J. Phys. Ther. Sci.
26: 749–751, 2014

Original Article

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

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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 carried out in twenty healthy adult men. The electromyographic activities of the rectus abdominis (RA), erector spinae (ES), exercises with 14 kg or 26 kg of resistance 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

(This article was submitted Oct. 28, 2013, and was accepted Dec. 14, 2013)

INTRODUCTION

Considerable research has been performed on posture and movement in recent years, with particular focus on core stability[1)]. In addition, core stabilization exercises are viewed as a means of preventing low back pain and rehabilitating patients with low back pain[2)].

At the center of the body, more than 29 pairs of muscles stabilize the spine, pelvis, and hip joints during various functional movements[3)]. The central muscles play important roles during movement of the trunk and stabilize the spine[4)].

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 limbs[5)]. 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 platform[6)]. The use of a USS that increases the trunk muscle activity may also be effective during core stability training[7–9)]. In addition, movements of the limbs and body weight during core stabilization exercises can be used to provide resistance to muscles of the trunk[10, 11)]. Shoulder resistance exercises increase the endurance and strength of core stability muscles[12)].

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Several studies have been performed on the use of a USS during core stability training[13–16)], 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

Table 1. Subject characteristics

Characteristics	
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

(EO) muscles. For the RA, the electrodes were placed 2 cm lateral, 1 cm superior, and 1 cm inferior to the umbilicus. For the EO, the electrode was placed midway between the anterior superior iliac spine and rib cage. For the ES muscle, the electrodes were placed parallel at a distance of 2 cm lateral from the 3rd lumbar vertebra to the iliac crest on the horizon. The locations of all electrodes were determined using the method reported by Cram and Kasman[17], and all electrodes were placed on the dominant sides.

Muscle activations of the trunk were measured during PBSE using a 14 kg or 26 kg resistance on a USS. The PBSE consisted of abduction, adduction, flexion, extension, internal rotation, and external rotation of the shoulder joint. The orders of the six types of PBSE were randomized, and the six exercises were repeated 5 times. A metronome, which was set at 80 bpm, was used during the shoulder exercises to control the speed. The subjects were given a rest for 1 minute between each shoulder exercise to minimize muscle fatigue[18]. All exercises were conducted with the feet apart (within shoulder width), and parallel to the shoulders. The abduction and flexion exercises were conducted from 0 to 90° of the shoulder range of motion with the elbow joint in extension. The adduction exercises were conducted from 90 to 0° of the shoulder range of motion with the elbow joint in extension. The extension exercises were conducted from 180 to 90° of the shoulder range of motion with the elbow joint in extension. The external rotation exercises were conducted from internal rotation of 45° to external rotation of 45° with the elbow joint at 90° of flexion. The internal rotation exercises were conducted from external rotation of 45° to internal rotation of 45° with the elbow joint at 90° of flexion.

A pulley machine (SANIMED Pulley EX, Ibbenbüren, Germany) was used for all shoulder exercises, the flat floor of the laboratory was used as the stable support surface, and a Pedalo®-Vestimed® 50 (diameter 50 cm, height 19 cm) was used as the USS during the shoulder exercises. The top and bottom of the Pedalo used were connected to four fixed cables, and the top of the Pedalo moved up and down in all directions.

A Biometrics DataLOG model P3X8 (Biometrics Ltd., Gwent, UK) was used to measure the muscle activity. The surface EMG signals extracted from the DataLog PC 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 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. Adduction	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. Adduction	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. Adduction	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 muscles[20]. Upon the occurrence of posture sway under unstable conditions, balance is recovered using an ankle strategy, hip strategy, or both[21]. In the event of sway in the support surface in an upright posture, balance can be maintained by ankle movement without hip joint extension[22]. 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.

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