

AGE DIFFERENCE IN TRUNK KINEMATICS DURING WALKING WITH DIFFERENT BACKPACK WEIGHTS IN 6 TO 12 YEAR OLD CHILDREN

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The study reported investigated age difference in trunk kinematics during walking with different backpack weights. Two groups of boys, aged 6 and 12 years old, participated in the study. A multiple trial test was conducted with backpacks loaded with 0%, 10%, 15%, and 20% of each subject's body weight. The subjects walked on a treadmill at a self-selected comfortable speed for 20 minutes. The movements of the subjects in sagittal plan were filmed and analyzed. The results indicate that trunk inclination angle progressively increased with the increase backpack weight in both age groups. Carrying a load heavier than 15% of body weight resulted in a significantly increased trunk inclination angle when compared to no load. The 12-year-old children showed a significantly larger amplitude in the trunk inclination angle than the 6-year-old children when carrying the same backpack weight.

KEY WORDS: trunk posture, walking, load carriage, child.

INTRODUCTION: The carriage of backpacks has been shown to constitute a considerable daily "occupational" load on the spines of school children. It is widely believed that the repeated carriage of heavy school backpacks places additional stress on the rapidly growing spine of children, making them more prone to postural change, and ultimately leading to lower back problems. Previous studies on the load carriage of children were mainly focused on the influence of load on energy expenditure, work intensity, cardiorespiratory responses (Hong, Li, Wong, & Robinson, 2000), gait alteration, trunk posture (Hong & Brueggemann, 2000; Pascoe, Pascoe, Wang, Shin, & Kim 1997), and the fatigue and activity of back muscles (Hong & Cheung, 2002). These studies documented that the carriage of heavy loads which were more than 10% of body weight induced significantly raised physiological strain, muscular activity, and fatigue of the erector spinae at L3 and the upper trapezius, as well as changed gait and trunk posture. However, the findings were obtained from subjects of single age group. There has been almost no research into responses to load carriage during walking by age group. The question of whether there is any age difference in trunk kinematics during walking with load carriage in children is unclear. The purpose of the study reported herein was to compare the trunk kinematics of children aged 6 and 12 years old who carried different schoolbag weights while walking.

METHODS: Subjects Twenty-two boys were randomly selected from grade 1 (11 boys) and grade 6 (11 boys) at a local primary school. The mean ages of the two groups were 6 ± 0.4 years and 12 ± 0.4 years respectively. Approval for the study was obtained from the Clinical Research Ethics Committee. Based on the full understanding of the subjects and their parents about the testing procedures, and the willingness of the children to participate in the study, parental consent was obtained. Body mass and stature were 22.8 ± 4.0 kg and 120.5 ± 5.1 cm for the 6-year-old age group and 44.6 ± 8.4 kg and 155.2 ± 6.5 cm for the 12-year-old age group.

Backpack: A two-strap backpack that was used by most students in Hong Kong was selected for the study. The backpacks were filled with books so that the weight of the bag was approximated different percentages (10%, 15%, and 20%) of each individual subject's body weight. The backpack without any additional weight (0%) served as a control. The backpack was carried on both shoulders, placed on the trunk and fixed to a position (at waist level) so that the subject felt most comfortable and stable.

Measurement: Each subject participated in four walking trails of 20 minutes each on treadmill on four different days, with a backpack without a load (0% of body weight), and with

10%, 15%, and 20% of the child's body weight. Before data collection, each subject was asked to walk for 10 min on a track at a comfortable speed. The recorded speed of each subject was then used as treadmill walking speed for that subject. The range of this self-selected speed was from 1.1 m/s to 1.3 m/s. In each trial, the subject's gait movements were recorded by a 3-CCD video camera of 50 Hz that was set at 1/250 shutter speed. The camera was positioned laterally to the subject with the lens axis perpendicular to the movement plane. The height of the camera was approximately the subject's hip joint height, and the distance of the camera from the movement plane was 7.5 m. Reflective markers were placed on 8 body segment anatomical landmarks (toe, heel, ankle, knee, hip, shoulder, forehead, and jaw) to facilitate the automatic video digitization. The recorded videotapes were digitized on a motion analysis system (APAS, USA) using a human body model that consisted of 8 points, which were determined by the reflective markers. In each trial, three complete gait cycles were taken for five time points: the 1st, 5th, 10th, 15th, and 20th minutes after the commencement of walking. For each complete gait cycle, the mean trunk inclination angle and the trunk motion range were calculated using the software in the motion analysis system. The trunk inclination angle was the angle of the line joining the shoulder and the hip in relation to the horizontal through the hip. Values of less than 90 degree represented a forward lean. The trunk range of motion was the range of trunk inclination angles observed through the stride.

Data analysis and statistics: All data were presented as mean and standard deviation. Repeated ANOVA (5 time points 4 loads) was performed to compare each data set obtained in trunk kinematics parameters for the five measuring time points and four loads within each group. Paired t-tests were used to compare any difference in trunk kinematic parameters at each time point in a given load condition between the two age groups. A value of $\alpha = 0.05$ was used for all tests as the criterion to determine the presence or absence of significance.

RESULTS AND DISCUSSION: Impact of walking time on trunk kinematics: When examining the influence of walking time with each load on trunk kinematics, no significant differences in trunk kinematics were found between the measurements at five time points. This suggests that walking time did not influence the trunk kinematics even at the load condition of 20% of body weight. When a backpack with a certain load is added to the trunk, an automatic postural adjustment to restore equilibrium is triggered. The postural responses involve a complex interplay of trunk and lower limb movement to move the center of mass in the direction of the perturbation, followed by an additional phase in which the posture is returned to upright equilibrium (Horak & Nashner, 1986). When a heavy load is carried on back, the body responds by adjusting its posture, and the trunk inclination angle increases. And when the body posture returns to equilibrium, that posture will be maintained for a period unless fatigue or new perturbation occurs. Therefore the trunk inclination angle increased as the backpack weight increased, and the trunk kinematics did not show significant change during the 20 minutes of walking.

Impact of backpack weight on trunk kinematics: Figure 1 illustrates the changes of trunk inclination angle at each load condition during walking in two age groups. The data analysis showed that the trunk inclination angle progressively increased as the load increased, while the trunk motion range progressively decreased with the increase of the load in both age groups. However, when comparing the influence of the load on the trunk inclination angle in the 6-year-old group, a significant difference was found in the 15% and 20% load conditions with respect to the unloaded condition from the 5th through to the 20th minute of walking. No significant difference was found between the 10%, 15%, and 20% load conditions throughout the 20 minutes of walking. In the 12-year-old group, any one of the additional loads produced a significant increase in trunk inclination angle throughout the 20 minutes of walking with respect to the unloaded condition ($P < 0.05$ for the 10% load, and $P < 0.01$ for the 15% and 20% load conditions). However, after 20 minutes of walking, significant difference was found in trunk inclination angle between the 10% and 20% load conditions ($P < 0.05$). The results demonstrated that backpack weight has an important impact on trunk posture, which is similar to our previous findings with 10-year-old children (Hong and Brueggemann, 2002), findings with

other loads, such as 17% of body weight in children aged 9-13 years old (Pascoe et al., 1997), or the findings in adult subjects (Kinoshita, 1985; Martin et al., 1986; Bloom & Woodhull-McNeal, 1987). Moreover, the increased trunk inclination angle has been observed in a quiet standing position (Grimmer, 1999). The present and previous data of the inclination angle is quite consistent, progressively increasing as the load of the backpack increases. The additional stress placed on the structure of the vertebral column due to the combination of load and trunk forward bend results in an increased intradiscal pressure on the spine. Studies have found that intradiscal pressure increases as the forward bending degree of the trunk increases (Rohlmann et al., 2001). Therefore, the carriage of heavy backpacks definitely exerts strain on the spine.

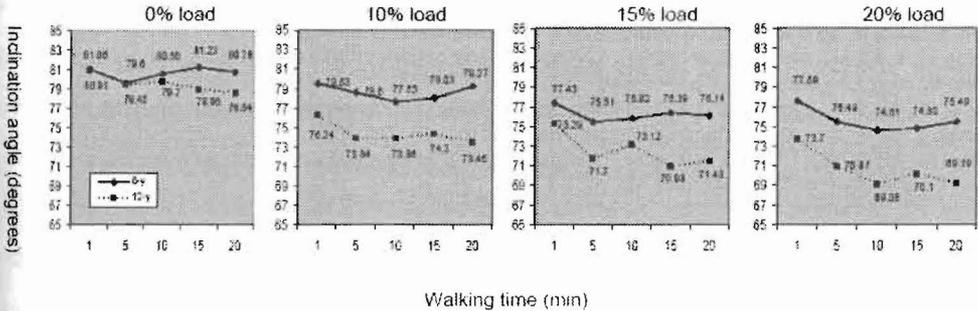


Figure 1: Trunk inclination angle at each load condition in 6 and 12 years groups.

Age difference in trunk kinematics: Age difference in trunk kinematics was presented in trunk inclination angle. The significant age difference in trunk inclination angle was found at the 20th minute of walking in the 10% load condition, at the 5th minute of walking in the 15% load condition, and throughout walking in the 20% load condition. To our knowledge, studies of age difference in trunk kinematics during walking with load carriage have not been reported. Grimmer et al. (1999) investigated the effects of backpack weight on adolescent head-on-neck posture through the response of the craniovertebral angle to backpack loads. They measured the posture of 985 high school students aged 12 to 18 years, with and without school backpacks, using photographs of the erect standing body. The students were categorized into five age groups. The results showed that there was a significant change in the craniovertebral angle in response to wearing a backpack for each of the five groups. This response was inversely related to age of the students, which suggests that as the spine matures, a less obvious head-on-neck response to load is invoked. However, the present data for 6- and 12-year-old children showed a trunk postural response pattern which differed from that of the Grimmer et al. study. The different study conditions and different age ranges might have led to the difference in results. Forward inclination of the trunk when an additional load is added to the back is a postural adjustment to gain body equilibrium. 12-year-old children showed larger trunk forward inclination angles in response to the load than did the 6-year-old children. Through the adjustment of trunk posture, body equilibrium was maintained. However, this adjustment was accompanied by a higher demand placed on the trunk muscles. The muscle strength of 6-year-old children is less than that of their 12-year-old counterparts. The smaller magnitude of trunk inclination angle in 6-year-old children who are carrying backpacks seemingly indicates that their body equilibrium might be maintained by something in addition to trunk postural adjustment. Therefore, age difference in other parameters such as gait stability should be further studied.

CONCLUSION: The study found that there was a significant age difference in trunk kinematics during walking with different backpack weights, which was presented as a forward inclination of the trunk. The trunk inclination angle progressively increased as the load increased. The magnitude of the increased trunk inclination angle when carrying an additional load on the back was significantly larger in 12-year-old children than their 6-year-old counterparts.

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