Changes in the Thickness of Trunk Stabilizer Muscles According to Increased Lifting Loads in Stoop Lifting

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Abstract. [Purpose] The aim of this study was to identify how the lumbar stabilizer muscles respond to increased lifting loads. Twenty-four healthy subjects (10 males, 14 females) participated in this study. [Subjects and Methods] The thicknesses of the internal oblique (IO), transverse abdominis (TrA), and lumbar multifidus (LM) muscle were measured by ultrasonography during lifting of loads 10%, 20%, and 30% of body weight. The data was analyzed measured by one-way repeated measures analysis of variance (ANOVA). [Results] There were statistically significant increases in thicknesses of the TrA and LM muscles when lifting a load of 20% of subject's body weight. The thickness of IO was not significantly different at different loads. [Conclusion] The findings of this study suggest that TrA and LM play important roles as lumbar spine stabilizers during lifting activities of less than 20% of body weight. Further study is needed to find the mechanisms of lumbar stability during stoop lifting of loads greater than 20% of body weight.

Key words: Lumbar stabilizers, Lifting load, Ultrasonography

(This article was submitted Sep. 5, 2012, and was accepted Oct. 5, 2012)

INTRODUCTION

Repeated lifting motions at work and in daily life are a major cause of musculoskeletal disorders such as low back pain¹⁾. Lifting motions involve increases in intra-abdominal pressure achieved through simultaneous contraction of the back and abdominal muscles^{2, 3)}. The abdominal muscles serve important roles in lumbar stabilization when loads are imposed on the trunk⁴⁾.

The lumbar stabilizer muscles are divided into global and local muscles based on their dynamic roles. The global muscles include the erector spinae, the rectus abdominis, the internal oblique (IO), and external oblique (EO) abdominal muscles. They induce movement or directly deliver loads to the pelvis and the thoracic cage, and act when large external loads are imposed on the spine⁵⁾. The local muscles include the LM (lumbar multifidus) and the transversus abdominis (TrA). They act to maintain posture and adjust movements between the vertebrae when small loads are imposed⁶⁾. Effective interactions of these muscles produce effective and safe lifting movements.

The general guidelines for safe lifting state that squat lifting postures are appropriate for reducing loads on the non-contractile tissues in the lower lumbar spine^{7, 8)}. However, many workers prefer stoop lifting because these postures consume less energy and facilitate balance during lifting⁹⁾. However, stoop lifting at work and in daily living activities raise the risk of spinal injury.

Studies of biomechanical changes in the trunk muscles related to lifting motions have been performed, including those of muscle fatigue in static and dynamic conditions¹⁰⁾, symmetrical or asymmetrical working postures used in lifting¹¹⁾, global muscle activities related to the degree of load¹²⁾, the angles of the trunk during lifting¹³⁾, and lifting speeds¹⁴⁾. However, these studies focused on the global muscles and working postures related to lifting. Studies of the actions of the lumbar stabilizer muscles during lifting motions in relation to the degree of load are insufficient. Furthermore, unlike individual muscles in the extremities, the force necessary for the movements of the lumbar stabilizer muscles cannot be directly measured. Also, surface electromyography cannot measure the muscle activities of deep muscles. Therefore, non-invasive ultrasonography is a useful tool for measuring the changes in thicknesses of deep muscles^{15, 16)}.

The present study examined the changes in the muscle thicknesses of the trunk stabilizer muscles, IO, TrA, and LM, at different loads in stoop lifting postures through measurement using ultrasonography.

SUBJECTS AND METHODS

Subjects

The subjects of the present study were 24 normal adults (10 males, 14 females). All the subjects agreed to participate in the study after hearing an explanation about the experi-

Table 1. General characteristics of subjects (N=24)

Characteristics	Mean $\pm$ SD
Age (yrs)	20.7 $\pm$ 0.9
Height (cm)	167.4 $\pm$ 8.3
Mass (kg)	60.9 $\pm$ 8.0
BMI ^a (kg/m ²)	21.6 $\pm$ 2.0

^aBody Mass Index

mental method. They were selected from those who had no experience of low back pain within the previous 6 months and had no orthopedic or neurological disease of the spine or lower extremities. The general characteristics of the study subjects are presented in Table 1.

Methods

Changes in the thicknesses of the trunk stabilizer muscles were measured in lifting motions with loads equal to 10%, 20% and 30% of each subject's body weight. The lifting motions were performed using a back strength dynamometer (Takei, Japan). A strain gauge (Noraxon Telemyo 1.06 software, Noraxon Inc., Scottsdale, AZ, U.S.A.) was used to accurately measure and monitor the amount of the load during lifting.

The thickness of the deep lumbar muscles was measured using a SonoAce X4 (Medison Co. Ltd., Seoul, Korea). Measuring points were marked with a ball-point pen to ensure the probe was positioned over same site for each trial. The thickness of the TrA and the IO muscles were measured using a 5–7 MHz linearly arranged probe. The thickness of the LM muscle was measured using a 5–7 MHz curved probe (Fig. 1).

The thickness of each muscle was normalized with the mean value of the muscle thickness measured in the resting position. The thicknesses of TrA and IO in the resting position were measured in the supine position with the knee joint and hip joint maintained at 50° and 90°, respectively. Thickness of the LM muscle in the resting position was measured in the prone position. Lumbar curvature was minimized by providing abdominal support with a pillow.

To measure the thicknesses of TrA and IO, the probe was placed at the lateral margin 25 mm anterior to the halfway point between the upper iliac crest and the subcostal angle on the center line of the right axilla. The probe was adjusted so that the lateral abdominal muscles were clear in a direction parallel to the muscle fibers of TrA^{17, 18)}. All ultrasonography images were collected at the end of exhalation in order to minimize the respiratory mobilization of the TrA. The thickness was measured after drawing a vertical line at the 25 mm position in the horizontal plane on the most medial side of TrA¹⁹⁾.

Before making measurements, the thickness, L4-5 spinous processes were palpated and marked. Then the transducer was placed upright on the centerline of the lumbar spine, and the facet joint was made to appear on the center of the monitor by moving the probe placed longitudinally until the

Fig. 1. Ultrasound images of the internal oblique (IO), transversus abdominis (TrA), and lumbar multifidus (LM) muscles

spinal facet joint was clearly seen²⁰⁾.

To measure muscle thickness during stoop lifting, the subject was instructed to bend the trunk to 30° without bending the knees (stoop lifting), and to remain forward and not raise the shoulders or extend the trunk during the measurement. The principal investigator checked the amount of the load on the monitor connected to the strain gauge. Muscle thickness was measured at the endpoint of exhalation while maintaining the lifting position for 5 seconds. The different loads were given in random orders. The mean value in the three trials was used for data analysis. To minimize muscle fatigue, one-minute's rest was enforced between trials.

Statistical analyses were conducted using PASW 18.0 for Windows. One-way repeated measures ANOVA was used to examine changes in muscle thickness in relation to the size of the load. The paired t-test was used post hoc to identify significant differences. Significance was accepted for values of $\alpha < 0.05$.

RESULTS

The thicknesses of both the TrA and the LM muscles significantly differed among the lifting loads. The thicknesses of both TrA and LM were greatest at 20% of body weight. The thicknesses of IO did not significantly differ among the lifting loads (Table 2)²¹⁾.

DISCUSSION

Among work performed using the hands, lifting activity requires stability of the spine for prevention of injury. Co-activation of the back and abdominal muscles is essential for increasing spinal stiffness. Also, stability needs to increase as the load to be lifted increases²²⁾. Granata and Orishimo⁴⁾ stated that the abdominal muscles contribute to the maintenance of normal posture when performing daily activities, and lifting loads safely and effectively. Especially, stoop lifting with 30–60° trunk flexion posture is often used at work and in daily living activities²³⁾. Bergmark⁶⁾ divided the trunk muscles into the local and global muscle systems. The global muscle (IO) and local muscles (TrA and LM) are

Table 2. The thicknesses of the lumbar stabilizers at different loads in stoop lifting

Muscles	10%	20%	30%	Post hoc
IO	10.1 ± 2.3 ^a	10.5 ± 2.1	10.3 ± 2.5	/
TrA	3.0 ± 0.6	3.3 ± 0.4	3.0 ± 0.5*	a<b, b>c ^b
LM	29.2 ± 4.2	30.2 ± 4.1	30.0 ± 4.1*	a<b

(unit: mm) ^a Mean ± standard deviation, ^b a: 10%, b: 20%, c: 30%, *p<0.05. IO: internal oblique, TrA: transversus abdominis, LM: lumbar multifidus

involved in the stability of the trunk. Therefore, the present study investigated whether the thicknesses of the TrA, IO, and LM muscles increase when lifting loads of 10%, 20%, and 30% of the body weight in a stoop lifting posture.

The result of this study show that the thickness of the TrA increased more significantly when the load was 20% of the subject's body weight than when the load was 10% or 30%. Hide et al.¹⁵⁾ examined the thicknesses of the TrA and IO using ultrasonography during rest, while lifting with a load of 25% of body weight during a simulated unilateral weight-bearing task against a footplate in the supine position. They reported that the thicknesses of TrA and IO significantly increased under the load of 25% of body weight compared to at rest, and that the thickness of the TrA increased more than IO. Granata and Orishimo⁴⁾ conducted a biomechanical model study of lifting weights (4.5 and 9.0 kg) and heights (0, 20, 40, 60, and 80 cm) in static lifting postures with 20 normal adults. They reported that as the weight and height increased, the activity of the abdominal and back muscles increased. They stated that abdominal muscles acted to maintain the stability of the trunk through co-contraction with the erector spinae muscle, and that if the erector spinae muscle were to contract alone during lifting motions, the spine would become unstable. In our study, the thickness of TrA significantly increased at a load of 20% body weight compared to the 10% load. However, the thickness of TrA at the load of 30% body weight was significantly decreased compared to the 20% load. This was an interesting result.

The muscle thickness of LM showed a more significant increase at the load of 20% of body weight than the load of 10% body weight. However, there was no significant difference in the thickness of LM between loads of 20% and 30% body weight. When loads exceeding 20% of body weight were lifted, the muscle thickness of a TrA, and LM decreased. With regard to changes in muscles related to lifting motions, Olson¹²⁾ examined the activities of the muscles around the lumbar spine, such as the rectus abdominis, and the EO muscles, in isometric lumbar extension performed by 13 normal adults with forces equal to 50% and 70% of MVIC (maximum voluntary isometric contraction) in a posture with trunk flexion of 30°. According to their results, the muscles around the lumbar spine showed no differences between 50% and 70%, while the abdominal muscles showed more significant increases in muscle activity at 50% than at 70%. Cholewicki et al.³⁾ reported that when loads equal to 0%, 20%, and 40% of body weight were imposed on the waists of 12 subjects, the stability index increased as the weight increased. The TrA and LM muscles act as local muscles, and local muscles contribute to the maintenance of

mechanical stiffness of the spine, controlling intersegmental motion rather than producing large torque. The TrA and LM muscles can maintain lumbar stability at loads below 20% loads of body weight, but other global muscles seem to be activated to maintain lumbar stability at loads above 20% of body weight. This would be a possible reason why the thicknesses of TrA and LM significantly decreased under the 30% load condition. Another possible reason is the validity of the measurement of muscle thickness using ultrasonography. Hodges et al.²⁴⁾ asserted that ultrasound imaging can be used to detect low levels of muscle activity, but that it cannot discriminate between moderate and strong contraction. We did not measure the muscle activities of TrA and LM directly, and a load of 30% load of body weight may induce strong contractions in TrA and LM. This is another possible reason why the thicknesses of TrA and LM did not increase under the load of 30% of body weight. IO did not show any statistically significant differences among the different loads. Hodges et al.²⁴⁾ reported that ultrasound measures reliably corresponded with changes in EMG of 22% MVC (maximum voluntary contraction) in IO. Although the thickness of IO increased at 20%, there was no significant difference from the load of 10% of body weight. Further study is needed to confirm whether EMG activity also shows no significant change among the different lifting loads.

The present study had some limitations. The thicknesses of TrA, LM, and IO were measured in static position. Therefore, the results of this study cannot be generalized to dynamic lifting techniques. We did not measure other global muscles, or lumbar stabilizers such as pelvic floor, diaphragm and lower extremity muscles. Further studies are needed to find the interactions between local and global muscles during stoop lifting.

In conclusion, the TrA and the LM muscles contribute to lumbar stabilization at loads of 20% of body weight in stoop lifting motions. Further studies are needed to find the mechanisms of lumbar stability and the coordination of local and global muscles during stoop lifting of loads greater than 20% of body weight.

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