Electromyographic Activities of Trunk Muscles Due to Different Exercise Intensities during Pulley-based Shoulder Exercises on an Unstable Surface

JAE YUN CHA, PT, MS1), DOO CHUL SHIN, PT, MS1), SEUNG HO SHIN, PT, MS1), MYUNG MO LEE, PT, MS1), KYOUNG JIN LEE, PT, PhD1), CHANG HO SONG, PT, PhD1)*

1) Department of Physical Therapy, Sahmyook University: 26-21 Gongneung 2-dong, Nowon-gu, Seoul 139-742, Republic of Korea

Abstract. [Purpose] This study examined the relationship between core stability and exercise intensity during a pulley-based shoulder exercise (PBSE) on an unstable support surface. [Subjects] Twenty healthy college students enrolled in this study. [Methods] Surface EMG was conducted in twenty healthy adult men. The electromyographic activities of the rectus abdominis (RA), erector spinae (ES), and external oblique (EO) muscles during pulley-based shoulder on an unstable support surface (USS) were compared. [Results] The EMG signals of the RA, ES, and EO did not increase with increasing exercise resistance. [Conclusion] Increasing the exercise intensity to increase the core stability during PBSE on a USS may be ineffective.

Key words: Electromyography, Core stability, Ankle strategy

INTRODUCTION

Considerable research has been performed on posture and movement in recent years, with particular focus on core stability1). In addition, core stabilization exercises are viewed as a means of preventing low back pain and rehabilitating patients with low back pain2).

At the center of the body, more than 29 pairs of muscles stabilize the spine, pelvis, and hip joints during various functional movements3). The central muscles play important roles during movement of the trunk and stabilize the spine4).

Core stabilization by strengthening the trunk muscles is important for activity, daily living, and sports, and during the rehabilitation of low back pain patients because it provides the basis for producing forces by limbs5). The methods for increasing core stability involve increasing the intensity and number of exercise repetitions and the use of an unstable support surface (USS), such as a ball or balance platform6). The use of a USS that increases the trunk muscle activity may also be effective during core stability training7–9). In addition, movements of the limbs and body weight during core stabilization exercises can be used to provide resistance to muscles of the trunk10, 11). Shoulder resistance exercises increase the endurance and strength of core stability muscles12).

Several studies have been performed on the use of a USS during core stability training13–16), but no study has addressed the trunk muscle activities with changes in exercise intensity during a pulley-based shoulder exercise (PBSE) on a USS. Therefore, this study examined the effects of exercise intensity on the trunk muscle activities during a PBSE on a USS.

SUBJECTS AND METHODS

Twenty healthy adult male subjects (mean SD height 176 ± 5 cm; weight 70 ± 9 kg; age 22 ± 3 years) were enrolled in this study (Table 1). The subjects were volunteers recruited from a university in Seoul. The inclusion criteria were subjects in good health; no current musculoskeletal, neuromuscular, or cardiovascular problems; and a normal range of shoulder joint motion. Subjects were excluded if they had trauma or pain in a trunk or shoulder joint or a history of surgery. In addition, those who had experienced core stabilization training or therapy within the last 3 months were excluded. The subjects signed an informed consent form prior to participation, and the study protocol was approved by the Institutional Review Board of the University of Sahmyook.

Forty-eight hours before starting the studies, all the subjects abstained from excessive exercise. A 5 min warm-up stretching exercise was conducted before commencing the study. Prior to electrode placement, the sites were prepared by abrading the skin with fine sandpaper and cleaning with 70% isopropyl alcohol. Removal of hair by shaving was performed where necessary. To measure the trunk muscle activities, the EMG data were collected from the rectus abdominis (RA), erector spinae (ES), and external oblique...
EMG signals were band-pass filtered from 20 to 450 Hz, and a 60 Hz notch filter was used to reduce noise. The sampling rate was set to 1,000 Hz per channel, the mean square (RMS) algorithm in MyoResearch XP Master software, Version 7.50, in ASCII were processed using a root mean square (RMS) algorithm in MyoResearch XP Master Edition 1.06 (Noraxon USA, Inc., Scottsdale, AZ, USA). The sampling rate was set to 1,000 Hz per channel, the EMG signals were band-pass filtered from 20 to 450 Hz, and a 60 Hz notch filter was used to reduce noise.

Table 1. Subject characteristics

| Characteristics | Value       |
|-----------------|-------------|
| Age (years)     | 22.4 ± 2.7  |
| Height (cm)     | 176.4 ± 5.1 |
| Weight (kg)     | 69.8 ± 8.6  |
| Dominant side   | Right       |

Values are expressed as means ± SD

Table 2. EMG activity of trunk muscles on a USS

| Shoulder Exercise | 14 kg       | 26 kg       |
|-------------------|-------------|-------------|
| Rectus abdominis  |             |             |
| 1. Abduction      | 73.22 ± 15.83 | 69.94 ± 14.13 |
| 2. Abduction      | 62.19 ± 15.92 | 43.70 ± 12.25 |
| 3. Extension      | 45.23 ± 9.22  | 27.01 ± 9.42  |
| 4. Flexion        | 69.08 ± 20.60 | 50.28 ± 19.34 |
| 5. External rotation | 80.09 ± 12.29 | 47.89 ± 8.34  |
| 6. Internal rotation | 75.56 ± 13.72 | 47.12 ± 16.05 |
| External oblique  |             |             |
| 1. Abduction      | 73.62 ± 15.10 | 63.43 ± 13.04*|
| 2. Abduction      | 61.97 ± 10.29 | 61.46 ± 8.97  |
| 3. Extension      | 62.56 ± 9.45  | 66.48 ± 9.75  |
| 4. Flexion        | 68.53 ± 13.10 | 70.46 ± 11.55 |
| 5. External rotation | 77.78 ± 10.23 | 75.88 ± 8.80  |
| 6. Internal rotation | 72.58 ± 11.36 | 75.29 ± 8.78  |
| Erector spinae    |             |             |
| 1. Abduction      | 70.29 ± 16.77 | 75.62 ± 15.94 |
| 2. Abduction      | 69.04 ± 16.78 | 66.16 ± 17.00 |
| 3. Extension      | 53.12 ± 16.33 | 54.73 ± 16.87 |
| 4. Flexion        | 81.21 ± 13.38 | 77.82 ± 12.80 |
| 5. External rotation | 75.64 ± 12.47 | 70.03 ± 13.69 |
| 6. Internal rotation | 74.01 ± 17.14 | 73.52 ± 10.26 |

Values are expressed as means ± SD. * Indicates significant changes between the 14 kg and 26 kg exercise intensities. (p<0.05).

SPSS ver. 19.0 was used for data analysis. All subjects had a normal distribution. Descriptive statistics were used to analyze the general subject characteristics, and one-way repeated-measures analysis of variance was applied for each muscle. Statistical significance was accepted for p <0.05.

RESULTS

The RA and ES muscles showed no significant difference with resistances of 14 and 26 kg for all shoulder exercises. On the other hand, the EO muscle showed a significant difference during the shoulder abduction exercise. During the other exercises, the EO muscle showed no significant difference at the two resistances (Table 2).

DISCUSSION

The Swiss ball, shake board, form roller, balance board, and others provide a USS. In the present study, the Pedalo®-Vestimed® 50, which comprises a platform, an upper and a lower plate connected to each other, was used. The lower plate moves up and down in all directions, which makes it suitable for use as an unstable support.

The results suggest that the EO muscle activity was reduced significantly by increasing the exercise resistance from 14 kg to 26 kg during shoulder abduction exercise on the unstable surface (p<0.05). On the other hand, the RA and ES showed no significant difference during all shoulder
movements.

None of the trunk muscles measured in this study showed an increase in their activities, despite the exercise intensity being increased.

Alpert et al.19 analyzed the activities of the deltoid and rotator cuff muscles during isokinetic shoulder exercises using different resistive weights. According to their results, the muscle activities depended on changes in the angle of movement. On the other hand, the maximum muscle activity was observed after applying the greatest resistance to all muscles. In the present study, the activities of the shoulder muscles during PBSE could not be measured, but an increased exercise intensity might induce larger activities of the shoulder muscles than the trunk muscles.

Borreani et al.20 compared the ankle muscle activities after applying therapeutic exercises on an unstable surface, and reported that exercises on an unstable surface increased the activities of the ankle muscles20). Upon the occurrence of posture sway under unstable conditions, balance is recovered using an ankle strategy, hip strategy, or both21). In the event of sway in the support surface in an upright posture, balance can be maintained by ankle movement without hip joint extension22). In the present study, increasing the exercise intensity to increase the trunk muscle activity might have increased the ankle muscle activity to maintain balance on an unstable surface.

With PBSE on the USS, increasing the exercise intensity did not increase the RA, EO, and ES muscle activities. According to the study results, increasing the exercise intensity to increase the trunk muscle activity during PBSE on a USS probably has no effect.

Further confirmation of these results will be necessary in a larger and more diverse population, including females and older individuals. In addition, measurements of the deep muscles, such as the transverse abdominis and internal oblique, will be needed.

REFERENCES

1) Airaksinen O, Brox JI, Cedraschi C, et al.: Chapter 4. European guidelines for the management of chronic nonspecific low back pain. European Spine Journal, 2006, 15 Suppl 2: S192–300.
2) Akuthota V, Nadler SF: Core strengthening. Arch Phys Med Rehabil, 2004, 85: S86–S92. [Medline] [CrossRef]
3) Akuthota V, Ferreiro A, Moore T, et al.: Core stability exercise principles.
4) Monfort-Pañego M, Vera-García FJ, Sánchez-Zuriaga D, et al.: Electromyographic studies in abdominal exercises: a literature synthesis. J Manipulative Physiol Ther, 2009, 32: 232–244 [Medline] [CrossRef]
5) McCurdy KW, Langford GA, Doscher MW, et al.: The effects of short-term unilateral and bilateral lower-body resistance training on measures of strength and power. Journal of Strength and Conditioning Research, 2005, 19: 9–15.
6) Hall CM, Brody LT: Therapeutic exercise: Moving toward function. Philadelphia: Lippincott Williams & Wilkins, 2005.
7) Anderson K, Behm DG: The impact of instability resistance training on balance and stability. Sports Med, 2005, 35: 43–53. [Medline] [CrossRef]
8) Anderson K, Behm DG: Trunk muscle activity increases with unstable squat movements. Canadian Journal of Applied Physiology, 2005, 30: 33–45.
9) Marshall PW, Murphy BA: Core stability exercises on and off a Swiss ball. Arch Phys Med Rehabil, 2005, 86: 242–249. [Medline] [CrossRef]
10) Arokoski JP, Valta T, Airaksinen O, et al.: Back and abdominal muscle function during stabilization exercises. Arch Phys Med Rehabil, 2001, 82: 1089–1098. [Medline] [CrossRef]
11) Souza GM, Baker LK, Powers CM: Electromyographic activity of selected trunk muscles during dynamic spine stabilization exercises. Arch Phys Med Rehabil, 2001, 82: 1551–1557. [Medline] [CrossRef]
12) Tarnanen SP, Ylinen JJ, Siekkinen KM, et al.: Effect of isometric upper-extremity exercises on the activation of core stabilizing muscles. Arch Phys Med Rehabil, 2008, 89: 513–521. [Medline] [CrossRef]
13) Colado JC, Pablos C, Chuluvi-Medrano I, et al.: The progression of paraspinal muscle recruitment intensity during dynamic upper extremity exercises is not based on instability alone. Arch Phys Med Rehabil, 2011, 92: 1875–1883. [Medline] [CrossRef]
14) Desai I, Marshall PW: Acute effect of labile surfaces during core stability exercises in people with and without low back pain. Journal of Electromyography and Kinesiology, 2010, 20: 1155–1162.
15) Keogh JW, Aickin SE, Oldham AR: Can common measures of core stability distinguish performance in a shoulder pressing task under stable and unstable conditions? Journal of Strength and Conditioning Research, 2010, 24: 422–429.
16) Kohler JM, Flanagan SP, Whiting WC: Muscle activation patterns while lifting stable and unstable loads on stable and unstable surfaces. Journal of Strength and Conditioning Research, 2010, 24: 313–321.
17) Cram JR, Kasmant GS, Holtz J: Introduction to surface electromyography. Gaithersburg: Md Aspen, 1998.
18) Smith LW, Weiss EL, Lehmkuhl LD: Brunstrom's clinical kinesiology. Philadelphia: F.A. Davis, 1996.
19) Alpert SW, Pink MM, Jobe FW, et al.: Electromyographic analysis of deltoid and rotator cuff function under varying loads and speeds. Journal of Shoulder and Elbow Surgery, 2000, 9: 47–58.
20) Borreani S, Calataudaj J, Martin J, et al.: Exercise intensity progression for exercises performed on unstable and stable platforms based on ankle muscle activation. Gait Posture, 2014, 39: 404–409. [Medline] [CrossRef]
21) Horak FB, Nashner LM: Central programming of postural movements: adaptation to altered support-surface configurations. J Neurophysiol, 1986, 55: 1369–1381. [Medline]
22) McCollum G, Shupert CL, Nashner LM: Organizing sensory information for postural control in altered sensory environments. J Theor Biol, 1996, 180: 257–270. [Medline] [CrossRef]