

Comparison of the Muscle Activity of Lumbar Stabilizers Between Stoop and Semi-Squat Lifting Techniques at Different Lifting Loads

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Abstract

This study was performed to compare the muscle activity of lumbar stabilizers between stoop and semi-squat lifting techniques at different lifting loads. Twenty healthy subjects (9 males, 11 females) were recruited for this study. Muscle activity of external obliques (EO), internal obliques (IO) and lumbar multifidus (LM) muscle was measured by surface electromyography during stoop and semi-squat lifting at different lifting loads (10%, 20%, and 30% of the subject's body weight). A one-way repeated measure ANOVA was applied. The results showed that EMG activity of EO was significantly increased with a load of 30% of body weight compared to 10% and 20% of body weight in both lifting techniques ($p < .05$). Muscle activity of LM was significantly increased in 20% compared to 10% and 30% compared to 10% of subject's body weight in stoop lifting and the muscle activity of LM was significantly increased in 20% compared to 10%, 30% compared to 20%, and 30% compared to 10% of the subject's body weight in semi-squat lifting ($p < .05$). However, there was no significant difference in activity of IO according to lifting loads in both lifting techniques. There were no significant differences in muscle activity of EO, IO, and LM between stoop and semi-squat technique ($p > .05$). Therefore, the results of this study suggested that the EO can contribute to increase the lumbar stability during stoop and semi-squat lifting at 30% of body weight rather than at lower loads, and the LM seems to act as counteractor to imposed loads during stoop and semi-squat lifting with increasing loads.

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Introduction

It has been reported that nearly 60% of industrial workers experience low back pain in their lifetime. Low back pain not only generates economic, productive losses in the work site, such as increased nursing rate and insurance costs for occupational accidents, but also negatively influences the quality of life in individuals. Thus, measures for preventing low back pain are being sought from various angles

(Murtezani et al, 2011). Recently, although manual material handling activities have been decreased with developing automatic equipment, lifting of objects is often used in industrial sites. Among manual handling activities, lifting is reported as the etiology with the highest risk factor among the various causes of low back pain (Granada and Marras, 1995; Ferguson, et al, 1997). Musculoskeletal diseases were caused by lifting activities in 48.3% of cases and by transport or movement in 33.1% (KOSHA, 2010).

There are several lifting techniques in common use, such as stoop (back lift), semi-squat, and squat. Straker (2003) stated that a squat lifting is characterized with a start position of deep knee flexion with the trunk close to erect. Quantitatively this can be described as knee flexion around 45° and trunk flexion $< 30^\circ$ for most workers when lifting from floor level. Stoop lifting techniques involve the inclined trunk and nearly-extended knees. Semi-squat technique uses a posture midway between the squat and stoop lifts.

Many studies have been conducted to compare various parameters among lifting techniques. In a study conducted on lifting postures, the squat lifting posture was found a proper lifting posture for reducing the burden on low back ligaments by decreasing pressure on the 5th lumbar segment and the 1st sacrum (Lariviere et al, 2002; Faber et al, 2009). However, although squat lifting was a safer posture for lifting objects, many workers prefer stoop lifting as it consumes less energy (Grag and Herrin, 1979) and is easier to keep one's balance (Hagen et al, 1993). Hwang et al (2009) reported that the knee extension that is the prominent kinematic feature during the squat lifting was produced by the contributions of the kinetic factors from the hip and ankle joints (extensor moment and power generation), and that the lumbar extension that is the prominent kinematic feature during the stoop lifting could be produced by the contributions of the knee joint kinetic factors (flexor moment, power absorption). Lifting from semi-squat postures, involving a moderate range of flexion at both knees and trunk, allows a pattern of inter-joint coordination that appears to be functional in reducing muscular effort (Burgess-Limerick, 2001).

Lifting capacity can be enhanced through spinal stabilization, which is achieved by cooperative co-activation of abdominal muscles and intra-abdominal pressure (Cholewicki et al, 1999). The co-activation of abdominal muscles and intra-abdominal pressure (IAP) are important factors that contribute to trunk

stabilization. By increasing intra-abdominal pressure, the compressive force of the spine is decreased (Cholewicki et al, 2000). Lumbar spinal stability is essential to reduce the risk of tissue overload or damage in carrying out various functions (Ferreira and Hodges, 2004). Various studies reported the importance of transverse abdominis (TrA) and local muscle system in lumbar spinal segmental stabilization (Davidson and Hubley-Kozey, 2005; Urquhart et al, 2005). Delitto and Lose (1992) demonstrated that the heavy load presented greater activity of erector spinae and oblique muscles than both the moderate and the light loads, and that the moderate load showed greater activity than the light loads during squat lifting. Allison and Henry (2001) reported that abdominal activation was increased during sustained sub-maximal trunk extension efforts.

However, there has been no study to find the muscle activity of lumbar stabilizers during lifting at different loads. Therefore, the present study was performed to compare of the muscle activity of lumbar stabilizers (external oblique; EO, internal oblique; IO, and lumbar multifidus; LM) between stoop and semi-squat lifting techniques at different lifting loads. We hypothesized that the muscle activity of lumbar stabilizers would increase as increased lifting load, And muscle activity of lumbar stabilizers would be different between stoop and semi-squat lifting techniques.

Methods

Subjects

Twenty healthy subjects (9 males, 11 females) participated in this study. This study selected subjects without congenital deformity or medical history in the muscular and neurological system of the back and legs and excluded subjects that had experienced trauma or pain in the back or legs but had regularly participated in exercise for the past 6 months. The general characteristics of subjects were showed in

Table 1. The subjects were informed of the investigational protocol and possible risks and gave written consent prior to their participation in this study.

Instruments and Measurements

The lifting load determined by the strain gauge

The strain gauge with the Noraxon Myoresearch 1.06 XP software was used to control the lifting load. The strain gauge was attached to the steel wire-connected steel bar (15 W 315 D × 328 H (mm)) on the back strength dynamometer¹⁾ Strain gauge was connected with Noraxon software. The subject was asked to watch a computer monitor for maintaining the predetermined lifting load. The lifting order was randomly determined to reduce variables related with the order effect.

Surface electromyography

To measure the muscle activity of EO, IO, and LM in right side, a surface EMG system²⁾ was used. Surface electrodes (Ag-Ag/Cl; Biopac, diameter 2 cm, interelectrode distance 2 cm) were used for collecting EMG signals. Sampling rate was 1,000 Hz and band pass (30~500 Hz) and notch filter (60 Hz) were applied. EMG signals were processed into the root mean square (RMS) using the software (Myolab-2.12 version). The surface electrode was attached on the lateral abdominal area, the part with the highest muscle activity. To minimize skin resistance before attachment, the electrode area was shaved and wiped with alcohol. After the area was completely dried, electrodes were attached to the muscle belly. Ground

electrode was attached on the C7 spinous process. Among abdominal muscles, electrodes for EO were attached over approximately 15 cm lateral to the umbilicus, electrodes for IO were attached over halfway between the anterior superior iliac spine of the pelvis and the midline, just superior to the inguinal ligament; and electrodes for LM were attached at 2 cm lateral to L5 of the spinous process (Silfies et al, 2005). To normalize the muscle activity measurement, maximum voluntary isometric contraction (MVIC) measurement of EO and IO were achieved according to the previous literature (Sánchez-Zuriaga, 2009). The subject was in a sit-up posture positioned on a bench with the legs bent and feet strapped down with a belt. The subject was asked to twist his/her upper trunk to right, and left while his/her thorax was manually braced by the principal investigator. MVIC measurement of LM was performed in prone position. The subject was strapped in a prone position, with the torso horizontally cantilevered over the end of the bench (Biering-Sorensen position). The subject was asked to extend the trunk in the sagittal plane while manual resistance was applied on the shoulders by the principal investigator. EMG activity was collected for 50 milliseconds for measuring the MVIC of each muscle. For normalization, RMS of the middle three second MVIC was measured three times for each muscle. The average RMS of the measurement was used to determine the MVIC of each muscle.

Table 1. General characteristics of subjects (N=20)

Characteristics	Mean±SD
Age (yrs)	20.5±1.0
Height (cm)	166.7±7.5
Mass (kg)	60.3±8.0
BMI ^a (kg/m ²)	21.6±2.1

^aBody Mass Index.

Procedures

Lifting loads were determined according to subject's body weight. 10%, 20%, and 30% of their individual body weights were calculated. Body weight was measured by digital weight scale. Two lifting techniques (stoop and semi-squat lifting) were applied at different lifting loads. Stoop lifting technique was defined as the lifting position with maintaining lumbar lordotic curve and hip flexed 30 degrees without knee flexion. Semi-squat lifting technique

1) Takei TKK 5402, Takei Scientific Inst. Co. Ltd, Tokyo, Japan.

2) BTS Pocket EMG, Garbagnate Milanese, Milano, Italy.

was defined as the lifting position with maintaining lumbar lordotic curve and hip and knee flexed 30 degrees. During lifting, the pelvis is aligned in an anterior tilt. Each subject practiced the two lifting techniques for familiarization with the testing procedure. Subjects were asked to hold the lifting loads of 10%, 20%, and 30% of their body weight and hold the posture for 50 milliseconds. Subjects were asked to not elevate scapula, and to extend the trunk during the lifting test. Measurement was performed three times and 3 minute resting periods were allowed between each trial. EMG signals were collected 50 milliseconds and the middle 30 milliseconds used for data analysis. EMG data of the initial one second and final one millisecond were excluded. The normalized muscle activity of EO, IO, and LM was expressed as percent of MVIC.

Statistical Analysis

Descriptive statistics were used to analyze the general characteristics of subjects. A one-way repeated measure ANOVA was used to compare the activity of the lumbar stabilizer (EO, IO, and LM) at different loads in each lifting technique and paired t-test was performed to determine the difference in muscle activity between two lifting techniques.

Post-hoc multiple comparison test was performed. This study was analyzed using PASW Statistics version 18.0 software. Significance level was set as $\alpha=0.05$.

Results

The results of a one-way repeated ANOVA revealed a significant difference for the activity of the EO and LM at different loads in both lifting techniques ($p<0.05$), and a paired t-test revealed no significant difference between the lifting techniques at each muscle according to lifting loads ($p>0.05$).

Comparison of muscle activity at different loads in stoop lifting

The muscle activity of EO and LM were statistically significant difference according to increased loads from the results of a one-way repeated measures ANOVA in stoop lifting ($p<0.05$). However, the muscle activity of IO was not significantly different ($p>0.05$). The results of the post-hoc analysis showed that the muscle activity of EO was significantly increased in 30% compared to 10% and 20%, whereas the muscle activity of LM was significantly increased in 20% compared to 10% and 30% compared

Table 2. Comparison of muscle activity of EO, IO, and LM at different loads in stoop lifting (Unit: %MVIC)

Muscle	10%	20%	30%	F	Post hoc
EO ^a	18.85±8.81 ^d	18.95±7.57	22.02±9.30	4.64*	a<c, b<c ^e
IO ^b	31.35±21.62	29.27±16.61	33.01±21.62	1.72	/
LM ^c	37.92±12.57	45.22±14.43	48.04±16.22	8.85*	a<b, a<c

^aexternal oblique, ^binternal oblique, ^clumbar multifidus, ^dmean±standard deviation, ^ea: 10%, b: 20%, c: 30%, * $p<0.05$.

Table 3. Comparison of muscle activity (%MVIC) of EO, IO, and LM at different loads in squat lifting (Unit: %MVIC)

Muscle	10%	20%	30%	F	Post-hoc
EO ^a	18.86±8.81 ^d	19.82±7.95	22.29±8.08	8.18*	a<c, b<c ^e
IO ^b	28.41±16.17	30.56±16.38	37.47±20.49	2.22	/
LM ^c	37.29±12.20	43.94±14.13	49.20±14.48	40.64*	a<b, b<c, a<c,

^aexternal oblique, ^binternal oblique, ^clumbar multifidus, ^dmean±standard deviation, ^ea: 10%, b: 20%, c: 30%, * $p<0.05$.

to 10% of subject's body weight in stoop lifting (Table 2) (Figure 1).

Comparison of muscle activity at different loads in semi-squat lifting

The muscle activity of EO and LM were statistically significantly different according to increased load from the results of a one-way repeated measures ANOVA in semi-squat lifting ($p < .05$). The muscle activity of IO was not significantly different ($p > .05$). The results of the post-hoc analysis showed that EO was significantly increased in 30% compared to in 10% and 20%, whereas the muscle activity of LM was significantly increased in 20% compared to 10%, 30% compared to 20%, and 30% compared to 10% of the subject's body weight in semi-squat lifting (Table 3) (Figure 2).

Discussion

The purpose of the present study was to compare of the muscle activity of lumbar stabilizers (EO, IO, and LM) between stoop and semi-squat lifting techniques at different lifting loads. The results of this study showed that muscle activity of EO and LM increased significantly as increased lifting load both stoop and semi-squat lifting. However, there was no difference in muscle activity of IO according to lifting loads in both stoop lifting and semi-squat lifting. In addition there was no significant difference in muscle activity of lumbar stabilizers between the two lifting techniques.

Tan et al (1993) reported that maximum extension torque was significantly increased at 35 degrees of trunk flexion and many activities of daily living and

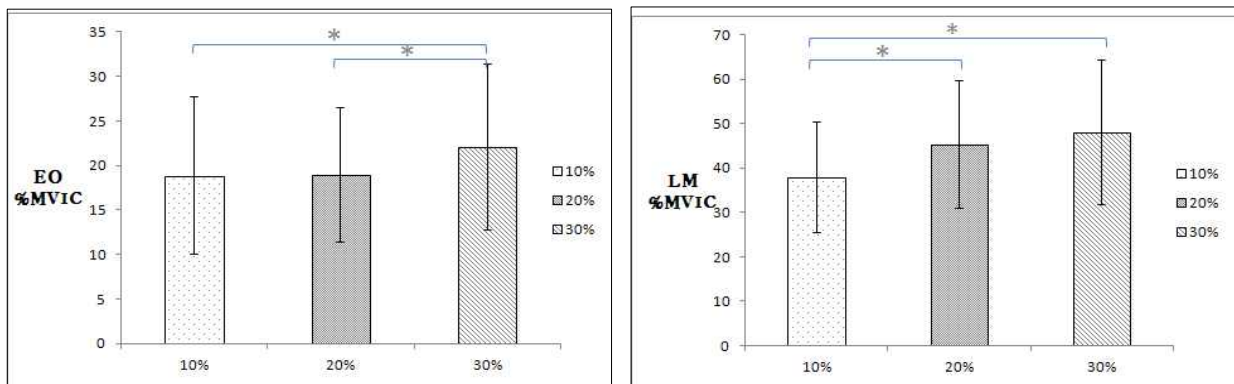


Figure 1. Comparison of muscle activity (%MVIC) of EO and LM at different loads in stoop lifting (EO: external oblique, LM: lumbar multifidus, %MVIC: %maximum voluntary isometric contraction, * $p < .05$).

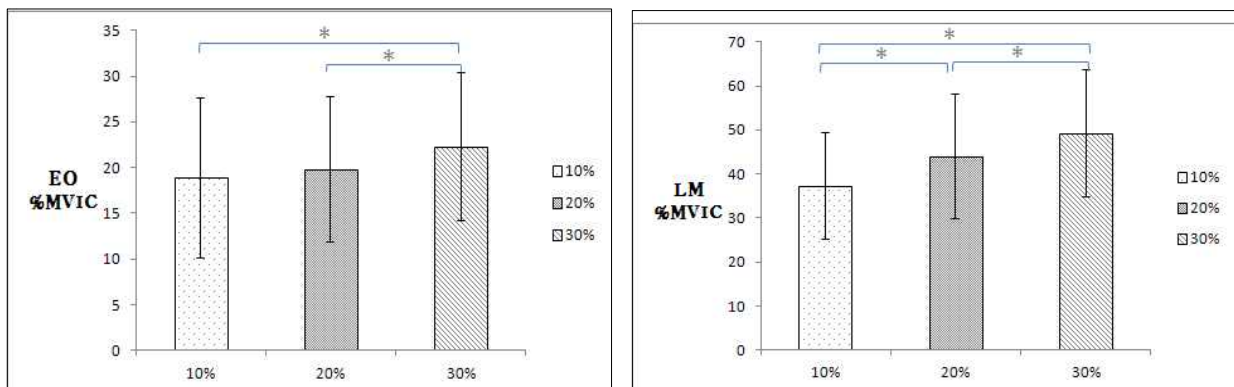


Figure 2. Comparison of muscle activity of (%MVIC) EO and LM at different loads in semi-squat lifting (EO: external oblique, LM: lumbar multifidus, %MVIC: %maximum voluntary isometric contraction, * $p < .05$).

trunk activities such as manual material handling and lifting are performed in the sagittal plane with the trunk slight flexed to about 30~60 degrees. Therefore, we selected 30 degrees of trunk flexion for stoop and semi-squat lifting techniques (Nordin et al, 1984). During lifting, the lumbar spine is maintained in its normal lordosis and the pelvis is aligned in an anterior tilt. It minimizes stretch on the posterior elements of the lumbar spine and thereby decreases the stress on these structures (Kisner and Colby, 2007). Delitto and Rose (1992) recommended that the greater trunk muscle activity occur with the anterior tilt position for optimal muscular support for the spine while lifting loads, thereby reducing the risk for low back injury. Therefore, we asked subjects to maintain the lumbar natural lordotic curve for minimizing lumbar injury during lifting.

The activity of abdominal muscle plays a vital role in determining the trunk's ability to maintain the normal posture and effectively function to do daily activities (Granata and Orishimo, 2001; Lavender et al, 1992) and is deeply related with the trunk stabilization of lumbar spinal disorder patients (Silfies et al, 2005; van Dieen et al, 2003). However, Tan et al (1993) reported that there was no co-activation of abdominal muscles at sub-maximal extension efforts at 0, 15, and 35 degrees of trunk flexion, whereas, Lavender et al (1992) stated that abdominal muscles are activated during submaximal lifting. Sitalertpisan et al (2011) stated that the lateral abdominal muscle group (LAM) including the IO, EO, and TrA shared a role in controlling the lumbar spine during weight-lifting. The EO and IO may control the rotary torque and balance the external loads on the lumbar segment (Hodges and Gandevia, 2000; Richardson et al, 2004; Teyhen et al, 2005). Therefore, the present study sought to determine whether IO and EO muscles are activated for lumbar stabilization during lifting at different lifting loads. In the present study, the muscle activity of EO was statistically significantly different according to increased loads. However, the muscle activity of IO

was not significantly different ($p>.05$). The results of the post-hoc analysis showed that the muscle activity of EO was significantly increased in 30% (22.02 ± 9.30) compared to 10% (18.85 ± 8.81) and 20% (18.95 ± 7.57) in stoop lifting. And the EMG activity of EO was also significantly increased in 30% (22.29 ± 8.08) compared to 10% (18.86 ± 8.81) and 20% (19.82 ± 7.95) in semi-squat lifting. Tan et al (1993) found that an activity of abdominal oblique muscles did not appear at submaximal levels (MVIC 20, 40, 60, 80%), but there was a activity of abdominal obliques at maximal level, Because of an increase in the need of trunk stabilization through coactivation of the abdominal oblique muscles.

Three major mechanisms of lifting have been introduced. There are the intra-abdominal pressure (IAP) (Cholewicki et al, 1999; Hodges et al, 2005; McGill 2002), the lumbodorsal fascia mechanism (Tesh et al, 1987), and the hydraulic amplifier (McGill et al, 1996). The stability of spine can be achieved by two mechanisms: antagonistic muscle co-activation (Gardner-Morse and Stokes, 1998) and/or an increase in IAP. IAP can increase by co-activation of the abdominal musculature, diaphragm, and pelvic floor muscles (Cresswell and Thorstensson, 1989; Cresswell et al, 1994). Norris (1995) stated that contraction of the transverse abdominis and internal and external oblique cause an increased IAP when the glottis is closed. The result of the study showed that muscle activity of EO was significantly increased with increasing lifting loads in either technique. These results suggest that EO contributes to increased IAP during stoop and semi-squat lifting techniques.

The rigidity of the trunk segment must be maintained during daily activities to allow for sufficient loading and energy transfer during loading. Paraspinal muscles, in particular the erector spinae, act as the primary agonist in lifting activities, whereas abdominal muscles such as rectus abdominis, IO, EO, and TrA act as the antagonist (Chow et al, 2005; Kingma and van Dieen, 2004). Previous lit-

eratures stated that the LM can contribute to stabilization of the lumbar spine (Barr et al. 2005; Beneck and Kulig, 2012; Freeman et al. 2010; Hides et al, 2008; Lee et al, 2011). Biomechanical studies showed that the LM has a high capacity to stabilize the spine when spinal stability is challenged (Panjabi, 1992; Wilke et al, 1995), and control the spinal segment's neutral zone (Panjabi et al, 1989). The LM may contribute to sub-maximal extension efforts at greater exertion intensity (Olson, 2010). Although, LM has been considered as an important lumbar stabilizer during lifting objects, there has been no study to determine the muscle activity of LM during lifting. In the present study, the muscle activity of LM was significantly increased in 20% (45.22 ± 14.43) compared to 10% (37.92 ± 12.57) and 30% (48.04 ± 16.22) compared to 10% (37.92 ± 12.57) of subject's body weight in stoop lifting. And the muscle activity of LM was significantly more increased in 20% (43.94 ± 14.13) compared to 10% (37.29 ± 12.20), 30% (49.20 ± 14.48) compared to 20% (43.94 ± 14.13), and 30% (49.20 ± 14.48) compared to 10% (37.29 ± 12.20) of the subject's body weight in semi-squat lifting. Previous studies reported that the activity of paraspinal muscles significantly increased as lifting load increased (Dolan et al, 1993; Lariviere et al. 2002; Olson, 2010; Tan et al, 1993; Yoon et al, 2012). LM muscle works together with TrA, diaphragm, and pelvic floor muscle to increase lumbar stability during lifting. Increased muscle activity of LM during lifting with 30% of body weight resulted in counterbalancing to the EO muscle contraction for maintaining the neutral position of lumbar spine.

Straker (2003) reported that there were different advantages and disadvantages according to various situations as the squat posture reduced shear force exerted on lumbar spine, whereas the stoop posture decreased muscular fatigue. Van Dieen et al (1999) found that reasonable evidence was not found for verifying the kinetic advantage of the squat rather than stoop posture in lifting activities. Kingma et al (2004) reported that squat lifting results in higher

compression forces on the spine compared to stoop lifting when the load is not positioned between the legs. In the present study, the EMG activity of EO, IO, and LM was not significantly different between stoop and semi-squat lifting technique. These result do not support the hypothesis of this study.

This study has some limitations. First, subjects were young and healthy. Therefore, the results of this study cannot be generalized to all populations. Second, deep muscles such as diaphragm, TrA, and pelvic floor contribute to lumbar stabilization; however, the muscle activity of these muscles was not measured in this study. Further study is needed to compare the muscle activity of TrA, diaphragm, and pelvic floor muscle according to lifting loads and lifting techniques.

Conclusion

The purpose of this study was to compare the muscle activity of lumbar stabilizers (EO, IO, and LM) between stoop and semi-squat lifting techniques at different lifting loads. Twenty healthy subjects participated. The muscle activity of EO was significantly increased at increased loads (30% of body weight) in stoop and squat lifting techniques and LM was significantly increased with increased loads in stoop and squat lifting techniques. However, the activity of IO was not significantly different at different loads in either lifting technique. Therefore, we suggest that the EO and LM can contribute to increased lumbar stability as increased loads in stoop and semi-squat lifting techniques.

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