variables and angular amplitudes with the RPE in all experimental conditions. The Pearson correlation test was used for normally distributed variables and the Spearman's correlation was used for non-parametric data. A significance level of $p \leq 0.05$ was adopted.

Results

Table 1 presents the mean and standard deviation values as well as the comparison of the time-space gait parameters considering the experimental conditions. A significant difference for the step length in the left cycle between the control condition and the 5% load condition was verified ($p = 0.006$). Consequently, differences regarding the stride length in the left cycle were observed comparing the control condition with the 5% ($p = 0.030$) and 10% ($p < 0.001$) load conditions. The cadence significantly altered only in the comparison between the control condition and the 5% ($p = 0.003$) load condition. Still, regarding the left cycle, the single support time presented significant differences in the comparison between all experimental conditions and the control condition (respectively: $p = 0.003$; $p = 0.012$, $p = 0.005$; $p = 0.006$). In the right cycle, this variable differed from the control condition in the 15% ($p = 0.012$) and 20% ($p = 0.010$) load conditions. The double support time in the right cycle presented a significant difference when comparing the 5% and 15% ($p = 0.019$) load conditions, in which the 20% load condition was significantly different from the other conditions. The step time in the left cycle was significantly different in the 5% ($p = 0.015$) and 15% ($p = 0.021$) load conditions in comparison to control. In the right cycle, the difference was observed only in the comparison between the 5% ($p = 0.013$) load and the control conditions.

Table 2 presents the mean and standard deviation values, and the comparison of the angular parameters considering the experimental conditions. A significant difference in the shoulder amplitude in the left cycle was observed when comparing the 5% ($p = 0.017$) load and control conditions. The thorax amplitude in the left cycle was significantly different in the 10% ($p = 0.023$), 15% ($p = 0.033$) and 20% ($p = 0.005$) load conditions in comparison to the control condition. This parameter also

Table 1 - Comparison of the walking gait time-space variables considering the conditions relative to body weight.

Cycle	Variables	Conditions relative to body weight				
		Control	**5%**	**10%**	**15%**	**20%**
Left	Step length (m)	0.51 ± 0.05	0.54 ± 0.07[a]	0.53 ± 0.07	0.51 ± 0.06	0.51 ± 0.05
	Stride length (m)	1.02 ± 0.10	1.06 ± 0.13[a]	1.06 ± 0.12[a]	1.02 ± 0.13	1.04 ± 0.11
	Single support time (s)	0.49 ± 0.05	0.46 ± 0.04[a]	0.46 ± 0.04[a]	0.46 ± 0.03[a]	0.46 ± 0.04[a]
	Double support time (s)	0.23 ± 0.06	0.21 ± 0.04	0.22 ± 0.04	0.24 ± 0.05	0.25 ± 0.05
	Step time (s)	0.60 ± 0.07	0.57 ± 0.05[a]	0.57 ± 0.05	0.57 ± 0.05[a]	0.58 ± 0.05
	Stride time (s)	1.21 ± 0.13	1.14 ± 0.09[a]	1.15 ± 0.10	1.15 ± 0.10[a]	1.17± 0.09
	Velocity (m/s)	0.85 ± 0.11	0.93 ± 0.14[a]	0.92 ± 0.14[a]	0.90 ± 0.13	0.88 ± 0.11
Right	Step length (m)	0.51 ± 0.05	0.54 ± 0.07	0.52 ± 0.06	0.51 ± 0.08	0.52 ± 0.06
	Stride length (m)	1.02 ± 0.11	0.54 ± 0.72[a]	1.05 ± 0.13[b]	1.04 ± 0.13[b]	1.03 ± 0.11[b]
	Single support time (s)	0.50 ± 0.05	0.48 ± 0.06	0.48 ± 0.05	0.47 ± 0.05[a]	0.47± 0.06[a]
	Double support time (s)	0.26 ± 0.07	0.24 ± 0.05	0.25 ± 0.06	0.27 ± 0.06[b]	0.28 ± 0.06[c]
	Step time (s)	0.61 ± 0.07	0.57 ± 0.05[a]	0.57 ± 0.05	0.58 ± 0.05	0.58 ± 0.05
	Stride time (s)	1.24 ± 0.15	1.19 ± 0.11[a]	1.19 ± 0.11	1.19 ± 0.10	1.20 ± 0.10
	Velocity (m/s)	0.83 ± 0.11	0.90 ± 0.13[a]	0.90 ± 0.15[a]	0.88 ± 0.13	0.86 ± 0.11
	Cadence (step/min)	99.33± 9.87	103.90 ± 9.17[a]	103.57 ± 8.91	103.32 ± 8.17	102.07 ± 8.29

Note: a = different from control condition; b = different from 5% load condition; Repeated measures ANOVA comparisons with Bonferroni correction; Significance level ($p \leq 0.05$).

Table 2 - Comparison of the angular amplitudes considering the conditions relative to body weight.

Cycle	Angular Amplitudes (degrees)	Conditions relative to body weight				
		Control	**5%**	**10%**	**15%**	**20%**
Left	Head	7.39 ± 5.93	7.05 ± 4.55	7.61 ± 4.12	8.29 ± 5.27	8.51 ± 3.07
	Shoulder	20.82 ± 9.99	15.15 ± 7.93[a]	17.35 ± 9.49	15.71 ± 8.64	14.66 ± 9.56
	Thorax	6.50 ± 1.40	5.91 ± 1.84	7.66 ± 2.35[a]	8.05 ± 2.74[a]	8.59 ± 2.61[ab]
	Pelvic Tilt	10.97 ± 4.35	10.91 ± 4.68	13.72 ± 7.78	12.84 ± 4.98	13.07 ± 6.54
	Knee	47.67 ± 8.59	46.97 ± 13.67	48.11 ± 9.02	49.67 ± 10.30	46.33 ± 14.23
Right	Head	8.46 ± 3.57	7.78 ± 5.37	9.48 ± 7.50	9.99 ± 6.20	8.86 ± 4.48
	Shoulder	21.33 ± 11.40	18.70 ± 0.39	19.35 ± 9.45	18.45 ± 8.89	17.69 ± 7.11
	Thorax	12.20 ± 3.17	11.84 ± 4.46	12.80 ± 4.26	13.40 ± 3.89	13.12 ± 3.51
	Pelvic Tilt	11.03 ± 4.40	11.01 ± 5.61	14.00 ± 7.91	13.47 ± 5.50	13.35 ± 6.73
	Knee	49.99 ± 10.32	48.54 ± 13.37	52.30 ± 8.35	51.13 ± 10.26	48.96 ± 13.25

Note: a = different from control; b = different from the 5% load; Repeated measures ANOVA comparison with Bonferroni correction. Significance level ($p \leq 0.05$).

showed a significant difference in the comparison between 20% and 5% ($p = 0.004$) load conditions.

Table 3 describes and compares the values obtained in the RPE assessment in each experimental condition. The RPE median values were significantly different in the comparison between all load conditions with the control condition, in which the highest loads presented higher RPE values (respectively: $p = 0.049$; $p = 0.009$; $p \leq 0.001$; $p \leq 0.001$). Moreover, we verified a strong and significant correlation ($r = 0.789$; $p = 000$) between all load conditions and the RPE. According to this result, the higher the load magnitude transported in the backpack, the higher the RPE.

Table 4 presents the correlation coefficients between the time space gait variables and the angular amplitudes with the RPE, considering all experimental conditions. The conditions analyzed presented weak and very weak significant correlations in the following variables regarding the left cycle of gait: single support time ($r = -0.232$; $p = 0.009$), double support time ($r = 0.200$; $p = 0.025$), head amplitude ($r = 0.189$; $p = 0.034$), shoulder ($r = -0.242$; $p = 0.006$), and thorax ($r = 0.368$; $p < 0.001$).

Table 3 - Comparison of the RPE values in the different conditions related to body weight.

		Conditions relative to body weight				
		Control	**5%**	**10%**	**15%**	**20%**
RPE	Mean (SD)	0.16 (0.47)	1.40 (1.75)	2.20 (1.55)	4.20 (2.10)	5.72 (2.26)
	Mean (IR)	0.00 (0.00)[a]	1.00 (2.00)[a]	2.00 (2.00)[a]	4.00 (3.00)[a]	6.00 (3.00)[a]

Note: a = different from all conditions; Comparison utilizing the Friedman and Wilcoxon statistical tests. Significance level ($p \leq 0.05$). Med = média; SD = standard deviation; IR = interquartile range.

Table 4 - Correlation coefficients between the kinematic variables and the angular amplitudes with the RPE considering all conditions related to body weight.

Cycle	Variables	Conditions related to body weight	RPE
Left	Step length [m]	0.023	0.006
	Stride length [m]	0.017	−0.010
	Single support time [s]	−0.232*	−0.242*
	Double support time [s]	0.200*	0.250*
	Step time [s]	−0.076	−0.012
	Stride time [s]	−0.072	−0.031
	Velocity [m/s]	0.011	−0.046
	Head amplitude [degrees]	0.189*	0.034
	Shoulder amplitude [degrees]	−0.242*	−0.148
	Thorax amplitude [degrees]	0.368*	0.263*
	Pelvic tilt [degrees]	0.089	0.142
	Knee amplitude [degrees]	0.031	0.178*
	Cadence (steps/min)	0.074	0.042
Right	Step length [m]	−0.031	−0.049
	Stride length [m]	0.025	0.012
	Single support time [s]	−0.205*	−0.163
	Double support time [s]	0.161	0.169
	Step time [s]	−0.066	−0.051
	Stride time [s]	−0.099	−0.064
	Velocity [m/s]	0.020	−0.012
	Head amplitude [degrees]	0.066	−0.052
	Shoulder amplitude [degrees]	−0.058	0.026
	Thorax amplitude [degrees]	0.142	0.050
	Pelvic tilt [degrees]	0.178*	0.232*
	Knee amplitude [degrees]	0.028	0.100

Note: *Significant correlation ($p \leq 0.05$) verified by the Spearman test.

Considering the right cycle of gait, significant correlations were observed for single support time ($r = -0.205$; $p = 0.022$) and pelvic tilt ($r = 0.178$; $p = 0.048$).

The RPE demonstrated very weak and weak significant correlations for the following variables from the left cycle of gait: single support time ($r = -0.242$; $p = 0.007$), double support time ($r = 0.250$; $p = 0.005$), thorax ($r = 0.263$; $p = 0.003$), and knee ($r = 0.178$; $p = 0.047$). As regards the right cycle of gait, a significant weak correlation was found for the pelvic tilt ($r = 0.232$; $p = 0.009$).

Discussion

The present study aimed to investigate the effects of different backpack loads on the walking gait kinematics and RPE in Brazilian scholars. The main finding was the significant adaptations in the time-space gait parameters, joint amplitudes, and RPE during the backpack carriage with loads of 5%, 10%, 15%, and 20%, which confirms the previously established hypothesis.

The results demonstrated that the most evident differences in the time-space gait parameters occurred in the 5% load condition since most of the variables (step length, stride length, single support time, step time, stride time, and velocity in the left cycle and stride length, step time, stride time, velocity in the left cycle) were statistically different compared to control, which was not demonstrated the comparisons between 10%, 15%, and 20% load condition and control condition. For example, the 10% load condition differed to control condition only for stride length, single support time and velocity (left cycle), and for velocity (right cycle). Considering the comparison between the 15% load condition and control, the differences were for the left cycle in the single support time, step time, stride time variables and for the right cycle in the single and double support times. Finally, in the 20% load condition, only was found significant differences for single support time during left and right cycles.

Alterations in the stride length and time, as well as in the cadence and velocity suggest a significant change in the gait motion pattern of scholars. These behaviors indicate that the gait was performed with a higher velocity, length, and support of the inferior limbs on the ground, favoring the maintenance of body balance.

Regarding the joint amplitudes, the increase in load promoted significant adjustments in the shoulder joint. Significant alterations were also observed in the thorax amplitude, which indicates an increase in the inclination when comparing the 10%, 15%, and 20% loads with the control condition. Generally, we noted that the shoulder joint diminished its angular amplitude according to the load increase. Meanwhile, the head and thorax segments presented the higher motion, promoting hence a postural adjustment during the walking gait. Taking into account the results found in the present study, we may infer that the scholars adopted as predominant strategy the adaptation of the time-space parameters instead of the joint amplitudes.

In the study of Rashid et al.[21], the most significant alterations during the walking gait with a backpack in Indian scholars were observed in the hip joint, with 15% and 20% loads according to the individual total body weight. This strategy suggests an adaptation in the motion of this joint to maintain the center of gravity within support base limits, favoring body balance despite an increase in load. Moreover, the pelvic amplitudes modify according to the mode of using the backpack (double or single strap) and its weight. Presta et al.[9] observed a diminishing in the pelvic rotation in the comparison between 10% and 20% load conditions and less inclination starting with the 15% load condition forth. In the comparison between the control and 10% load conditions, there was a significant reduction in the rotation and obliquity, besides the maintenance of inclination angles.

The significant reduction in the single support time of the left inferior limb in all load conditions was observed when compared to the control condition, and in the right inferior limb in the comparison between the 25% and 20% load conditions with the control condition, as well as a significant increase of the step and stride length variables. Therefore, the scholars reduced their balance phase of walking gait. It demonstrates a higher necessity to use the support limbs for carrying the backpack, favoring the postural stability during the walking gait1[11,22]. Significant adaptations in time-space parameters of walking gait in the 15% and 20% load conditions were also reported in the recent studies of Rashid et al.[21] and Paez-Moguer et al.[11].

The most recent guideline of the Aytmerican Academy of Pediatrics[23] recommends that the school backpack should not weigh more than 10% to 20% of the total individual body weight. Significant alterations in the left stride length, single support time of the left inferior limb and the increase in velocity in the comparison between control and 10% load conditions partially corroborate with this recommendation, once the 5% load condition also promoted notable adaptations on the gait kinematics.

Concerning the RPE results, they indicate that the scholars perceived themselves as “a little tired” during the walking gait with a 5% load backpack, wherein they reported themselves as “tired” with a 20% load backpack. The highest RPE values were obtained in the conditions with loads in comparison to the control conditions, with a significant increase starting from the lowest load (5%). Similar outcomes were described by Orantes-Gonzalez and Heredia-Jimenez[5]. Nevertheless, a significant increase has occurred in the comparison between the control condition and the 20% load condition, and between the 10% and 20% load conditions. The 5% load condition was not performed in this study.

The increase in RPE suggests that the carriage of heavy loads in the school backpack can be a factor of body discomfort and increase in energy expenditure, which is in accordance with previous reports from literature[24]. The RPE might be an important tool for future studies to investigate the weight carriage in the school backpack. It occurs because the utilization of body weight relative percentage to increase load might not be related to the physical capacity of scholars in face of the increase of overweight and obesity in Brazilian children over the last years[25-26].

Furthermore, from the correlation results described in the present study, we observed that the RPE presented a relationship with the load. Also, we verified that there is a relationship between the time-space gait variables and the amplitudes with the load increase in the school backpack and with the self-perceived exertion scale.

The sample composed exclusively of male individuals can be considered a limitation of the present study. We opted to include only male scholars due to the likely discomfort that the vestment used could cause in female scholars. In addition, another limitation was the lack of sample size calculation before carrying out the study. Finally, concerning the practical application of our study, our findings will contribute to producing scientific knowledge in the area of biomechanics and, in the school context, to help physical education teachers to develop a conscious thought of their students about carrying the school backpack with load safely. Finally, the findings of this research can support new health care policies.

Conclusion

Therefore, we conclude that the adaptations in the walking gait kinematic patterns observed in the backpack carriage with 5% load according to the total body weight emphasize the necessity of further studies that consider this condition in order to contribute to the discussion about which would be the load limit scholars can safely carry in their backpacks, contributing for the revision of the actual guideline. It is suggested that future studies consider investigating other aspects that can be observed in the routine of children and adolescents during the transport of their backpacks, such as walking on inclined surfaces at different speeds and using different models of backpacks.

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Corresponding author

Bruna Felix Apoloni. Universidade Estadual de Maringá, Departamento de Educação Física, Maringá, PR, Brazil.
E-mail: felixapoloni@gmail.com.

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