ELECTROMYOGRAPHIC RESPONSES OF BACK MUSCLES DURING LOAD CARRIAGE WALKING IN CHILDREN

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Eleven primary school boys aged between 9 and 10 years old completed carrying backpack loads of 0%, 10%, 15%, and 20% of their body weight while level walking using natural cadence. Electromyographic signals from the upper trapezius, thoracic erector spinae and lumbar erector spinae were analyzed. Results showed that under the carrying conditions of this study, load significantly influenced the degree of fatigue and muscular activity in upper trapezius, while walking distance significantly influenced degree of fatigue and muscular activity on lumbar erector spinae. This suggested that long distances and heavy loads might lead to low back pain or muscular disorder.

KEY WORDS: load carriage, children, EMG, floor walking.

INTRODUCTION: Concern has been raised over the heavy school bags carried by children and the associated spinal fatigue symptoms. A number of studies (Hong, et al. 2000; Hong, et al., 2000) have revealed that a heavy load induced physiological strain and alteration in gait and posture which may indicate local muscular fatigue of particular muscle groups. However, few comprehensive studies have been attempted to examine the back muscle electromyographic activity amongst children. The purpose of this study was to examine the biomechanical stresses on children during prolonged load carrying by quantifying the electromyographic responses of back muscles during load carrying in a field setting.

METHODS: Twenty-three primary school boys aged between 9 and 10 years old were recruited as subjects. All children and parents were provided with all the information necessary to allow participation with informed consent. Children included in the study had neither musculo-skeletal disorders nor indications of heart disease, as was determined from completion of a health history questionnaire. The experimental procedure was approved by the local Medical Ethics Committee. The study took place in a university gymnasium. The subjects came to the gymnasium for four different days to complete the required four sessions. In each session, the subjects were assigned to carry backpack load that was equivalent to one of the following weight: 0%, 10%, 15%, or 20% of their body weight. In each session, the subject was walking around the perimeter of a basketball court (28m long and 15m wide) for 23 laps: i.e. a total of 1978m which was approximately the average distance of backpack carrying of Hong Kong children walking from home to school. The order of sessions was randomized using a Latin square design. Only 11 subjects completed the required four sessions and the data collected from these subjects were used for analysis. The mean age, body weight and body height of these subjects were 9.43(0.51) years, 31.20(5.41) kg, and 134.52(6.00) cm respectively. After consent was obtained, the anthropometry data – including body height and body weight – were recorded. At the beginning of each session, each subject was required to sit on the chair at the starting point of the walkway for three minutes, then stand with the backpack for one minute. Afterward, the subjects were required to walk at their natural cadence around the perimeter of the basketball court. The most popular school bag – a two straps backpack – was employed in this study. The EMG signal was collected for four different distances of total walking, with the first distance being one lap from the starting point of walking and the other distances having seven laps increment, i.e. 86 meter (1st distance), 688 meter (2nd distance), 1290 meter (3rd distance) and 1892 meter (4th distance) from the starting point. Disposable silver/silver chloride preamplified bipolar surface electrodes (Blue Sensor T-00-S, Medicotest, Denmark) were used in the recording of myoelectric activity from the muscles of upper trapezius, thoracic erector spinae at T12 and lumbar erector spinae at L3. The upper trapezius (narrow) placement was located at the descending part of the trapezius. T12 paraspinal placement represented the thoracic erector spinae, which is the paraspinal stabilizer of the erector spinae. It is located 2cm lateral to the posterior spinous process at the level of T12. L3 erector spinae placement represented the lumbar erector spinae, which are the main trunk movers and stabilizers of the erector spinae. It is located 2cm lateral to the posterior spinous process at the level of L3. The common ground electrode was placed over the acromioclavicular joint. All electrodes were placed on the right side of the back. To reduce skin/electrode impedance, the areas of electrode placement were shaved, abraded with sandpaper, and washed with rubbing alcohol, with electrolyte gel used to improve conductance. The electrodes and cables were taped to the skin to reduce movement artifacts and to allow freedom of movement. The EMG signals were amplified at selected gains to optimize resolution, and transmitted telemetrically (Bioengineering Technology & Systems, Italy) to a PC through a 12-bit A/D conversion board (National Instruments, USA) which was used to sample the EMG signals at 1000Hz. The software LabView (National Instruments, USA) was used to process the EMG signals. The EMG signals were band pass filtered to reduce noise with low pass (500 Hz) and high pass (10 Hz), and was full-wave rectified. The integrated (IEMG) was used to represent the muscle activity during load carrying. This value provided a measure of the total myoelectric activity recorded from the surface of the contracting muscle. IEMG was normalized as a percentage of the corresponding maximum values determined from 100% maximal voluntary contraction. The EMG power spectral density was computed for the 1-second samples using Fast Fourier Transform. Mean power frequency (MNF) which was indices of the EMG power spectrum was calculated. The MNF is commonly used to evaluate local muscle fatigue and was employed in this study. Since the EMG responses have a great degree of between-muscles, inter-individual and intra-individual variation, they could not be used for comparison directly. The relative changes in the frequency with respect to walking with a load were employed (Bobet & Norman, 1984). In the present study, MNF at 10%, 15%, and 20% load conditions was normalized to that at 0% load condition. The effect of fatigue is localized to the muscle or group of synergistic muscles performing the contraction. In this study a shift in the frequency components of the surface EMG signal toward the low end was used to indicate local muscle fatigue. Three individual strides of EMG data at each observation position were identified for analysis. Prior to the test, each muscle group for the purpose of EMG normalization performed a maximal voluntary contraction (MVC). All EMG segments were analyzed in the amplitude and frequency domains. Univariate two-way ANOVA (weight by distance) with repeated measures was performed on the critical factors selected in this study to determine which dependent variables possessed significant variance. These factors included IEMG and MNF for each of the upper trapezius, thoracic erector spinae and lumbar erector spinae muscles. If a univariate two-way ANOVA showed significance for the main effect of Distance and Weight-by-Distance interaction, trend analysis was performed as a multiple comparison. For the significant main effect of Weight, a Tukey post hoc test was used to identify the specific mean differences between weights. Statistical significance was accepted at the 0.05 level of confidence.

RESULTS AND DISCUSSION: For the upper trapezius muscle, the results showed that the main effect for Distance and Weight-by-Distance interaction were not statistically significant. However, the main effect for Weight was found to be significant (Wilks' Lambda = .377, $p < 0.05$) on IEMG and MNF. The further test revealed that the load of 15% body weight resulted in significant increase in IEMG and decrease in MNF ($p < 0.05$) in upper trapezius muscle. For the erector spinea at T12, the main effects for Weight and Distance in EMG data were found to be insignificant. Moreover, significant Weight-by-Distance interaction was not found (Wilks' Lambda = .237, $P > 0.05$). For the erector spinae at L3, the two-way ANOVA found no significant difference with the EMG data in the main effect for Weight and the Weight-by-Distance interaction. The significant main effect, however, was found for Distance in all EMG data. Furthermore, by examining the trend of the EMG parameters across progressive Distances, significant linear trends were found in MNF ($F = 44.617$, $p < 0.005$) which consistently decreased across progressive walking distances (Figure 1). Significant Weight effect was found on the EMG responses of the upper trapezius. The results of present study found that when subjects were carrying a load of 15% body weight, the IEMG of the upper trapezius increased and its corresponding frequency parameters significantly decreased at 3rd Distance. EMG responses of the upper trapezius was a unique dependent factor in this study that was significantly mainly affected by weight. Bobet and Norman (1982) stated that the trapezius was sensitive to the changes in the load carrying position on the back. In their study, the average electromyogram of the upper trapezius decreased 8% for lower placement of the load and increased 8% for high placement.

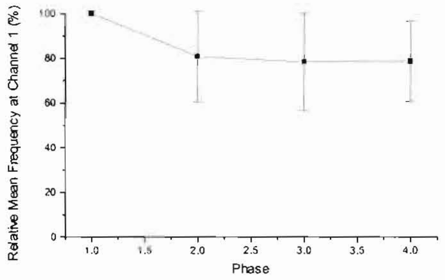

Figure 1. Mean frequency as a function of distance at lumbar erector spinae at L3.

The trapezius is well recognized to be the stabilizer of the shoulder, neck and head in order to limit their movement. In the present study, subjects were under the condition of carrying a heavy load with prolonged floor walking, experiencing significant change in trunk posture. Stabilizing the shoulder and maintaining a relatively erect head position was essential. The long-lasting postural adaptation process during repetitive tasks is clearly distinguished from the preparatory activation of the postural muscles.The EMG responses at the lumbar and thoracic erector spinae showed different response to the load carried. At L3 level, both frequency shift and muscular activity in erector spinae were dependent on walking distance rather than on the weight of backpack. On the other hand, the erector spinae at T12 level did not show either a significant main effect or interaction in the EMG responses. It implies that the load under walking conditions in the present study did not influence the electromyographic responses of the thoracic erector spinae. During load carriage, the muscle length did not change rapidly and its level of contraction was submaximal. It could be assumed that there is a linear EMG-tension relationship in the muscle. Although there is controversy concerning the exact relationship between EMG and tension, there is no doubt that as tension increases, EMG increases. The significant Distance effect on the lumbar erector spine was similar to the result in load handling found by Jörgensen et al. (1985). They suggested that the EMG changes are highly dependent on the time factor, such as lifting frequency or distance rather than on the weight or mechanical work. In terms of the muscular responses of the erector spinae at L3 level under different weights, the results of this study were partially consistent with the work of Bobet and Norman (1982, 1984). They showed that the electromyographic activity was not significantly influenced by increment of load carried. Bobet and Norman (1984) attempted to explain the decrease of EMG activity during load carrying by a biomechanical model. They stated that the back extension moment created by load on the back reduced the flexion moment of the abdomen muscles. Normally, when the trunk bends forward, it is difficult for the muscle and ligaments of the back to maintain the upper body in balance. The stress becomes large in the lower back. However, the trunk inclination did not compromise the balance of the upper body, but instead assisted in the stability and reduced the stress. As a result, the EMG activity of lumbar erector spinae decreased as the weight increased. The results indicated that local muscle fatigue of the lumbar erector spinae depended on the distance walked. Since local muscle fatigue of lumbar erector spinae was a risk factor contributing to low back pain, time factors, such as walking distance and duration, should also be considered in determining the permissible load to be carried.

CONCLUSION: Under the carrying conditions of this study, load carried significantly influenced the degree of fatigue and muscular activity of upper trapesius. On the other hand, walking distance significantly influenced the degree of fatigue of the lumbar erector spinae.

Although the results of this study could not support the hypothesis that increased muscular activity and muscle fatigue induced by heavy load carriage would lead to chronic muscular disorder or low back pain directly, it has at least quantified the muscular activity induced by load carriage walking. The results of this study provided baseline information for further investigation toward exploring the etiological factors. This suggests that longer distances and heavier loads that induce fatigue and muscular activity, may lead to low back pain or muscular disorder.

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