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Analysis of the weight of school backpack with double strapson the postural control of children

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ABSTRACT. To investigate the influence of the weight of school backpacks on postural control of children. Cross-sectional study in healthy children aged eight years old. The postural control was evaluated on the force plate (FP) and the Timed Up and Go test (TUG) in three distinct conditions: without backpack (WB), and the backpack adjusted with 5% (.5) and 10% (. 10) of body mass. 90 children were evaluated, and 80% of them used backpacks with two shoulder straps, and 16% of the children carried over 10% of their body mass in the backpacks. Regarding the postural control with load on school backpack, there was increase in the sway area of the center of pressure (A-COP.WB = 6.92 cm^2; A-COP.5 = 8.39 cm^2; A-COP.10 = 7.96 cm^2) and time, in seconds, the performance of the TUG (TUG.WB = 4.75 s; TUG.5 = 4.99 s; TUG.10 = 5.06 s), with statistically significant difference between the loads ($p = 0.0001$; $p = 0.0005$), respectively. The anteroposterior (VELAP.SM = 2.41cm s-1; VELAP.5 = 2.30 cm s-1; VELAP.10 = 2.22 cm s-1; $p = 0.0001$) and mediolateral velocity (VELML.WB = 2.38 cm s-1; VELML.5 = 2.28 cm s-1; VELML.10 = 2.20 cm s-1; $p = 0.0001$) had a decrease in the median values with statistically significant difference in different conditions. School backpack load increased the COP area, the time of the TUG and modified the response mechanisms. Therefore, loads up to 5% of body mass imposed on school backpack have negatively influenced the postural control.

Keywords: postural balance; weight-bearing; school health.

Análise do peso da mochila escolar de alças sobre o controle postural de crianças

RESUMO. Investigar a influência do peso das mochilas escolares no controle postural de crianças. Estudo transversal em crianças saudáveis com oito anos. O controle postural foi avaliado na plataforma de força (PF) e pelo teste Timed Up and Go (TUG) em três condições distintas: sem mochila (SM) e com a mochila escolar ajustada com 5% (.5) e 10% (.10) da massa corporal. Foram avaliadas 90 crianças, 80% utilizavam mochilas com duas alças apoiadas sobre os ombros e 16% transportavam acima de 10% da massa corporal. Quanto ao controle postural com carga na mochila escolar, houve aumento da área de oscilação do centro de pressão (A-COP.SM = 6,92 cm^2; A-COP.5 = 8,39 cm^2; A-COP.10 = 7,96 cm^2) e no tempo, em segundos, no desempenho do teste TUG (TUG.SM = 4,75 s; TUG.5 = 4,99 s; TUG.10 = 5,06 s), com diferença estaticamente significante ($p = 0{,}0001$; $p = 0{,}0005$), respectivamente. As velocidades de oscilação ântero-posterior (VELAP.SM = 2,41 cm s-1; VELAP.5 = 2,30 cm s-1; VELAP.10 = 2,22 cm s-1 e $p = 0{,}0001$) e médio-lateral (VELML.SM = 2,38 cm s-1; VELML.5 = 2,28 cm s-1; VELML.10 = 2,20 cm s-1 e $p = 0{,}0001$), obtiveram diminuição dos valores, com diferença estaticamente significante nas diferentes condições. A mochila escolar com carga aumentou a área do COP, o tempo do TUG e também modificou os mecanismos de resposta. Portanto, cargas impostas à mochila escolar a partir dos 5% da massa corporal já influenciaram negativamente no controle postural.

Palavras-chave: equilíbrio postural; suporte de carga; saúde escolar.

Introduction

The childhood represents the ideal period for the process of motor development of the child, since it encompasses a large number of motor tasks (Al-Khabbaz, Shimada, & Hasegawa, 2008). Thus, the student´s health has been the object of study, due to their vulnerability to external conditions. Among several aspects covered in the student´s health, the backpack has been the target of concern for health and child education professionals, as it is the most practical and used way to transport materials. However, if the backpack is not well adjusted and appropriate to the child, it may bring risks, as the predisposition of musculoskeletal disorders and appearance of vertebral pain (Brackley & Stevenson, 2004).

The literature recommends the ideal maximum load of school backpacks between 10 and 15% of body mass of the child, to minimize the installation of postural and gait changes, and pain. However, the authors also consider the need for more studies involving other aspects linked to the student´s health (Brackley & Stevenson, 2004; Grimmer, Dansie, Milanese, Pirunsan, & Trott, 2002). Lemos, Teixeira and Mota, (2009) and Al-Khabbaz et al. (2008) showed that the application of external forces to the body (such as a backpack), move the center of mass to a back position, however, the body uses the strategy to generate muscle strength in the opposite direction to the inclination, and bone changes occur on the base of support for balancing the applied forces, in order to restore the balance.

The postural control is responsible for the maintenance, the achievement and/or restoration of balance during different postures and movements performed in day-to-day, and it is fundamental to avoid falls in children (Pollock, Durward, & Rowe, 2000; Duarte & Freitas, 2010). The maturation of the controller systems of the posture reaches the final stage around eight to 12 years of age, assuming similar strategy in adults (Hsu, Kuan, & Young, 2009).

Several tools can be used for the assessment of postural control, high lighting the Force Plate (PF), which is considered the gold standard (Mancini & Horak, 2010) and ideal (Duarte & Freitas, 2010), and *Timed up and Go* (TUG), which evaluates the dynamic balance through a functional activity (Williams, Carroll, Reddihough, Phillips, & Galea, 2005).

Thus, this study aims to investigate the influence of the weight of school backpacks with double straps on static and dynamic postural control of children in school age. Its importance is justified due to the need to identify, in a particular manner, the different factors that can be influenced by the loads imposed by backpack, such as the postural control, in order to provide greater subsidies for the standardization of safe limits on children´s health, since the studies so far are still inconclusive. In addition, it is proposed to evaluate the static and dynamic postural control associating two different instruments facing the use of school backpack. The hypothesis is that it will be identified a worse performance in postural control of the child, both static and dynamic, as the weight of the school backpack increases.

Material and methods

Study design and ethical aspects

The cross-sectional study was conducted in schools of the Municipal School Network of Londrina/PR, in children of eight years old, with the authorization of the Municipal Education Department of Londrina/PR. The research project was approved by the Ethics Committee in Research of the University Hospital of State University of Londrina (Protocol number 160/2014).

Sample

The sample of 80 participants was estimated by Statistical Power with alpha of 0.1 and beta of 0.2 to detect the difference of the mean area of COP of 1.58, with standard deviation of 0.90. The students included were: healthy children, with 8 years of age due to the function of the maturation of postural control (Hsu et al., 2009), from both genders, with permission from their parents or responsible adults after having signed the Free and Informed Consent Statement (FICS), and those who accepted to participate in the moment of data collection. The exclusion criteria were children with orthopedic, rheumatological, vestibular and/or neurological dysfunctions, chronic and/or acute diseases, or with any condition that impedes to stay in the orthostatic position, in continuous use of medications with influence in balance and without understanding and/or collaboration for conducting the assessment.

Procedures and data collection

The identification, anthropometric and backpack data were obtained. The school backpack used daily by the children and the body mass were verified in digital precision scale, calibrated, brand *Marte*, model LC 200/2010, maximum capacity of 200 kg and minimum of 100 g. The nutritional classification was performed by means of the *software Anthro WHO Plus*, which provides the Z score (World Health Organization [WHO], 1995). The load of the school backpack established at 5 and 10% of body mass of the child was obtained by adding notebooks with weight of 25, 50, 100, 500 grams (g) and one kilogram (kg), until they reach the estimated proportion. The approximate value was, for example, if the child weighed 38.300 kg, the test was performed with a backpack with 3.8 kg (10%) and 1.9 kg (5 %). The standardized backpack for the study was adapted to each child, next to the trunk, with tight straps and without gap (Brackley & Stevenson, 2004; Whittfield, Legg, & Hedderly, 2005).

The evaluation of postural control was performed at portable Force Plate (FP), BIOMEC400 of *EMG System* Brazil/ Ltda (SP/Brazil). The main parameters analyzed were the center of pressure area - A-COP (cm^2) and velocity of the oscillations - VEL ($cm\ s^{-1}$), in the plans AP and ML, since these two parameters are considered the most sensitive and reliable in order to detect differences in postural balance of different populations (Lin, Seol, Nussbaum, & Madigan, 2008; Pinsault & Vuillerme, 2009). The FP signs were processed and treated by the system itself of stabilometric analysis BIOMEC400, compiled with routines of MATLAB computing (*The Mathworks, Natick, MA*).

The position established for the assessment protocol was in orthostatism, barefoot, upper limbs relaxed and parallel to the trunk (Bauer, Groger, Rupprecht, & Gassmann, 2008) with gaze directed to a fixed point, whose front distance was two meters from the FP at the height of the eyes. The child remained on the FP for 30 seconds, double-leg stance with lower sustaining basis (feet together/ less distance of the child), in three attempts (Pinsault & Vuillerme, 2009) and in three conditions: without the backpack(SM), with 5% (.5) and 10% (.10) of body mass. In the period between each attempt, it was performed one interval with the child seated and without using backpack for 30 seconds (Parreira, Boer, Rabello, Oliveira, & Silva, 2013). For the analysis, the average of the three attempts in FP in each condition was used.

The dynamic balance was evaluated by the test *Timed up and Go* (TUG), developed by Podsiadlo and Richardson (1991), and validated for children by Williams et al. (2005) with excellent reliability (Verbecque, Costa, Vereeck, & Hallemans, 2015). The test consisted into requesting the child, who was wearing his/her sneakers, in: a) getting up from a chair, in this case the standard school furniture; b) walking a distance of three meters; c) touching a target on the wall; d) walking back to the chair, and e) sitting again. The time was measured in seconds with a stopwatch, brand *Kenko* (model KK-2808), and the test was performed in two attempts, with the shortest time being chosen, which corresponded to the best performance. The TUG was also conducted on the three conditions: SM, backpack with 5 and 10% of body mass. The rest interval between each attempt was one minute, in the sitting position and without the school backpack. In the pilot test, this resting time showed to be enough for the return to the initial heart rate to the test.

Each child was evaluated individually in different days (a day for the collection of information and TUG, and another day to the evaluation on the FP). The procedures (SM, .5, .10) performed were randomized by raffle, using opaque and sealed envelopes to prevent the occurrence of fatigue, learning effect and adaptation in the loads progression. The data collection was performed by two evaluators, trained, both in assessment in FP and in the performing of the TUG. The children were asked about the presence of pain or discomfort during the test, immediately after and in subsequent days of evaluations, and no complaint was reported.

Statistical analysis

The analyzes were processed in the 'Graphpad Prism' 6 software and the statistical significance level established was $p < 0.05$. As the variables did not meet the assumption of normality presented by Shapiro-Wilk test, the Friedman test was applied for comparative analysis of repeated measurements and the Dunns test, as the respective post-test, to locate the intragroup differences for each variable studied.

Results and discussion

A total of 90 children were evaluated, of which 46 (51.1%) were girls and 44 (48.9%) were boys, with a mean body mass of 31.7 kg. (± 7.95). The mean stature was 133 cm (± 6.86), 52 (57.8%) of them were eutrophic, 18 (20%) overweight and 20 (22.2%) obese.

In relation to the backpack, 72 (80%) children were using backpacks with two straps, followed by 17 (18.9%) with wheels and only one (1.1%) cross body. Regarding the mode of backpacks transport with dorsal fixation, 70 (77.8%) children carried with bilateral support on the shoulders and two (2.2%) with unilateral support. The mean value of the usual weight of backpacks was 1.7 kg. (± 1.68), being that 15 (16%) of the school children were above 10% of the body mass. Among the children above the weight, overweight and obese, 27 (71%) used the backpack with load higher than the mean of the usual weight of backpacks (1.7 Kg), with a mean of 2.5 Kg (± 0.55), however, only one child exceeded the limit of 10% of body mass.

The FP and the TUG variables were presented as median and interquartile intervals (Table 1). The A-COP and TUG raised the median values, when compared to the conditions without and with a backpack. The A-COP was higher with the use of the backpack with load of 5%, when compared without backpack and with 10% of body mass. On the contrary, the VELML and VELAP decreased the median values with the increase of the backpack weight.

Table 1. Description of Postural Control in three conditions: without backpack, with backpack with load of 5 and 10% of the body mass.

Postural Control	Parameters	25%	Median	75%
Static	A-COP.WB	4.66	6.92	10.55
	A-COP.5	5.51	8.39	11.25
	A-COP.10	5.68	7.96	12.16
	(in cm^2)			
	VELAP.WB	2.07	2.41	2.97
	VELAP.5	1.96	2.30	2.76
	VELAP.10	1.93	2.22	2.75
	(in $cm\ s^{-1}$)			
	VELML.WB	2.01	2.38	2.90
	VELML.5	1.94	2.28	2.76
	VELML.10	1.89	2.20	2.71
	(in $cm\ s^{-1}$)			
Dynamic	TUG.WB	4.11	4.75	5.38
	TUG.5	4.59	4.99	5.48
	TUG.10	4.65	5.06	5.62
	(in seconds)			

Subtitles: WB - without backpack; (.5) - 5 % of body mass; (.10) - 10 % of body mass. A-COP - Center of pressure area; VEL - velocity of the oscillations of COP; AP – anterior-posterior; ML – medial-lateral. TUG – Timed up and go test.

There was statistically significant difference in the A-COP (p = 0.0001), VELAP (p = 0.0001), VELML (p = 0.0001) and TUG (p = 0.0005), when compared without backpack and with loads of 5 and 10% of body mass (Figure 1).

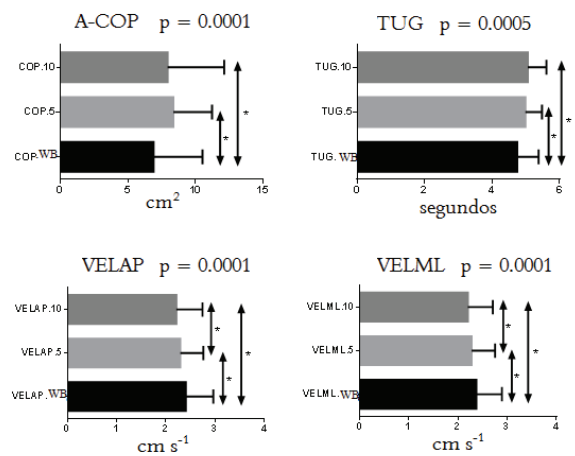

Figure 1. FP variables and TUG performance. *Median values with statistically significant difference.

The transport of materials through backpacks is common for students. The results indicated a preference for using school backpacks with two handles at the back (80%) supported symmetrically on the shoulders. These findings corroborate with Candotti, Nunes, Noll, Freitas and Macedo (2011), who verified that 75.9% of children of elementary education also used the backpacks in a similar way. The use of two-handle backpack is the most suitable for the transport of school material, so that there is less risk, energy expenditure, an in order to avoid an overload on the dorsal region and the emergence of musculoskeletal pain and symptoms (Brackley & Stevenson, 2004; Whittfield et al., 2005).

The mean weight of the backpack was within the recommended, without exceeding 10% of body mass of the students. Only 16% of the children were carrying their backpacks with loads above 10% of body mass. This data corroborates with the study by Ries, Martinello, Medeiros, Cardoso and Santos (2012), which found that 18% of the evaluated students exceeded this limit. The mean weight of the usual backpack of children with excess weight generates concern, because even though the weight of school backpack complies with the weight recommended by literature, it might be excessive if considered as load for the age group. De Paula, Silva, Paschoarelli and Fujii (2012) evaluated students and found that 15.33% were overweight, and of these, 37.7% were carrying their backpacks above the recommended limit. Based on the findings, the authors suggested that the appropriate weight for the transport of school backpacks for overweight children must be less than 10% of their body mass, given that they already carry additional intrinsic load.

The backpack used in our data collection was adjusted for each child, according to its positioning and weight, since these factors may interfere in the postural displacement (Grimmer et al., 2002). However, the A-COP increased with the load of the school backpack, as there was the need to counterbalance the displacement of the center of mass generated by the weight of the backpack, in order to adjust the center of gravity into the support base (Heller, Challis, & Sharkey, 2009). The median A-COP was higher for the load of the backpack, with 5% than with 10% of body mass, and this may have occurred in accordance with the physical principles of the second law of Newton, whose force applied to the object is proportional to its mass and the acceleration. Thus, when it was imposed on the load of 10% of body mass in child, a proportionately greater force should occur to move his or her body, this way, the corporal oscillations were decreased in response to stability generated by active physical properties.

The variables VELML and VELAP decreased their values when the school backpack was added. This mechanism may be related to a set of posture adjustments, which are modulated by the perception of the alterations of short duration in body mass, from external loads, like the backpacks. These adjustments may lead the central nervous system to give priority to the information on the magnitude and the position of this additional weight, and to request the strategy of coactivation of anticipation of postural muscles directed to the stabilization of body segments (Li & Aruin, 2007).

With respect to the base of support on the Force Plate, the unipodal position is considered the most reliable task for the discrimination of postural control in elderly and young adults (Parreira et al., 2013). In this study, the double-leg position (feet together) was standardized for data collection, and it is justified due to the load imposed by backpack on the child. The position double-leg (feet together/ less distance of the child), even not being as challenging as the unipodal position, showed to be enough and discriminative to find differences regarding the influence of the weight of the school backpack in postural control. Studies such as Andrade et al. (2012*)* and Reilly, Woollacott, Donkelaar and Saavedra (2008) verified that the position double-leg (feet together/ less distance of the child) was also capable of detecting differences in postural control of children with visual deficit and cerebral palsy.

The daily use of backpacks can be incorporated to the habits of the school children, and this motor ability reaches fine adjustments so that the task be well carried out (Rodrigues, Montebelo, & Teodori, 2008). Pinetti and Ribeiro (2008) evaluated the postural control with the use of school backpack in children, from 11 to 13 years old, and obtained an increase in the velocity of the body oscillations, reduction in the use of the strategies of the ankle, hip and the step, and an increase in radial displacement of the body, without statistically significant difference between the variables with and without backpack. The differences of results among the last mentioned study and ours may have occurred due to the difference between the use of the usual school backpack of the student and the standardized model according to body mass, and also due to the feet position, double-leg stance (feet parallel to the hip) and double-leg stance (feet together/ less distance of the child). In addition, such differences between the results might be due to the evaluated age in both studies, 11 to 13 and eight years, since the strategies used may differ in each phase of development, and also due to the time of use of school backpacks, since its use by younger children has not yet undergone fine adjustments.

In relation to the TUG, we observed an increase in the time spent to walk the path when the load of 5 and 10% of body mass was placed in the backpacks, which represents a negative interference in functional performance, since the children were less agile, probably due to reduced confidence and greater risk of imbalance or even fall. The destabilization induced by the backpack transport in children alters the gait pattern in relation to time, speed and cadence (Singh & Koh, 2009). Therefore, the TUG on the study was important as an evaluation instrument, since walking with backpacks is performed with frequency by school children, also by showing the influence of the load on the performance of this functional activity.

The backpack with 5% of body mass has already led to changes in postural control of the child, a fact that leads to questions about the recommendation of the school backpack not to exceed the limit of 10% of body mass. It is suggested that children of eight years use double strap backpacks on the posterior trunk region, preferably with a load less than 5% of body mass, in order to prevent larger interferences in postural control. Moreover, it is recommended the use of individual lockers in schools, aiming to reduce the amount of material transported. These results also demonstrated the need to rethink the recommendations for the use of the school backpack in childhood regarding weight, since the different stages of development, growth and the particularities of each child must be considered (postural aspects, anthropometric and mechanisms of postural control), and should not be analyzed in isolation. It is expected that our study assists in raising awareness of parents, teachers and managers about the importance of the correct use of school backpacks and the deleterious effects when they are inadequate to the child. The educational programs and preventive care of healthy postural habits in childhood should include recommendations on the use of school backpacks and the individual relationship of children.

The evaluations in the Force Plate are described as reliable and with better accuracy to detect small balance disorders (Duarte & Freitas, 2010), however, present difficulties in simulating functional activities (Piirtola & Era, 2006). Thus, the associations between objective and subjective tests define better the complexity of postural control. The FP and the TUG have relatively high correlations between their variables (Sabchuk, Bento, & Rodacki, 2012). In this study, it was possible to verify that the FP and the TUG were sensitive to detect changes in postural control with and without the use of the school backpack in children.

The limitation of the study is related to the restricted age group of the sample, although eight years have been defined as the base age for maturation of postural control in childhood. Further studies about the use of different instruments to evaluate postural control are suggested. These instruments may also be associated with other aspects that interfere in the recommendations on the use of the school backpack in children, such as, anthropometric, and these studies must be performed in controlled environments and encompass different age ranges.

Conclusion

The study hypothesis was confirmed, since the load of the backpack modified the static and dynamic postural control of the assessed children. The school backpack with load caused increase in the A-COP, i.e., it impaired the postural control and modified the response mechanism, since the VELML and VELAP had lower values and interfered in the time of performance of the TUG, which resembles a functional activity, in children with 8 years of age.

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