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Original Article

Correlations between Muscle Activities and Strap Length and Types of School Bag during Walking

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Abstract. [Purpose] The purpose of this study was to examine correlations between muscle activities and strap length and type of the school bag during walking. [Subjects and Methods] The subjects of this study were 20 healthy students. An 8-channel electromyograph (8-EMG) (Pocket EMG, BTS, Italy) was used to measure the muscle activities of the right upper trapezius, left upper trapezius, right erector spinae and left erector spinae during walking with the bag. The collected data were analyzed using Kendall's coefficient of concordance. [Results] The muscle activities of the right upper trapezius, left upper trapezius, right erector spinae and left erector spinae were significantly higher when walking with a shoulder bag than when walking with a backpack. No significant correlations were found between muscle activities and strap lengths of the bag. [Conclusion] While carrying a bag, the activities of the trunk muscles were influenced more by the type of the bag than by the strap length. These results indicate that a backpack is a better method of carrying a load than a shoulder bag.
Key words: Muscle activity, Strap length, Bag type

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INTRODUCTION

School bags have long been thought to be associated with back and neck pain in adolescents[1)]. The focus to date has been on the effects of school bag weight on back and neck pain, and evidence suggests that carrying a school bag weighing more than 15% of body weight increases the risk of back pain[2)]. Current recommendations for school bag carriage are mainly concerned with reducing bag weight and optimizing bag design in order to minimize postural changes when carrying a school bag[1, 2)]. However, other factors including strap length and the type of school bag may also be important.

Students in school and university settings are known to carry heavy loads in a variety of pack systems. Both type and mode of load carriage have been shown to cause significant postural adaptations that can lead to injuries in the shoulder, arms, hands and back[3)]. Normal walking is characterized by symmetric kinetics between the left and right limbs and around the L5/S1 joint. Asymmetric loads produce unbalanced lateral trunk muscle dominance between the left and right limb stance phases, increase right hip and knee moments, and decrease left hip and knee moments. During normal walking, the L5/S1 moment is dominant on the contralateral trunk side of both limbs. Asymmetric loads applied to the left side caused a shift in L5/S1 moment dominance to the right side during left and right single support phases[4–6)]. Fowler et al.[7)] described the quantification of kinematics of the spine and stature loss induced by the asymmetric load carriage. Increased forward leaning (up to 6 degrees) and lateral bending of the spine (up to 12 degrees) was observed with an asymmetric load. A Shoulder bag increases the asymmetry of the trunk during walking[4–7)].

Navuluri and Navulur[8)] reported the relationship between backpack use and back and neck pain among adolescent boys and girls. A higher percentage of girls than boys rated their pain as being moderate to extremely strong. The correlation between pain and backpack weight per body mass index among girls was positive and significant, but negative and not significant among boys. The L4–L5 and L5–S1 intervertebral disc compress, particularly anteriorly, when transitioning from the supine to the upright position when carrying a 10% body weight backpack[9)]. Al-Khabbaz et al.[10)] reported that the rectus abdominis muscle activity increased progressively and disproportionately as the backpack load increased. As for the trunk posture, almost the same backward inclination was adopted even with increasing backpack heaviness.

While backpacks have been studied in a number of studies[3, 8–10)], there is a paucity of study on the effects on muscle activities of strap length and type of school bag during walking. Therefore, the purpose of the current study was to examine correlations between muscle activities and strap length and the type of school bag during walking.

SUBJECTS AND METHODS

The subjects of this study were 20 healthy students aged

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Table 1. The muscle activities of different strap lengths and types of bag during walking (Unit: mV/sec)

Measured muscle	Length of strap	No bag	Backpack	Shoulder bag
		Mean±SD	Mean±SD	Mean±SD
%MRUT	iliac crest	0.168±0.126	0.211±0.176	0.310±0.163
	below 10 cm		0.182±0.160	0.357±0.172
	below 20 cm		0.189±0.144	0.421±0.251
%MLUT	iliac crest	0.148±0.125	0.198±0.169	0.226±0.169
	below 10 cm		0.182±0.158	0.230±0.157
	below 20 cm		0.183±0.150	0.233±0.180
%MRES	iliac crest	0.197±0.073	0.182±0.085	0.170±0.079
	below 10 cm		0.182±0.094	0.166±0.069
	below 20 cm		0.203±0.081	0.185±0.092
%MLES	iliac crest	0.196±0.063	0.177±0.068	0.251±0.111
	below 10 cm		0.187±0.090	0.248±0.094
	below 20 cm		0.206±0.078	0.252±0.089

%MRUT: %MVIC (maximum voluntary isometric contraction) of Right Upper Trapezius, %MLUT: %MVIC of Left Upper Trapezius, %MRES: %MVIC of Right Erector Spinae, %MLES: %MVIC of Left Erector Spinae

22.65±1.82 years (Mean±SD) with an average height and weight of 170.69±4.69 cm and 66.79±8.02 kg, respectively. None of the subjects had problems with their musculoskeletal, nervous, or cardiovascular systems, and they were able to complete walking with the bags according to the instructions given by the researcher. Before participating in this research, all the subjects were given an explanation about the content and the procedures of the experiment. The subjects voluntarily participated in this research, and signed an informed consent form.

An 8-channel electromyograph (8-EMG) (Pocket EMG, BTS, Italy) was used to measure muscle activities during walking. The sampling rate of the electromyograph was set to 1,000 Hz (1,000 samples/second) and the amplified wave was band-pass filtered between 20–500 Hz. The EMG electrodes (Ag/AgCI Monitoring Electrode 2225, 3M, Korea) were attached to the right upper trapezius, left upper trapezius, right erector spinae and left erector spinae. The activity of each muscle was normalized to the EMG activity of maximal voluntary isometric contraction (MVIC), which was measured in manual muscle tests, after linear filtering of the data for 5 seconds. The first and the last 1 seconds of data were discarded, and the average EMG signal of the middle 3 seconds was used as 100% MVIC. The average root mean square (RMS) value was used to exhibit the activity of each muscle group while the subjects walked with a bag. This study used the averaged EMG data of 5 minutes walking on a treadmill.

All subjects walked on a treadmill with no bag, and while carrying a shoulder bag or backpack at the height of the iliac crest, 10 cm lower than the iliac crest, or 20 cm lower than the iliac crest[11]. The weight of the bag was set at 10% of the body weight of each subject[2, 9, 12, 13]. The order of the tasks was carried out at random to prevent a carry over effect.

Subjects walked on the treadmill at 4 km/h for 5 minutes[14]. The interval for the change of the strap length was 30 minutes, and for the type of bag, 24 hours, to prevent a carry over effect. The shoulder bag was carried on the right side regardless of the dominant hand[15].

SPSS Version 18.0 for Windows was used for the data analysis. The data were confirmed to conform to a normal distribution using the Kolmogorov-Smirnov test. Kendall's coefficient of concordance was used to analyze the correlations between muscle activities and strap length and type of bag during walking. Statistical significance was accepted for values of $\alpha \leq 0.05$.

RESULTS

The mean and standard deviation of the muscle activities for the different strap lengths and types of bag during walking are presented in Table 1.

The muscle activities of the right upper trapezius (tau_b= 0.346, $p<0.01$), left upper trapezius (tau_b= 0.235, $p<0.01$), right erector spinae (tau_b= 0.131, $p<0.05$), and left erector spinae (tau_b= 0.167, $p<0.01$) were significantly higher when carrying the shoulder bag than when carrying the backpack during walking. No significant correlations were found between the muscle activities and the different strap lengths of the bags during walking ($p>0.05$) (Table 2).

DISCUSSION

Motmans et al.[15] reported that the activity levels of the erector spinae significantly decreased when carrying a backpack, and increased when carrying a shoulder bag. Our research shows that the muscle activities of the right upper trapezius, left upper trapezius, right erector spinae and left erector spinae were significantly higher when carrying a shoulder bag than when carrying a backpack while the subjects were walking. Backpacks may be more suitable for load carriage within the young adult student population, as they produce a symmetrical postural deviation in one plane

Table 2. Correlation between the muscle activities of different strap lengths and types of bag during walking

		%MRUT	%MLUT	%MRES	%MLES
Bag Type	tau_b	0.346**	0.235**	0.131*	0.167**
Length of Strap	tau_b	0.024	0.006	0.058	0.058

tau_b: correlation coefficient, %MRUT: %MVIC (maximum voluntary isometric contraction) of right upper trapezius, %MLUT: %MVIC of left upper trapezius, %MRES: %MVIC of right erector spinae, %MLES: %MVIC of Left Erector Spinae,
* p<0.05, ** p<0.01

in response to load. On the other hand, the shoulder bag produces postural deviations in all planes which may cause adverse stress and strain on spinal structures, and ultimately lead to increase of muscle activities around the neck and spine[3]. Asymmetrical activity between the right and the left part of the back muscles was clearly observed while carrying a shoulder bag with the weight on the right side of the body. These findings suggest that the physical stresses associated with carrying book bags can be minimized by the design of a backpack. Asymmetry in muscle activity may indicate a failure of trunk stabilization and contribute to the development of back pain[3, 15]. Most studies of carriage load according to different types of bag, muscle activity of erector spinae was focused[10, 13, 15]. However, there is a paucity of study on the effects on the muscle activity of the trapezius caused by different types of bag. Our research shows that the muscle activities of right upper trapezius, left upper trapezius increased more significantly when carrying the shoulder bag than when carrying the backpack while the subjects were walking. This result reinforces the theoretical evidence for the best method of carriage with different types of bags.

Chansirinukor et al.[16] reported that both backpack weight and time carried influenced cervical and shoulder posture. Forward head posture increased when carrying a backpack with a heavy load. Carrying a backpack weighing 15% of body weight appeared to be too heavy to maintain a standing posture for adolescents. In our study, subjects carried a bag weighing 10% of their body weight. However, this study did not measure kinematic characteristics, and, the characteristics of the kinematics and kinetics of different strap lengths, and types of school bag during walking will be investigated in the future.

In this study, no significant correlations were found between the muscle activities and different strap lengths of the bag during walking. As stated earlier, walking on the treadmill was performed at 4 km/h for 5 minutes[14]. The short walking time performed in this research could not verify correlations between the muscle activities and different strap lengths of the bag during walking. These findings suggest that the walking time should be investigated in future studies of carriage with different types of bags.

In conclusion, the backpack is the best method of carrying loads because it has the lowest muscle activities and the best postural symmetry. A limitation of the present research was that this experiment was conducted using only a small number of healthy students in their 20s. Thus, we cannot safely generalize our research results to any other age group.

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