THE EFFECT OF LOAD CARRIAGE AND SCHOOLBAG DESIGN ON LATERAL TRUNK POSTURE DURING STAIRS DESCENT IN CHILDREN

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The aim of this study was to investigate the way that the schoolbag weight combined with carrying method effects the trunk posture laterally during stairs descent. Thirteen male children performed stairs ascending and descending on a 33-step staircase at their natural cadence for three complete cycles with athletic bag and backpack, each with loads of 0%, 10%, 15% and 20% of their body weight. The trunk posture of one complete gait cycle during every descent was analyzed. Significant load effects on trunk posture were found when the load was increased from 0% to 15% when carrying athletic bag, and when the load was increased to 20% when carrying backpack. For loads of 10%, 15% and 20% the body weight, a backpack design significantly reduced the trunk posture alternation compared with athletic bag.

KEY WORDS: load carriage, schoolbag, lateral trunk posture, stairs descent, children.

INTRODUCTION: Stair walking is a common functional activity in daily life which may result in increased dynamic loading on human. In Hong Kong, schools and living places are often many-stories buildings, and thus walking stair with schoolbag is a must for all school children. In addition, the schoolbag weight of Hong Kong children was found to be 20.2% of their body weight (HKSCHD, 1988), which exceeded the recommendation in previous studies (Hong et al, 2000). In order to cope with increasing load, adjustment in trunk posture was found during level walking (Hong and Brueggemann, 2000). Troussier et al (1994) studied the risk factors leading to low back pain and found a significant correlation between the present of low back pain and the load carrying position in 1178 pupils. Kinoshita (1995) found that a double strap backpack significantly reduced trunk tilt during level walking. However, there is little similar study on stair walking. Lau (2002) studied the effect of load and schoolbag design during stair walking in children and found significant effect on the trunk posture in sagital plane. Hong et al (2003) reported that the biomechanics of walking downstairs was significantly different from walking ascending and on level ground. It is believed that during stair descent,
the increasing load and the schoolbag design will affect the trunk posture also in lateral plane, which may lead to higher risk of spinal symptoms. Therefore, the aim of this study is to study the effect of the load and schoolbag design on lateral trunk posture during stair descent.

METHODS: Thirteen male secondary school students (mean ± S.D.: age: 12.21 ± 0.98 yrs; mass: 47.12 ± 9.69 kg; height: 159.66 ± 9.67 cm) participated in this study. The test was taken place at the audience seat of the university gymnasium. All of them were free of injury on the testing day, and had no history of injury that may cause them to have abnormal gait or difficulties in walking stairs. Consent forms from subjects and parents were collected before the test. Subjects were required to dress in black and tight t-shirt and shorts provided, with eight reflective skin markers attached at the positions of left and right shoulder, hip, knee and toe. Each subject performed upstairs and downstairs walking with different loads and carrying methods in each trial. They started at the bottom of the 33-step staircase. In each trial they walked up to the top and then walk down to the bottom at his natural cadence for three times. A total of eight trials in random sequence were performed by each subject, each with a combination from four loads and two carrying methods. The four load conditions equaled 0%, 10%, 15% and 20% of the subjects' body weight. Percentage weight instead of absolute weight was used in order to achieve normalization across subjects. The required weight was prepared by filling the schoolbag with objects that students usually bring to school, such as books, pencil box, drawing material, PE T-shirt and shoes. The two types of schoolbag included a single strap athletic bag across the shoulder and a double strap backpack. They represented asymmetrical and symmetrical carrying methods. A high-speed video camera (JVC DVL9800, Japan) was positioned at the bottom of the staircase in parallel with the staircase to record the trunk movement in frontal plane with 50 Hz filming rate and 1/250s shutter speed. The films were captured and saved in computer. Video data of one complete gait cycle from the 17th to 15th step was trimmed during every descent, from 5 frames before the first contact of one foot strike on the 17th step to the next contact of the same foot strike on the 15th step. The video data were digitized by Ariel Performance Analysis System (APAS, USA). A six-point model (left and right shoulder, hip and toe) was applied. Left and right trunk segment angles, which were defined as the angles between the line joining the mid-point of the left and right shoulders and the mid-point of the left and right hips to the horizontal, were obtained after transforming and filtering the digitized model. It was then normalized to the initial vertical position of each subject. A value larger than 90 degrees meant that the trunk was tilted to the right, and vice versa. The dependent variables in this study were the average, maximum and minimum lateral trunk angle, trunk lateral range of motion and maximum trunk lateral angular velocity during one complete gait cycle. Trunk lateral range of motion was calculated by determining the difference between maximum and minimum trunk segment angles. The measurements in the three stair descents in each trial were averaged. Two-way multivariate analysis of variance MANOVA) with repeated measures was applied to see the main effect by schoolbag design and load on the dependent variables. Provided that if significant main effect on either load weight or schoolbag design, one-way analysis of variance (ANOVA) post-hoc multiple comparison LSD test was applied to determine any significant difference on the dependent variables between each of the four load conditions. Repeated measure t-test was applied to determine the significant difference among the two schoolbag designs. Significance levels for all tests were set at 0.05.

RESULTS AND DISCUSSION: Table 1 and 2 shows the mean and standard deviation of the trunk posture parameters including the average, maximum and minimum lateral trunk angle, trunk lateral range of motion and maximum trunk lateral angular velocity at each load and with each schoolbag.

Table 1 Mean and standard deviation of trunk posture parameters at each load with athletic bag

Trunk posture parameters	Athletic bag			
	0%	10%	15%	20%
Average angle (degree)	88.86 ± 1.68	88.11 ± 1.70	88.78 ± 2.29	88.64 ± 2.37
Max angle (degree)	91.53 ± 1.83	91.14 ± 1.91	92.09 ± 2.43	92.51 ± 2 59
Min angle (degree)	86.37 ± 1.87	85.39 ± 2.08	85.79 ± 2.44	85.32 ± 2.67
Range (degree)	5.16 ± 1.50	5.75 ± 2.05	6.30 ± 1.90	7.20 ± 2 60
Max angular velocity (degree/s)	26.32 ± 6.19	31.09 ± 10.27	28.14 ± 5.38	35.22 ± 7 56

Table 2 Mean and standard deviation of trunk posture parameters at each load with backpack

Trunk posture parameters	Backpack			
	0%	10%	15%	20%
Average angle (degree)	89.42 ± 1.60	88.72 ± 1.16	88.79 ± 1.13	89.07 ± 1.49
Max angle (degree)	91.61 ± 1.71	91.12 ± 1.57	91.15 ± 1.42	91.80 ± 2.08
Min angle (degree)	87.12 ± 1.61	86.33 ± .95	86.49 ± 1.27	86.45 ± 1.02
Range (degree)	4.49 ± 1.30	4.79 ± 1.34	4.66 ± 1.42	5.35 ± 1.33
Max angular velocity (degree/s)	22.54 ± 8.38	20.95 ± 7.10	20.38 ± 5.12	22.00 ± 3.11

MANOVA with repeated measures showed that both schoolbag design ($F = 61.170$, $p = .035$) and load condition ($F = 7.384$, $p = .039$) had significant effect on the dependent variables. One-way ANOVA showed that schoolbag design had significant effect on trunk lateral range of motion ($p = .000$) and the maximum trunk lateral angular velocity ($p = .000$), while the load condition had significant effect only on the trunk lateral range of motion ($p = .002$). Both schoolbag design and load condition had no effect on the average lateral trunk angle (p > 0.05). One-way ANOVA for each condition showed that significant differences were found on trunk lateral range of motion for both athletic bag (F = 4.205, p = .012) and backpack (F = 5.265, p = .019), and on maximum trunk lateral angular velocity for athletic bag (F = 5.825, p = .014). Post-hoc multiple comparison LSD tests showed that significant increase in trunk lateral range of motion was found when the load is increased from 0 % to 15% of the body weight when carrying athletic bag (p = .031). It is further increased when the load is further increased to 20% (p = .012). Significant difference was found between 15% and 20% load conditions (p = .032). For backpack, the trunk lateral range of motion was significantly increased when the load is increased from 0% to 20% (p = .034). The maximum trunk lateral angular velocity was significantly increased when the load is 20% when carrying athletic bag (p = .007). Repeated measure t-test showed that significance increases were found when carrying athletic bag compared to backpack when the load was increased from 0% to 10% (F= 5.379, p = .039), 15% (F = 11.520, p = .005) and 20% (F = 9.854, p = .009) on the trunk lateral range of motion, and when the load was increased from 0% to 10% (F = 20.407, p = .001), 15% (F = 15.474, p = .002) and 20% (F = 44.630, p = .000) on the maximum trunk lateral angular velocity.

In order to minimize the disturbance of balance and stability of the body center of mass, the human body's motor control will alter the posture with respect to the external surroundings. Athletic bag represented an asymmetrical load carrying method that may alter one's balance. Therefore the trunk posture was more altered when carrying single strap athletic bag compared with double strap backpack. This indicated the human's own adaptation technique. Heavy load was also found to be associated with spinal symptoms, low-back pain or musculoskeletal disorder (Troussier et al, 1994). Therefore, the repetitive activation of trunk muscles in prolonged load carriage walking may lead to muscular pain, low back pain or chronic injuries. Recommendation on schoolbag designs and maximum schoolbag weight should be suggested to students, parents, schools and government. Although Hong et al (2000) found no significant difference in trunk posture with increasing load in carrying backpack in level walking, significant differences were found in stairs descent when the loading was increased from 0% to 20%. This may due to the nature of the activity. In level walking, a person stays in the same horizontal level. In stairs descent, a person needs to propagate his center of mass downwards. In achieving this, one needs to bend his legs and to lower one side of his body in order to step on the next stair. This may introduce a larger trunk range of motion in frontal plane compared with level walking.

CONCLUSION: The result of this study showed that in carrying athletic bag, the trunk lateral range of motion was increased when the load was increased from 0% to 15% of body weight, and was further increased when the load was 20%. The maximum trunk lateral angular velocity was also increased when the load was 20%. In carrying backpack, trunk lateral range of motion was increased when the load was 20%. When the load was 10%, 15% and 20%, an athletic schoolbag design significantly introduce increase in trunk lateral range of motion and maximum trunk lateral angular velocity compared with a backpack design. It is concluded that a backpack design schoolbag with a load not exceeding 15% should be recommended for school children in order to avoid trunk posture alternation during stairs descent. Further study in muscle activity or plantar pressure distribution is suggested.

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