THE POTENTIAL INJURY RISK OF BACKPACK WEIGHT ON POSTURE AND GROUND REACTION FORCES OF OBESE CHILDREN DURING STAIR DESCENT

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This study investigated the effects of backpack weight on posture, gait pattern, and ground reaction forces for children with obesity in an attempt to define a safe backpack weight limit for them. A total of 16 obese (11.19±0.66 years of age) and 21 normal body weight (11.13±0.69 years of age) school boys were recruited. Two force plates and two video cameras were used. Multivariate analysis of variance with repeated measures was employed. Obese children showed increased trunk and head forward inclination angle, increased ground reaction force in the medial-lateral and anterior-posterior directions when compared to male children with a normal body weight. The changes were observed even with an empty backpack in comparison with normal body weight children and a 15% increase in backpack weight led to further instability and damage on their already strained bodies.

KEYWORDS: Children with obesity, Gait and posture, Stair descent

INTRODUCTION: Carrying a backpack is an activity in daily life for students. Many studies have been conducted to investigate the effects of backpack weight on children. These studies reported that excessive backpack weight result in back pain, muscle soreness, numbness, shoulder pain, and muscle fatigue (Johnson 1995; Pascoe 1997). Previous studies on effects of backpack weight on gait were mainly focused on individuals with normal body weight. Our literature review did not show any study on the effects of backpack weight on posture and ground reaction forces of children with obesity. Obesity results in significant disadvantage in movement and discomfort in simple daily activities such as walking and stair-climbing (Hills 1991) because large proportions of their body weight do not contribute to their movement performance. A good understanding of the effects of backpack weight on these children's posture, gait, and ground reaction forces will provide significant information for preventing musculoskeletal system injuries and disorders among these children.

Stair descent results in increased GRF in comparison to level walking and stair ascent. Andriacchi (1982) found that the maximum external knee flexion moment in stair descent was 2.7 times of that in stair ascent. Hong (2005) reported that the maximum peak force in stair descent with a backpack of 15% body weight was1.89 times greater than that in stair ascent, while the ground reaction force was 3 times of that in stair ascent.

Many studies have attempted to establish safe weight carrying limits for children, and the guidelines vary among countries. Load carrying limits were set as 10% of the body weight in New Zealand (Whittfield 2005); 10% to 12% in India (Malhotra 2007); 15% in Hong Kong (Hong 2008), Australia (Chansirinukor 2001), and Singapore (Singh 2009); and 20% in Turkey (Seven 2008). These load carrying limits were set for subjects with normal body weight in standing or level walking, and thus may not be appropriate for children with obesity in stair descent. The purpose of this study was to determine the effects of backpack weight on posture, gait pattern, and ground reaction forces of male obese children in stair descent.

METHODS: Subjects: A total of 16 school boys with obesity and 21 school boys with normal body weight between 10 to 12 years of age from Shimuyuan Primary School in Jinan, China were recruited as subjects. The mean age, standing height, body weight, and body mass index (BMI) were 11.19 ± 0.66 years, 148.85±14.07 cm, 75.26±15.99 kg and 29.78±4.10 kg/m^2, respectively, for children with obesity, and 11.13±0.69 years, 152.22±6.95 cm, 48.13±9.52 kg, and 20.03±3.08 kg/m2, respectively, for children with normal body weight. A BMI of 26 kg/m^2 or higher was defined as obesity for 12-year-old male children (Cole 2000). **Testing Protocol:** Each subject was asked to complete 1 testing session per day for a total of 4 testing sessions. In each session, the subject was asked to carry a two-strap backpack with both shoulders in a given backpack weight (0, 10,. 15, or 20% of body weight). **Data collection:** A staircase with 6 steps was built for the data collection in this study. The step dimensions were 17.0 cm (riser) × 29 cm (tread). Two force plates (KISTLER, 9287BA and 9281CA, Switzerland) were embedded in the 3rd and 4th steps of descent to collect GRF data at a sample rate of 1000 Hz. Two 50 Hz video cameras were placed 12 m from the walking track with an angle of 90^o to record movements. Six landmarks were manually digitized from video records (Left and right shoulder, left and right hip, forehead and lower jaw).**Data Reduction:** Trunk inclination angle was defined as the angle between trunk longitudinal axis and horizontal plane projected to the sagittal plane. The head inclination angle was defined as angle between the line connecting digitized forehead and lower jaw landmarks and the horizontal plane projected to the sagittal plane. Seven characteristic magnitudes of the ground forces were identified(Figure 1). **Data Analysis:** A two-way MANOVA with mixed design was performed to determine the effects of backpack weight and obesity condition. The back weight was treated as a repeated measure while the obesity condition was treated as an independent measure. If the effect of backpack weight was significant, post-hoc paired t-tests were performed to locate the differences.

RESULTS: Compared with normal weight children, obese children showed increased trunk inclination angle (p=0.003), head inclination angle (p=0.001). Trunk inclination angle significantly increased with the loads of 10% (p=0.012), 15% (p=0.011) and 20% (p=0.000) of the body weight for normal weight children, and with loads of 15% (p=0.002) and 20% (p=0.000) of the body weight for obese children.
Obesity increased F2 (p=0.005), F3 (p=0.017), F5 (0.004) and F7 (p=0.007), but it resulted in decreased F1 (p=0.000). F2 significantly increased with loads of 15% (p=0.003) and 20% (p=0.001) of the body weight for normal weight children, and with loads of 10% (p=0.008), 15% (p=0.000), and 20% (p=0.000) of the body weight for obese children. F3

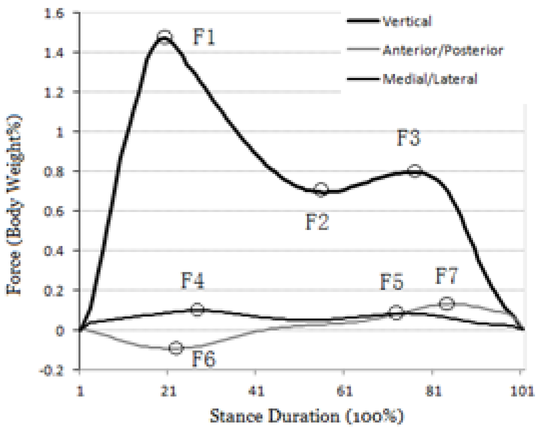

Fig. 1. Three components of the GRF for a stair descent trial; the 7 dependent variables chosen for analysis (F1 to F7) are shown.

significantly increased with loads of 15% (p=0.015) and 20% (p=0.000) of the body weight for normal weight children, and with loads of 15% (p=0.000) and 20% (p=0.000) of the body weight for obese children. F4 and F5 significantly increased with a load of 20% of the body weight for obese children (p=0.028, p=0.002, respectively). F7 significantly decreased with loads of 10% (p=0.044), 15% (p=0.000), and 20% (p=0.000) of the body weight for normal weight children. F1 significantly decreased with loads of 10% (p=0.003), 15% (p=0.003) and 20% (p=0.000) of the body weight for normal weight children, and with loads of 10% (p=0.010), 15% (p=0.005), and 20% (p=0.018) of the body weight for obese children. There were no significant differences between the F6 values among the different backpack loads(Table 1).

Table 1: Posture and GRF variables during stair descent.

Variables	Normal weight (mean and standard deviation)				Obese (mean and standard deviation)			
	0%	10%	15%	20%	0%	10%	15%	20%
Trunkangle	5.54 (2.61)[a]	6.78 (2.22)[b]	7.31 (2.39)[b]	7.57 (3.00)[b]	8.55 (2.61)[a]	10.46 (3.79)	11.87 (4.02)[c]	11.43 (3.53)[c]
Head angle	18.3 (11.23)[a]	16.29 (10.56)	17.36 (8.88)	17.91 (12.26)	22.68 (10.03)	23.82 (8.06)	23.77 (9.95)	22.48 (10.05)
F1 (BW%)	171.52 (30.72)[a]	195.70 (33.92)[b]	197.80 (33.58)[b]	203.76 (27.68)[b]	161.87 (16.86)[a]	177.49 (12.27)[c]	180.99 (19.00)[c]	181.39 (23.56)[c]
F2 (BW%)	55.53 (8.50)[a]	58.06 (12.69)	67.92 (14.98)[b]	72.60 (15.73)[b]	66.35 (8.02)[a]	73.61 (4.99)[c]	80.86 (6.06)[c]	82.63 (5.71)[c]
F3 (BW %)	80.63 (13.91)[a]	84.73 (13.45)	91.13 (10.29)[b]	94.47 (11.91)[b]	83.10 (8.98)[a]	87.81 (9.62)	93.92 (7.39)[c]	97.34 (9.86)[c]
F4 (BW %)	9.96 (1.60)	10.64 (1.87)	11.16 (1.77)	10.22 (2.05)	10.66 (2.19)	11.13 (2.34)	9.29 (2.47)	11.56 (1.85)[c]
F5 (BW %)	7.23 (2.14)[a]	7.33 (1.36)	8.29 (1.63)	8.36 (2.36)	8.65 (2.09)[a]	9.28 (2.37)	8.91 (2.37)	9.93 (1.82)[c]
F6 (BW %)	-9.82 (1.51)	-10.65 (2.20)	-10.56 (2.86)	-11.07 (2.72)	-10.01 (1.40)	-10.28 (2.55)	-10.75 (2.95)	-10.44 (2.75)

a: p<0.05 between the average backpack loads of normal weight and obese subjects

b: p<0.05 vs. 0% in normal weight subjects c: p<0.05 vs. 0% in obese subjects

DISCUSSION: The kinematic data obtained from this study revealed that both, normal and obese, male children increased their trunk forward inclination angle as the backpack weight increased to10% and 15% of the body weight, respectively. As the weight of the backpack increases, the trunk forward inclination angle increases progressively. The additional stress placed on the structure of the vertebral column due to the combination of load and trunk forward bend results in increased intradiscal pressure on the spine. The current research showed that schoolbag weight did not increase the head forward inclination angle. However, children with obesity tended to lean their heads further than children with normal body weight. During stair descent, normal body weight subjects had to identify the location of the next staircase step, while children with obesity had to lean their head to avoid the blocking of the sightline resulting from their relatively raised abdomen; in turn, the increased head forward inclination angle leads to greater muscular strain on the cervical vertebra.

Although some studies have concluded that F1 tends to decrease in children with obesity (Dowling 2004), no study has yet to examine GRF during stair descent for obese subjects. The first peak of the vertical GRF reflects the nature of energy absorption. For obese children, the relatively larger plantar contact area (Mickle 2006) and thicker plantar skin may cushion energy absorption that, in turn, can help children with obesity avoid first vertical shock.

F5 and F7 values showed that children with obesity exerted more medial-lateral and anterior-posterior forces. Mizrahi (1989) concluded that anterior-posterior stability is applied to the support surface using the feet and ankle concurrently, whereas medial-lateral adjustments result from foot forces applied in the opposite direction. Ankle rotation versus lateral weight shift is typically used to maintain anterior-posterior versus medial-lateral stability. Therefore, the addition of noncontributory mass to the body system would have greater influence on one's ability to shift weight laterally, thus leading to difficulties in maintaining medial-lateral stability. The additional backpack weight can certainly be problematic for children with obesity attempting to maintain anterior-posterior and medial-lateral stability.

CONCLUSIONS: Children with obesity increased their trunk forward inclination angle, head forward inclination angle in comparison to children with normal body weight when carrying backpack weight between 0 to 20% of their body weight during stairs descent.Children with obesity exerted greater GRF in the medial-lateral and anterior-posterior directions and less GRF in the vertical direction in comparison to children with normal body weight.A backpack weight more than 15% of body weight led to further instability and damage on their already strained bodies of children with obesity.

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