GAIT PATTERN, HEART RATE AND BLOOD PRESSURE OF CHILDREN IN LOAD CARRIAGE

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The objective of this study was to examine the gait pattern with increased carrying weight in children. Fifteen male children, aged 10.31, were selected from a primary school to carry school bags of 10%, 15% and 20% of their own body weight, and no load (0% as control). Subjects walked at 1.1 m.s^{-1} for 20 min on the treadmill. Walking movement was recorded in two dimensions by a video camera at 50 Hz and analysed on a motion analysis system. Heart rate and blood pressure were recorded before, throughout and until 5 min after the walk. Loads of 20% and 15% body weight induced increases in trunk forward inclination, stride frequency, and single leg support time, as well as blood pressure recovery time, but decreases in stride length when compared to 10% body weight. No differences in heart rate responses were found between all load conditions.

KEY WORDS: children, carrying weight, gait, heart rate, blood pressure.

INTRODUCTION: Problems pertaining to overloading school boys are a major concern within the community. A local survey (HKSCHD, 1988) found that Hong Kong students carried school bags which were approximately equal to 20% of their body weight. Sander (1979) found German students commonly carried school bags that weighed more than 10% of their body weight, with the heaviest one reaching 18.2% of their body weight.

Load carriage in adults has been studied in some detail. However, only few experimental studies, to our knowledge, on load carriage by children have been published. Malhotra and Sen Gupta (1965) examined the physiological responses to different ways of carrying school bags by children. The school bags were carried in four different positions: a rucksack on the back, low the back, across the shoulders, and hand held. Pascoe et al. (1997) studied the kinematic impact of different methods of carrying bags on static postures and gait kinematics of youth for four different conditions: without bag, one-strap backpack, two-strap backpack and one-strap athletic bag. Hong et al (1998) investigated the energy expenditure of children under four different loads carried, that is 0%, 10%, 15% and 20% of their own body weight. From the reviewed literature, information on the movement effect of increased load on gait pattern in children is still lacking. The purpose of this project was to investigate the possible change of gait patterns with increased carrying weight in children.

METHODS: Fifteen boys aged 10.31 ± 0.26 years were selected from a local primary school. The criterion of selection was that, they best represented this age group under the mean Body Mass Index according to the measurement during the sampling. The body mass and stature of the subjects were 33.60 ± 3.62 kg and 141.80 ± 4.77 cm respectively. Before the load carriage test, the subjects and their parents were informed about the purpose, procedures and applications of the study and parental consent were obtained. This study was approved by the Clinical Research Ethics Committee, the Chinese University of Hong Kong.

Each subject participated in all four trials: walking on a treadmill without bag (0% of body weight) and with a school bag of 10%, 15% and 20% of the body weight of each subject. The subjects wore their school physical education uniform with socks and sporting shoes. The backpack type of school bags was positioned at waist level for each of the subjects. Loads were put inside the backpack. Subjects were asked to walk at a speed of 1.1 m.s^{-1}, a comfortable speed of walking for children (Malhotra and Sen Gupta, 1965), on a treadmill for 20 min. Trials for each subject were conducted over four different days with the test order randomly assigned to prevent any test order effect.

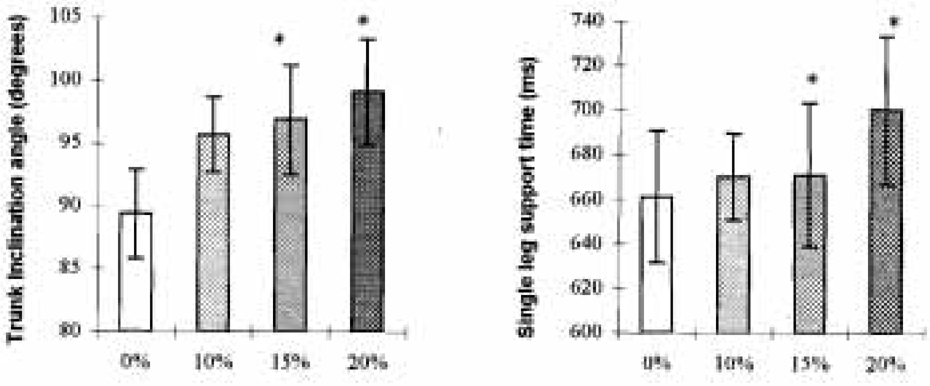
The walking movement was filmed by a 3-CCD video camera (50 Hz) positioned lateral to the subject with the lens axis perpendicular to the movement plane. The distance of the camera to the movement plane was 7.5 m and the shutter speed was set at 11250 s. The recorded video tapes were then digitised on a motion analysis system by using a human body model consisting of 21 points, including the toes, heels, ankles, hips, shoulders, elbows, wrists, fingers, ears and the neck. Raw data were filtered by using the Butterworth low-pass filter with a cut-off frequency of 6 Hz. Variables that are frequently used in describing the kinematic characteristics of walking gait were quantified from the film for each trial. These variables included stride frequency, stride length, single leg support time, double leg support time, swing time, trunk forward inclination, and the height of the centre of gravity. Stride frequency was quantified as the number of steps completed per second. Stride length that represented the distance travelled with each step was calculated by walk speed divided by stride frequency measured. Single leg support time was measured as the time from the instant of heel strike to the instant of toe-off the ground. Swing time, on the other hand, represented the time of non-support for a leg as it moved forward in preparation for the next heel strike. Double leg support time was that period in which both feet were in contact with the ground simultaneously. The angle of trunk inclination was measured as the angle of the line connecting the shoulders and hips with the horizontal. Two complete strides were taken every 5 min after the beginning of walking for analysis for each load each subject. Blood pressure was measured before walking, immediately afterward, and at 3 and 5 min after every trial.

One-way analysis of variance with repeated measures design was used to test for significant differences. Post hoc analysis was conducted by Scheffe's Significant Difference Test. The level of a = 0.05 was used for all tests as the criterion value in determining the presence or absence of significance.

RESULTS: For the loads of 15% and 20% of body weight, in the first 5 min, stride length and leg swing time significantly decreased while stride frequency, single leg support time and trunk forward inclination angle significantly increased. When compared with loads of 0% and 10% body weight, carrying backpacks of 15% and 20% of body weight resulted in significant increase in stride frequency and decrease in stride length. Furthermore, under the loads of 15% and 20% of body weight, the single leg support time was significantly increased (Figure 1) while the swing time decreased. Along with these effects, the trunk forward inclination was significantly increased (Figure 1) with loads of 15% and 20% body weight compared with 0% and 10% body weight. No change was found in these parameters with the 10% load when compared with no load.

Among all load conditions, heart rate increased significantly in the first 5 min of walking, which gradually increased thereafter with no significantly difference during the walk over time. After 3 min of recovery, heart rate returned to the level that approximated the baseline. No significant difference was found in heart rate among the different loads carried.

Walking for 20 min significantly increased the systolic blood pressure at all work loads. A significant increase in diastolic blood pressure measured after 20 min of walking was only found for the 15% and 20% load conditions. The recovery in blood pressure showed significant differences among different loads. In carrying loads of 0% and 10% body weight, after 3 rnin of recovery the systolic blood pressure fell to the level recorded before walking. However, even after 5 min of recovery the systolic blood pressure in carrying loads of 15% and 20% body weight were still higher than that recorded before walking. Comparing the measurements among different loads, significant differences in systolic and diastolic blood pressure were found between 0% and 20% loads of body weight, whereas there was no significant difference in the alteration of blood pressure among the loads of 0%, 10% and 15% body weight.



Carrying loads in % body weight

*, $p<0.05$ **compared** with **0% and 10% body** weight

Figure 1 - Single leg support time and trunk inclination angle at 20 min after walking (Mean ± SD).

DISCUSSION: The main findings of this study were that walking for 20 min while carrying loads equal to 15% and 20% body weight induced significant increase in stride frequency and trunk forward inclination as compared to the 0% and 10% body weight conditions. No significant difference was found with the loads of 0% and 10% body weight. Based on visual observations, Malhotra and Sen Gupta (1965) concluded that children did not bend their trunk significantly more when the weight carried did not exceed 10-12% of their body weight. This present study provided objective evidence to support the previous subjective observations. The findings of this study also supported Pascoe et al. (1997) who found that carrying a two-strap backpack of 17% body weight significantly promoted forward lean of the head and trunk compared to walking without a bag. They found that as a result of the load carried, stride length was decreased while stride frequency was increased.
In the first 5 min, the walk elicited the significant increases in heart rate for carrying each of the four loads. However, heart rate did not show any difference in carrying different loads over time. These results were comparable to the previous findings on load carriage by children. Malhatra and Sen Gupta (1965) reported that there was a significant increase in heart rate during the first 10 min of walking with 6 lb load carriage by children of 9-15 years old. No significant difference in heart rate among the loads was found. The trends of increasing heart rate with load were previously found in the study on adults (Holewijn, 1990). In evaluating the heart rate responses of children, it was found that walking for 20 min with a load equal to 20% of body weight elicited an average heart rate of 125 bpm. This figure is 30 bpm higher than the baseline and accounts for about 60% of the maximum heart rate of children of the 12 years old. These measures reflected that the heart rate response to load carriage is substantially in homeostasis balance (steady state). The result is in line with Astrand and Rodahl (1977), who stated that when a fit subject is exercising at less than 60% of maximal oxygen uptake ($\dot{V}O_{2\,max}$), heart rate response is in a steady state.
Although measurements of blood pressure immediately after walking did not show any significant difference among the four carrying conditions, a rise in systolic blood pressure by an average of 12 mmHg for 0% body weight load and an average of 19 mmHg for 20% body weight was found. Likewise the different effects of carrying different loads on the cardiovascular system were observed for the recovery of blood pressure. Carrying loads equal to 15% and 20% of body weight required a longer time for blood pressure to return to the baseline. Systolic blood pressure increases in direct proportion to an increase in exercise intensity (Berger, 1982). Therefore, the changes of blood pressure in this study indicated that the loads of 15% and 20% of body weight produced a greater stress on the cardiovascular system than lighter loads.

Malhotra and Sen Gupta (1965) recommended that the weight that should be carried by students was not likely to exceed 10-12% of the body weight because in their study nobody was observed bending forward. This recommendation was then widely accepted as a criterion for students carrying school bags. The biomechanical and physiological evidence of the present study supported this recommendation. The significantly increased forward flexion of trunk at higher carrying loads would cause the hamstring, semispinalis, tibialis anterior, vastus lateralis, erector spinae and trapezius muscles to work harder to support the movement (Cook and Neumann, 1987). As the intensity became higher, subjects were forced to alter their locomotion biomechanics, and this resulted in higher actual power output to carry a given load (Martin and Nelson, 1986).

CONCLUSION: It is hypothesised that carrying heavier weight would induce greater biomechanical and physiological strain in children. For the participants in this study, carrying a load of up to 20% of body weight while walking resulted in a steady state with about 60% of the maximum heart rate of children of this age. Carrying school bags of 20% and 15% of body weight caused higher bomechanical and physiological strain in terms of significantly increased trunk forward inclination and prolonged blood pressure recovery time compared to 10% and 0% of body weight in children. It was hoped that the findings of this paper would enrich the scope of this issue and help parents and teachers to give guidelines on the weight of school bags.

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