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THE INFLUENCE OF BACKPACK CARRIAGE ON TRUNK POSTURE IN CHILDREN DURING UNPLANNED GAIT TERMINATION

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This study aimed to examine the trunk posture in children with different backpack loads during unplanned gait termination. Twelve school boys aged 9–10 years completed unplanned and planned gait termination with a backpack load of 0%, 10%, and 15% of their body weight (BW) while level walking. Trunk inclination angle and trunk range of motion at sagittal plane and spinal angle at frontal plane were examined. In comparison with 0% BW load condition, the spinal angle increased significantly at 10% and 15% BW load condition during gait termination ($p<0.05$). The spinal angle was significantly larger under unplanned gait termination than that in planned gait termination. Therefore, unplanned gait termination and carrying a load heavier than 10% BW of the subject were found to significantly influence trunk posture.

KEY WORDS: backpack, trunk posture, gait termination, children.

INTRODUCTION: Walking with load carriage, such as carrying a school backpack, is a common daily activity among children. The repeated carriage of heavy school backpacks is widely believed to possibly place additional stress on the rapidly growing spines of children. This additional stress could make children more prone to postural change, and ultimately lead to lower back problems. According to LeVeau BF (1984), load carrying may influence the growth, development, and maintenance of the alignment of the human body. In addition, as the combined center of mass of the backpack and body greatly increases, walking with backpacks may induce postural imbalance for dynamic conditions and increase the risk of falling.

Unplanned gait termination is one of the main strategies to avoid falling or crashing under sudden external interferences. Gait termination (GT), a “sub-task” of walking, is defined as the transient period from repetitive gait (a dynamic locomotor task) to a full stop (a quasi-static postural task) (Crenna, et al., 2001; Jaeger & Vanitchatchavan, 1992; Jian, et al., 1993; Meier, et al., 2001; Oates, et al., 2005; Vreiling, et al., 2008). Unplanned gait termination is a special type of gait termination. In this locomotor task, balance is challenged during the transition from one dynamically stable movement pattern to a statically stable movement pattern.

Unplanned gait termination occurs commonly on children’s way to school or home while carrying school backpacks. Previous studies on the load carriage of children were conducted in level walking or standing condition (Li & Hong, 2004; Li, Hong & Robinson, 2003; Hong & Cheung, 2003; Pascoe, et al., 1997). To the author’s knowledge, all published work in biomechanics study of unplanned gait termination to date was conducted only in adults and the elderly (Tirosh & Sparrow, 2005; Tirosh & Sparrow, 2004). There is a lack of information on how the posture responses during unplanned gait termination in children when carrying different backpack loads. The purpose of the present study was to examine the trunk posture in children with different backpack loads during unplanned gait termination. The information obtained from the study can add to the understanding of influences of load carriage and external interference on gait and posture in children.

METHODS: Twelve boys aged 9–10 years participated in the study (Table 1). They were asked to walk along an 8 m walkway at a comfortable speed while carrying a backpack. Three different weights were utilized for the backpacks: 0%, 10%, and 15% of the body weight (BW) of the participant. In the unplanned gait termination trials, the participants were asked to stop walking immediately when one of 10 lights located within their vision field turned on. In contrast, in the planned gait termination trials, the participants were asked to stop walking when they reached a stop sign. Two cameras (JVC 9800 Inc., Japan) with 50 Hz filming rate and 1/250 s shutter speed were placed 10 m away from the walking path to record the locomotion at the sagittal and frontal planes. Four reflective markers were placed on spinous process of C7, acromion process of left shoulder, left posterior superior iliac spine (PSIS), and L5-S1 joint to facilitate automatic video digitization. Five walking trials of each walking condition were filmed. The recorded videos were digitized on a motion analysis system (APAS, USA). A model of a human body consisting of 21 points was used to examine the trunk inclination angle and trunk range of motion at the sagittal plane and the spinal angle at the frontal plane during the period from the breaking moment to a full stop. Trunk inclination angle (Li, Hong & Robinson, 2003) refers to the angle formed by the line connecting the left acromion process and left PSIS, and the horizontal line passing through the left PSIS. Values less than 90° represent a forward lean of the trunk, whereas values greater than 90° represent a backward lean. The trunk range of motion (ROM) refers to the range of trunk inclination angles observed in one complete gait cycle (Li, Hong & Robinson, 2003). A gait cycle in this present study was incomplete due to gait termination. Thus, the time of the trunk ROM was defined as the period from the moment of breaking to a full stop. The spinal angle, used to describe the lateral tilt of the trunk at the frontal plane, refers to the lateral deviation of the trunk segment from a horizontal position (Pascoe, et al. 1997). In the current study, the spinal angle is formed by the vertical line and a line joining the process of C7 and the S5-L1 joint. Values of 90° represent an upright posture. Measures greater or less than 90° designate a right or left lateral spinal bend, respectively. All data are presented as mean and standard deviation. Repeated ANOVA measurement (2 gait termination conditions × 3 backpack loads) was used to examine if there are any significant differences in the measurements between unplanned and planned gait termination with different load carrying conditions. Statistical significance was set at α=0.05.

RESULTS: Data analysis showed that the trunk inclination angle decreased as the backpack load increased. However, no significant difference was found in the measurements among the different load conditions (Table 2). Under both unplanned and planned gait termination, the spinal angle significantly increased as the load increased. The spinal angle was significantly larger while carrying 15% and 10% BW load than under 0% BW load condition during unplanned gait termination (p=0.015 and 0.049, respectively). The spinal angle was also significantly larger while carrying 15% BW load under planned gait termination than while carrying 10% and 0% BW load (p=0.000).
Significant differences in the spinal angle were also found between unplanned and planned gait termination. Compared with the spinal angle produced under planned gait termination, the spinal angle was significantly larger while carrying 10% and 0% BW load under unplanned gait termination (p=0.015 and 0.018, respectively).

Table 1
Subject Characteristics (mean ± SD)

	Age (y)	Body Height (cm)	Body Weight (kg)	Body Mass Index (kg/m^2)
n=12	9.85±1.34	140.89±11.57	34.96±9.62	16.28±1.45

DISCUSSION: Backpack weight and gait termination methods were found to have an important impact on trunk posture in sagittal plane. As the load increased, the trunk inclined forward and trunk motion range was inhibited, but there was no significant difference. Even when the backpack load increased to 15% BW, trunk posture at sagittal plane was the same as in 0% load during gait termination for this age group. From a statistical viewpoint, significant differences were found at spinal angle while carrying 10% BW load during unplanned gait termination and 15% BW load during planned gait termination. However, the differences of the spinal angle among three backpack loads were smaller than 2°. Such change in trunk posture might be too small to cause any discomfort. The unplanned gait termination caused larger changes in spinal angles compared with the planned gait termination, indicating that external interference can lead to more remarkable changes in trunk posture.

The findings in trunk inclination angle and trunk motion range of the present study are not consistent with previous published work. Previous research found that trunk inclination angle and trunk motion range change significantly, and no significant change is found in spinal angle during level walking or static standing (Li, Hong & Robinson, 2003; Hong, & Cheung, 2003; Pascoe, Pascoe, Wang, et al., 1997). Different test conditions may be the cause of the differences. In the present study, participants stopped walking when they saw a termination signal, and trunk posture angle were examined from the moment of breaking to a full stop. During gait termination, a forward torque, which may increase trunk inclination, was produced. At the same time, the extra load on the back torso produced a backward torque, which may cause a backward trunk inclination. Thus, the trunk kept a normal posture as the net torque was not enough to cause forward or backward trunk inclination. Furthermore, during gait termination, the breaking limb and trailing limb did not stop at the same time. Asymmetrical force was experienced in the limbs, which may cause a lateral tilt of the spine.

The spinal angle under unplanned gait termination condition significantly increased in comparison with that produced under planned gait termination condition. Compared with planned gait termination, response time to gait terminal signals was very short during unplanned gait termination. Participants had to stop walking as quickly as they can and did not have enough time to modify their posture like they did in planned gait termination. This might be a reason leading to the difference in spinal angle between two termination methods. However, the difference in spinal angle between the two gait termination conditions is less than 2°. Therefore, the impact of unplanned gait termination with a load of 10% or 15% BW on trunk posture might be very small.

Table 2
Trunk Kinematics Measures under Different Test Conditions (mean ± SD)

GT Conditions	Variables (Degrees)	Backpack load			F	*p*
		0%BW	10%BW	15%BW		
Planned GT	Trunk inclination angle	90.77±4.64	86.34±6.76	86.61±4.45	2.549	0.093
	Trunk motion range	14.89±5.28	14.25±5.02	14.17±4.35	0.078	0.925
	Spinal angle	1.53±0.47	1.83±0.37	2.87±0.54 **§	24.989	0.000
Unplanned GT	Trunk inclination angle	88.91±4.57	83.77±8.36	83.67±4.15	3.082	0.059
	Trunk motion range	15.21±5.62	15.23±6.32	14.26±6.99	0.091	0.914
	Spinal angle	2.06±0.51 #	2.73±0.78 *#	2.91±0.93 *	3.745	0.035

GT, Gait Termination; * $p<0.05$, ** $p<0.01$, 15%BW and 10%BW Vs 0%BW; § $p<0.01$, 15%BW Vs 10%BW; # $p<0.05$, Unplanned GT Vs Planned GT

CONCLUSION: The findings of this study provide information in trunk biomechanics changes in gait termination in children with a load carriage, for the first time. From a statistical viewpoint, unplanned gait termination and a carrying weight of 10% BW of the subject had a significant impact on trunk posture in the frontal plane. The walking condition of the study was even, walking distance was very short, and testing was conducted in the lab. To get further understanding to the biomechanical responses to gait termination in children with a load carriage when walking on uneven surface, or in a prolonged walking time, further study should be done. Many sports involving children participation demand load carrying and walking for longer time, over uneven surfaces such as Alpine hiking. Biomechanics study in these topics would contribute to the safety and injury prevention.

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