THE EFFECT OF LOAD CARRIAGE ON GAIT PATTERN AND TRUNK POSTURE IN SCHOOL CHILDREN

Chi-Kin Cheung and Youlian Hong
The Chinese University of Hong Kong, Hong Kong SAR

The purpose of this study was to examine the way in which the weight of schoolbags combined with walking distance effects the gait pattern and trunk posture of school children over a long period of time in field situations. Twenty-three male primary school students were randomly assigned to carry loads of 0%, 10%, 15% and 20% of their body weight. Subjects were required to walk along a basketball court for 22 laps, i.e. 1892 meters were analyzed, using natural cadence for the duration of the session. The gait pattern and trunk posture at about 10, 700, 1300 and 1890 meters were analyzed. From the data that was obtained it was apparent that there were significant differences in trunk inclination angle, stance duration, double leg support duration, and swing duration between the loads of 0% and 20% body weight.

KEY WORDS: load carrying, gait pattern, trunk posture, children

INTRODUCTION: The influence of heavy schoolbags on the health of school children has drawn much attention from the community. Malhotra and Sen Gupta (1965) compared ventilation, oxygen consumption and pulse rate of children, walking with the requisite heavy schoolbag in four different locations. They found that carrying the schoolbag or rucksack induced the minimum increase in their physiological measurements. Hong et al. (1999) also reported that the metabolic costs of carrying a schoolbag with 20% of body weight were significantly different from those with the bag containing 10% of body weight. Therefore, they recommended that 10% of body weight is an appropriate weight of schoolbags for children. While much work has been done on the impact of load carrying in children with physiological studies, little research has been done to investigate this problem from a biomechanical perspective.

Bobet and Norman (1984) pointed out that energy expenditure could only reflect the total work rate of the body. They maintain that these measurements are not sufficient for assessment of muscle load demands involved in carrying heavy weights. It is also important to provide insight into the aetiology of injuries associated with carrying tasks. Recently, Pascoe et al. (1997) have investigated selected gait parameters and the posture of youths while carrying a schoolbag with 17% of their body weight. They found that use of a backpack promoted a forward lean in the posture and increments in stride length and stride frequency. However, in a study similar to previous biomechanical research concerning load carrying, Pascoe et al. (1997) collected data on walking a short distance with weights under laboratory conditions. Kinoshita (1985) also suggested that the long-term effect of load carrying on changes in gait pattern should be examined. Therefore, the purpose of this study is to examine the way in which the weight of schoolbags combined with walking, effect the gait pattern and trunk posture of school children for a long period of time in field situations.

METHODS: Twenty-three male primary school students (age 9.43 $\pm$ 0.51 years, stature 134.52 $\pm$ 6.00 cm, body mass 31.20 $\pm$ 5.41 kg) were served as subjects in this study. All subjects were injury free at the time of testing and none had history of injury that may have resulted in an abnormal gait. In addition, all subjects were screened for postural asymmetry and chronic low back pain. The subjects and their parents were supplied with relevant information and gave informed consent to participate in this study.

Subjects came to a university gymnasium for one full day in order to complete the required two trials. Standard clothing in the form of T- shirt, shorts and shoes was required. In each trail, each subject was assigned randomly to carry a schoolbag of 0%, i.e. without a schoolbag, 10%, 15% and 20% of the subject's body weight. To simulate a real situation, the most popular schoolbag was used in this study and books were added to the schoolbag to provide the specific weight. The straps of the schoolbag were adjusted for each subject so

that it could be carried in a comfortable position on the back. In each trail, each subject was required to walk along the borderline of basketball court, with natural cadence for 1892 meters. A one and a half-hour break were provided between trails.
Two-dimensional video filming technique was employed to record the subject's locomotion. Video camera (JVC, GY-X2BE) with 50 Hz in filming rate and 1/250 shuttle speed was positioned at 10 meters distance away from the subject laterally to record the locomotion. The filming fields of 5 to 7 meters width provide at least one gait cycle for analysis. The gait pattern was recorded at about 10, 700, 1300 and 1890 meters and were digitized manually and analyzed by a motion analysis system (Bewegungs Analyse System, Germany). The parameters of gait pattern investigated in this study were walking velocity, stride length, cadence, cycle duration, stance duration and swing duration. A correction for difference in body height has been made before comparing values of stride length and walking speeds for subjects. In addition, fundamental temporal measures included swing and stance duration were expressed as percentage of the total cycle duration. Beside gait pattern, the motion analysis system also provided body posture parameters, which included mean trunk inclination angle and its range of motion, during all frames of one complete stride. Two-way ANOVA with the level of significance set as $p < 0.05$ was used to examine the effects of schoolbag weight and walking distance and their interactions on gait pattern and trunk posture. When significance was found, a Scheffe post hoc test was employed to identify the specific mean trial differences.

RESULTS AND DISCUSSION: The two-way ANOVA performed on the gait pattern and trunk posture did not result in a significant interaction effect. Besides, the main effects of walking distance were also not statistically significant at all variables. It is possible that the walking distance in this study was not of sufficient duration to induce significant changes. Only the main effects of weight were statistically significant at stance duration, second double support duration, swing duration, and trunk inclination angles. Table 1 shows the gait pattern and trunk posture parameters at each load.

Table 1. Mean and Standard Deviation of Gait Pattern and Trunk Posture Parameters at the Loads of 0%, 10%, 15% and 20%

Variable	0%	10%	15%	20%
Normalized Velocity, unit/s	1.08E-2 ± 1.20E-3	1.07E-2± 1.24E-3	1.08E-2± 1.25E-3	1.04E-2± 1.36E-3
Normalized Stride length	0.95±0.09	0.93±0.09	0.94±0.09	0.94±0.08
Cadence, step/sec	136.57±9.31	138.15±10.12	137.91±11.33	132.60±12.76
Cycle duration, sec	0.88±0.061	0.87±0.064	0.88±0.064	0.91±0.064
Duration of stance, %	62.02±1.81	62.98±1.93	62.87±1.73	63.26±1.79**
Initial double support, %	12.05±1.91	12.32±2.01	12.83±1.70	12.91±2.08
Single limb support, %	37.90±1.92	37.45±2.01	36.98±1.821	37.11±1.87
Second double support, %	12.08±1.99	13.20±2.09	13.07±1.83	13.36±2.02**
Duration of swing, %	37.98±1.81	37.02±1.93	37.13±1.73	36.74±1.79**
Initial swing, %	17.73±4.58	17.25±1.25	17.32±1.65	16.69±1.14
Mid swing, %	8.09±1.29	8.09±1.52	7.83±1.10	7.56±1.38
Terminal swing, %	12.15±2.06	11.69±2.06	11.98±1.54	12.25±1.76
Trunk inclination angle, degree	4.88±4.81	6.79±3.59	7.52±5.25	11.91±4.42**
Trunk range of motion, degree	11.67±3.72	10.61±2.93	9.63±3.93	10.41±3.20

** Statistical significant difference was found between the load of 0% and 20%.

Gait pattern. In the present study, there were no significant differences to be found between loads in normalized walking velocity, stride length and cadence. However, the results of this study indicated that there were dramatic decreases in walking velocity and cadence when the load that was carried increased from 15% to 20% of body weight. The result of this study partially confirms the hypothesis suggested by Kinoshita (1985). He proposed that if speed was freely chosen by the subjects who carrying heavier loads, then the subjects would prefer to walk at a slower speed with reduced stride length. This inconsistency in findings on stride length can be explained by the employment of normalized stride length used in the present study. On the basis of these results, the decrement of walking can be explained in relation to the decline of walking cadence. One reason for this could be that walking at slower velocity could compensate the additional energy expenditure required for load carrying.

The cycle duration was raised as the load carried increased, but the differences between loads were not statistically significant. However, after the cycle duration was broken down into stance and swing duration and expressed in terms of percent cycle duration, the stance duration increased and swing duration decreased from 0 % to 20% of body weight. Significant differences between loads could also be found between 0% and 20%. When the stance duration was divided into three sub-phases: initial double support, single limb stance and second double support, only the second double leg support time showed significant increment. These findings are consistent with the results of Ghori and Luckwill (1985). They stated that load carrying is an abnormal condition in human walking. The purpose of adjustment in gait pattern during load carrying is to maintain balance and a stable posture and permit the natural free swing of the lower limbs, and adopting a smooth type of walking motion. When walking while using a backpack, the body's center of gravity is raised, making walking unstable. In order to maintain balance, the subject adjusts the gait by shortening the swing phase by delaying toe-off, i.e. the second double support duration increase. As a result, the proportion of step cycle with both feet on the ground will be increased. Kinoshita (1985) suggested that these adjustments on gait patterns could reduce stress upon the body.

Trunk posture. The mean trunk inclination angle increased from 0% to 20%, while only the difference between 0% and 20% was statistically significant. There was no significant difference in range of motion of trunk angle between loads. Kinoshita (1985), Martin & Nelson (1986), Pascoe et al. (1997) and Hong (2000) also showed that the trunk inclination angle increased when the load was carried. The trunk inclination can be explained by the motor control theory. One of the main functions in motor control is to orient the body with respect to the external world, which involves maintaining posture to minimize the disturbance of balance, stabilizing the whole-body center of gravity. As a result, relying on trunk posture during load carrying may cause chronic injuries and lead to muscular pain or lower back injury. In a survey of 1178 students conducted by Troussier et al. (1994), the risks factors in back pain among school children has been investigated. They found that that there was significant correlation between presence of back pain and the satchel carrying position which suggested that habitual or prolonged carrying of excessive loads might result in lower back pain, muscular-skeletal disorders and related compensation cost. Longitudinal studies are recommended in order to identify specific injury resulting from the carrying of heavy schoolbags.

CONCLUSION: The result of this research could determine the upper limits for the appropriate weight of children's schoolbags. According to physiological studies concerning carriage load, 10% of body weight was the recommended weight for school children. However, the result of this study indicated that significant changes in gait pattern and trunk posture were observed when the loads were increased from 15% to 20% of body weight. These findings seem to indicate that 15% body weight is also an acceptable load for children to carry in their school bags.

The results of this study supported the finding of previous studies, which showed that load carrying causes significant changes on the gait pattern and trunk posture of school children. However, the results found that walking naturally on level ground for about 1900 meters did not produce an effect on the gait pattern and trunk posture. Therefore, it was suggested the walking distance employed in this study is not of sufficient duration. Further experiments designed to indicate the effect of loading carrying on gait pattern on trunk posture should be conducted using a longer walking distance or duration.

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