CHANGES OF TRUNK POSITION AND BREATHING PATTERN IN CHILDREN WALKING UNDER CONDITIONS OF LOAD CARRIAGE

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Twenty-five boys aged 10.31 ± 0.26 years were selected from a primary school. Each subject participated in four walking trials on a treadmill: one without a bag (0% of body weight) and three carrying school bags, weighing 10%, 15%, and 20% of the child's body weight. Subjects walked at 1.1 m s^{-1} for 20 minutes on a treadmill. Walk movement was 2-D video filmed and analyzed. Tidal volume, respiratory frequency, and ventilation were measured with a cardiopulmonary function system before, during, and up until 3 minutes after the walk. The results show that there is a positive linear relationship between load weight, trunk forward lean, and breathing frequency. A 20-minute walk with a 20% load induced significant trunk forward lean and decreased trunk movement range, as well as increased respiratory frequency.

KEY WORDS: children, load, walking, breath

INTRODUCTION: School children carrying heavy bags are a common phenomenon. Overloading of school bags has aroused the concern of communities in many countries. Reports from Europe and Asia have found that many students carry weights of more than 10%, and in some cases even up to 20%, of their body weight (Sander, 1979; HKSCHD, 1988). However, compared with our understanding of physiological and biomechanical responses to load carriage in adults, we know little about responses to load carriage in children. Malhotra and Sen Gupta (1965) examined the metabolic cost to children associated with different ways of carrying schoolbags while walking. Pascoe *et al*. (1995) studied the kinematic impact on children's static postures and gait kinematics of walking under four different conditions: without a load and carrying a book bag weighing 17% of mean body weight in the form of a one-strap backpack, a two-strap backpack, and a one-strap athletic bag. The one-strap book bag induced significant elevation of the strap-supporting shoulder and concomitant lateral bending of the spine. Hong *et al*. (1998) investigated the energy expenditure of children walking under four different load conditions-- 0%, 10%, 15%, and 20% of their body weight. The results showed that walking 20 minutes at 15% and 20% load conditions produced significantly higher physiological strain than that measured at 0% and 10% load conditions. Recently, Hong and Brueggemann (2000) reported their findings on changes of gait patterns in 10-year-old boys carrying school bags of 0%, 10%, 15%, and 20% of their body weight while walking on a treadmill for 20 minutes. The results found that the 20% load condition induced a significant increase in trunk forward lean, double support and stance duration, as well as decreased trunk angular motion and swing duration; the 15% load condition induced a significant increase in trunk forward lean. Based on the reviewed literature, no study has reported on how breathing patterns, in terms of tidal volume (Vt), respiratory frequency (fb), and ventilation (Ve), alter in children under conditions of increased load carriage during walking. It is unknown whether trunk position, carried weight and breathing patterns are associated. The purpose of this project was to determine the impact on children's' trunk position and breathing patterns of carrying different weights of schoolbags while walking, and to examine possible associations between school bag weight, trunk position and breathing patterns through an analysis of kinematics and pulmonary function.

METHODS: Twenty-five boys aged 10.31 ± 0.26 years were selected from a primary school. The criterion of selection was that they best represented this age group in terms of mean Body Mass Index. The body mass and stature of the subjects were 33.60 ± 3.62 kg and 141.80 ± 4.77 cm respectively. All subjects were determined through medical examination and questionnaires to be free from cardiorespiratory and skeletal muscle diseases.. Each subject participated in four walking trials on a treadmill: without a bag (0% of body weight) and with a school bag of

10%, 15% and 20% of the child's body weight. Subjects walked at 1.1 m s^{-1} for 20 minutes on the treadmill. Their movement was recorded by one 3-CCD video camera (50 Hz) positioned laterally to the subject with the lens axis perpendicular to the movement plane. The distance of the camera from the movement plane was 7.5 m and the shutter speed was set at 1/250 s. The recorded video tapes were then digitized on a motion analysis system using a human body model consisting of 21 points, including the toes, heels, ankles, hips, shoulders, elbows, wrists, fingers, ears and neck. In each trial, three complete gait cycles were taken, at the beginning of the test, at the point when the child's walking gait was observed to become consistent, and 20 minutes after starting walking. For each complete gait cycle, the mean trunk inclination angle and the trunk motion range were calculated. 'Trunk inclination angle' refers to the angle of the line connecting the shoulders and hips in relation to a horizontal line through the hips during all frames of one complete stride. Values of less than 90 degrees represent a forward lean of the trunk, while values greater than 90 degrees represent a backward-leaning trunk position. 'Trunk motion range' refers to the range of angular motion that was observed during the stride. Vt and fb were measured with a cardiopulmonary function system (Oxycon Champion, Yeager, Germany) before, during, and up until 3 minutes after the walk. All parameters measured were calculated automatically and continuously and were averaged every thirty seconds by the cardiopulmonary function system. The data for Vt and fb recorded at the beginning of the test and 20 minutes after starting walking were used for analysis. Ve values were calculated based on the data of Vt and fb. The values of Vt and fb measured after 1 minute of walking under a 0% load condition served as baselines. Changes of Vt in response to load carriage were calculated as a percentage increase of Vt compared to its baseline. A two-factor repeated measures analysis of variances was used for statistical analysis of Vt, fb, trunk inclination angle and trunk motion range. A Pearson correlation was performed between the load condition, trunk inclination angle, Vt, and fb. A value of $\propto = 0.05$ was used for all tests as the criterion value in determining the presence or absence of significance.

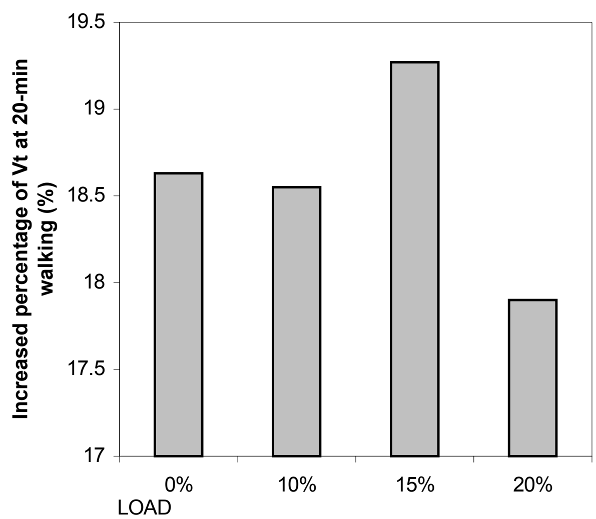

Figure 1 – Percentage increase of Vt after 20 min. of walking under different loads.

RESULTS: Trunk positions: No significant differences were found in trunk inclination angle and trunk motion range between the measurements at the 1 and 20 minute marks for each load level. Trunk inclination angle significantly increased under loads of 20% and 15% body weight, as compared to 0% and 10% load conditions. Trunk motion range decreased significantly under a load of 20% body weight when compared to a 0% load condition.

Breathing patterns: Ve increased with the load. No significant difference was found in Vt among the four load conditions. The only significant difference in fb ($P < 0.05$) was found between the 0% and 20% load conditions. Figure 1 shows the percentage increase of Vt under each load condition after 20 minutes walking and the lowest increase in Vt under a 20% load.

Association of trunk position, load, and breathing patterns: The data reveal that the Pearson's correlation coefficients between load and trunk inclination angle and between load and trunk motion range are 0.674 and –0.282 respectively, with significant difference at the 0.01 level. Trunk inclination angle increases linearly with the load weight, while the trunk motion range reduces linearly with the load weight. Weight carried is positively correlated with fb, yielding a Pearson's correlation coefficient (0.360) that is significant at the 0.01 level.

DISCUSSION AND CONCLUSION: Changes of trunk position in children carrying loads have already been reported by several studies. Malhotra and Sen Gupta found that a load of 10% to 12% of the subjects' weight did not produce appreciable trunk forward bend. Pascoe et al. (1995) found that carrying a two-strap backpack of 17% of body weight significantly promoted forward lean of the head and trunk in young subjects, compared to Figure 1 – percentage walking without a bag. The present study examined four different loads and found a positive linear relationship between trunk position and weight carried; a load equal to or greater than 15% of the subject's body weight results in significant trunk forward lean and reduced trunk motion range. In this study, Ve showed a trend increasing with load weight, indicating increased metabolic cost as the weight of load grows. However, when we analyzed Vt and fb, the two determinant factors of Ve, significant change was found only in fb. In this study, fb showed a positive linear relationship with load, but not Vt. The percentage increase of Vt under a 20% load condition was even lower than that with other load conditions. These results demonstrate that increased Ve in children during walking under conditions of load carriage is mainly caused by the increase in fb. Increased trunk inclination angles and limited trunk motion ranges might have an impact on the respiratory change found in this study. Children carrying heavy loads have to bend their trunks forward to maintain body posture and body balance while walking. Significantly increased forward lean might affect chest and abdominal respiratory muscle movement. Thus, the only way that the subjects can increase oxygen uptake to support the increased metabolic cost is to breathe faster. A previous study (Hong et al, 1998) reported that the work intensity of 10-year-old children who walked for 20 minutes with a load equal to 20% of their body weight was around 44.11% VO_{2max} of the subjects. This intensity, to the best of our knowledge, does not produce harmful strain for children. This study shows a positive linear relationship between the load weight, trunk position, and breath frequency. Children walking 20 minutes with a load weight of 20% of body weight were forced to lean forward and to breathe more rapidly with a stiffer upper body position, which would result in physical strain. Children at this age are experiencing significant growth and motor development. Carrying a bag of 20% of body weight for daily schooling would have harmful effects on children of this age.

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