

Comparisons of shoulder stabilization muscle activities according to postural changes during flexi-bar exercise

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Abstract. [Purpose] The purpose of this study was to compare shoulder stabilization muscle activities according to postural changes during flexi-bar exercise. [Subjects] The subjects included 18 students (10 males, 8 females) at B University. [Methods] The subjects performed the following flexi-bar exercises: 1) medio-lateral oscillation with the 90° shoulder abduction, with the hand in the neutral position; 2) dorso-ventral oscillation with 90° shoulder flexion, with the hand in the neutral position; 3) superior-inferior oscillation with 90° shoulder flexion, with the 80° hand pronation. [Results] The activity of the serratus anterior showed significant differences between each position; however, activities of the upper trapezius and middle trapezius were not significantly different. [Conclusion] The results of this study indicate that posture control is important for selective strengthening of the serratus anterior muscle during flexi-bar exercises.

Key words: Flexi-bar exercise, Shoulder stabilization, Muscle activity

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INTRODUCTION

Normal functioning and stability of the shoulder joints is important to activities of daily living. These movements rely on the balance and interactions of the various joints that comprise the shoulder complex¹⁾. In addition, the shoulder joints are a region of frequent activity, and being susceptible to structural changes due to abnormal movements, can be easily damaged²⁾. Imbalanced muscle activation, rather than an overall weakening of muscles surrounding the shoulder joints, mainly causes these changes³⁾. Functional recovery using muscle rehabilitation training is used as a therapeutic approach^{4, 5)}.

The serratus anterior (SA) and the trapezius are the leading shoulder-stabilizing muscles. Excessive activation of the upper trapezius (UT) in patients with pain due to unstable shoulder causes abnormal shoulder joint movements and results in various types of shoulder damage due to malfunctioning of the SA and compensatory actions of the UT⁶⁾. An appropriate relationship between the length and tension of the muscles is required for selective muscle strengthening exercises, and proper posture is essential to induce optimal muscle lengths, strengths, and movements⁷⁾. Currently,

therapists focus exercise methods on the recovery of balanced control between the shoulder stabilizer muscles⁸⁾, and exercise methods using vibrations have recently been introduced to strengthen the stabilizers⁹⁾.

The flexi-bar (FB) is a double oscillating exercise device that generates vibrations and is effective in the control of nerve roots, muscle strengthening, and proprioceptive feedback¹⁰⁾. A previous study reported that bridging exercises combined with FB exercises increases activation of the trunk muscle¹¹⁾. Another study noted that this device generates higher levels of activation in the erector spinae muscle than that generated by a single oscillating device¹²⁾. Previous studies involving FB exercises, however, focus more on the core muscles than shoulder muscles. Thus, the purpose of the present study was to compare the activation of shoulder-stabilizing muscles by changing postures during shoulder exercises using the FB and to suggest effective and selective postures for muscle exercises.

SUBJECTS AND METHODS

Subjects

This study included 18 students (10 males, 8 females) attending B University in Cheonan, South Korea. The subjects' mean age was 20.56 ± 1.00 years, mean height was 168.94 ± 8.71 cm, and mean weight was 62.17 ± 9.48 kg. The subjects who had shoulder, elbow, and or wrist pain during the six months prior to the study and those limited muscle strength or a limited range of upper-extremity joint motion, were excluded from subject selection. All study subjects received explanations about the study procedures,

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voluntarily participated, and provided written informed consent. The experimental procedures were designed and conducted in accordance with the tenets of the Declaration of Helsinki.

Methods

In the present study, we used a double-oscillating FB device (FLEXIBAR[®], Flexi-bar Inc., Germany) was 1,530 mm in length with a weight of 650 g, a thickness of 9 mm, and a vibration frequency of approximately 4.6 Hz. All study subjects were right-hand dominant. The subjects were first instructed to place their feet apart at shoulder width. The first posture involved maintaining shoulder abduction at 90° with hand in the neutral position so that they could hold the FB with, and medio-lateral oscillation in the frontal plane (posture 1). The second posture involved dorso-ventral oscillation in the sagittal plane while maintaining shoulder flexion at 90° (posture 2). The third posture involved superior-inferior oscillation in the transverse plane with a shoulder flexion at 90°, and 80° hand pronation (posture 3). Each exercise was performed for 30 s with 3 repetitions. A rest interval of 90 s was given after each set. The values measured during the during the mid-20 s of the 30-s exercise duration were collected, excluding the first and last 5 s of data¹¹.

Muscle activity was measured using surface electromyography (Trigno, Delsys Inc., USA). After removing body hair and keratin, and disinfecting the skin using alcohol to reduce skin resistance, electromyography was performed using 1-cm diameter Ag/AgCl electrodes with an inter-electrode distance of 2 cm. The electrodes were attached to the UT (muscle belly in the middle between the C7 spinous process and the right acromioclavicular joint, which is the region of insertion of the trapezius)¹³, the middle trapezius (MT) (midway on a horizontal line between the root of the scapula spine and the T3 spinous process)¹⁴, and the SA (the muscle belly on the mid-axillary line of the right fifth rib)¹³. The sampling rate was set to 2,000 Hz, and the bandwidth was set between 400 and 500 Hz. During the exercises, to normalize electromyography signals from individual muscles, the maximal voluntary isometric contraction (MVIC) of each muscle was measured for 5 s. To yield the MVIC, root-mean square values were obtained; of the 5 total measurements for root-mean square values, the average of the middle 3 values (excluding the largest and smallest values) were used to calculate MVIC. The muscle activities of the UT, MT, and SA of each group were normalized to %MVIC.

Statistical analysis was conducted using SPSS for windows (ver. 18.0). Repeated one-way ANOVA were used to analyze the data in order to compare differences in the activities of the UT, MT, and SA muscles according to types of posture. Multiple comparisons were examined using Bonferroni's correction. The statistical significance level was set to 0.05.

RESULTS

In the muscle activity comparison, posture 1 and 2 were MT, UT and SA was higher in the order. However, posture 3 was MT, SA and UT. With regard to posture, there was a significant difference in muscle activity of the SA between

Table 1. Comparison of activities of the UT, MT, and SA in different postures

	Posture 1	Posture 2	Posture 3
UT	52.8 (24.3)	56.3 (24.0)	61.0 (29.3)
MT	66.7 (26.1)	57.0 (18.5)	74.3 (22.7)
SA	38.3 (18.3)	51.1 (21.6)	67.5 (18.0) ^{†‡}

(unit: %MVIC) Mean (SD), * $p < 0.05$, [†]significant difference between posture 1 and 3, [‡]significant difference between posture 2 and 3, UT: upper trapezius, MT: middle trapezius, SA: serratus anterior

each posture ($p < 0.05$); however, no significant differences were observed in UT or MT activity (both $p > 0.05$). Post-hoc comparisons revealed that muscle activity of the SA was higher in posture 3 than in posture 1 or 2 ($p < 0.05$) (Table 1).

DISCUSSION

This study compared the activation of shoulder stabilizer muscles according to postural changes during shoulder exercises using the FB. The UT and MT showed no differences in muscle activation with postural changes, whereas the SA exhibited statistically significant differences in muscle activity. Vibrations activate muscles connected by alpha motor neurons by stimulating sensory nerve fibers originating from the muscle spindle¹⁵. In addition, vibrations affect not only the spindles of muscles that are directly influenced by the vibrations, but also the spindles of the surrounding muscles¹⁶. The vibrations caused by the FB are effective in the movement perception of patients with various neurological disorders, as well as, that of healthy adults, through the generation of strong proprioceptive stimulation¹⁷. In addition, this rehabilitation tool can be used in various kinetic chain movement patterns that enable scapular control through the activation of the shoulder muscles¹⁸.

Sugimoto et al.¹⁹ stated that shoulder joint rotation exercises using the FB and the thera-band produced no differences in muscle strength. However, Lister et al.²⁰ reported that FB for shoulder-stabilizing exercises increased scapular activity more than that with general resistance devices. Concurrently, Eom et al.²¹ argued that exercises that provide dynamic environments increase myotility due to increases in myofibrils that engage in motor control. Additionally in rehabilitation programs for patients with shoulder pathology, the importance of muscle strengthening of the trapezius and the SA, which are scapular upward rotators, is further emphasized²².

Sánchez-Zuriaga et al.²³ stated that different postures did not result in different levels of muscle activation. On the other hand, Oliver et al.¹⁸ compared the levels of muscle activation of the UT when postures 1 and 3 were applied and reported higher levels of muscle activation in posture 1. This result, which differs from that of the present study, may be because, in posture 1, the location of the FB grip and exercises using the FB were set in medio-lateral directions. Arora et al.¹² reported that posture 3 showed higher levels of muscle activation in the anterior deltoid and the lumbo-sacral erector spinae than posture 2 did. This is a similar

result to that of the present study in terms of increases in muscle activation in posture 3; although, in the aforementioned study the authors assessed different muscles from those measured in the present study. A comparison of the levels of muscle activation according to exercise postures showed the following results: The UT showed 52.8%MVIC, 56.3%MVIC, and 61.0%MVIC in postures 1, 2, and 3, respectively. The MT exhibited 66.7%MVIC, 57.0%MVIC, and 74.3%MVIC in postures 1, 2, and 3, respectively. The SA showed 38.3%MVIC, 51.1%MVIC, and 67.5%MVIC in postures 1, 2, and 3, respectively. The higher levels of muscle activation shown in posture 3 than in postures 1 and 2 may be because the exercises were performed while the scapula was fixed rather than moving, and the activation of the SA increased to stabilize the scapula.

The results of the present study show higher levels of SA activation in postures that require stabilization of the scapula. As such, exercises with posture 3 may have induced high levels of muscle activation in the shoulder stabilizers, including the SA. Therefore, for treatment purposes, selective muscle strengthening exercises for specific shoulder stabilizers should be performed according to muscles. Nevertheless, this study has some limitations to be considered. The subjects of this study included a younger subset of males and females, and therefore, the results cannot be generalized for all age groups. In addition, the study could not effectively control compensatory actions such as lumbar lordosis, which could have been caused by the subjects not having sufficient time to adapt to their assignment during the FB exercises. In this regard, future studies should compare more postures with the activation of various muscles around the shoulder.

REFERENCES

- Hess SA: Functional stability of the glenohumeral joint. *Man Ther*, 2000, 5: 63–71. [Medline] [CrossRef]
- Lippitt S, Matsen F: Mechanisms of glenohumeral joint stability. *Clin Orthop Relat Res*, 1993, (291): 20–28. [Medline]
- Sahrmann S: *Diagnosis and treatment of movement impairment syndrome*. St. Louis: Mosby, 2002.
- Comerford MJ, Mottram SL: Functional stability re-training: principles and strategies for managing mechanical dysfunction. *Man Ther*, 2001, 6: 3–14. [Medline] [CrossRef]
- Magarey ME, Jones MA: Dynamic evaluation and early management of altered motor control around the shoulder complex. *Man Ther*, 2003, 8: 195–206. [Medline] [CrossRef]
- Ludewig PM, Cook TM: Alterations in shoulder kinematics and associated muscle activity in people with symptoms of shoulder impingement. *Phys Ther*, 2000, 80: 276–291. [Medline]
- Chang YW, Su FC, Wu HW, et al.: Optimum length of muscle contraction. *Clin Biomech (Bristol, Avon)*, 1999, 14: 537–542. [Medline] [CrossRef]
- Ludewig PM, Hoff MS, Osowski EE, et al.: Relative balance of serratus anterior and upper trapezius muscle activity during push-up exercises. *Am J Sports Med*, 2004, 32: 484–493. [Medline] [CrossRef]
- Bogaerts A, Verschueren S, Delecluse C, et al.: Effects of whole body vibration training on postural control in older individuals: a 1 year randomized controlled trial. *Gait Posture*, 2007, 26: 309–316. [Medline] [CrossRef]
- Schulte RA, Warner C: Oscillatory devices accelerate proprioception training. *Clin Biomech (Bristol, Avon)*, 2001, 6: 85–91.
- Kim JH, So KH, Bae YR, et al.: A comparison of flexi-bar and general lumbar stabilizing exercise effects on muscle activity and fatigue. *J Phys Ther Sci*, 2014, 26: 229–233. [Medline] [CrossRef]
- Arora S, Button DC, Basset FA, et al.: The effect of double versus single oscillating exercise devices on trunk and limb muscle activation. *Int J Sports Phys Ther*, 2013, 8: 370–380. [Medline]
- Lehman GJ, Gilas D, Patel U: An unstable support surface does not increase scapulothoracic stabilizing muscle activity during push up and push up plus exercises. *Man Ther*, 2008, 13: 500–506. [Medline] [CrossRef]
- De Mey K, Cagnie B, Danneels LA, et al.: Trapezius muscle timing during selected shoulder rehabilitation exercises. *J Orthop Sports Phys Ther*, 2009, 39: 743–752. [Medline] [CrossRef]
- Rothmuller C, Cafarelli E: Effect of vibration on antagonist muscle co-activation during progressive fatigue in humans. *J Physiol*, 1995, 485: 857–864. [Medline] [CrossRef]
- Kasai T, Kawanishi M, Yahagi S: The effects of wrist muscle vibration on human voluntary elbow flexion-extension movements. *Exp Brain Res*, 1992, 90: 217–220. [Medline] [CrossRef]
- Cohen LG, Starr A: Vibration and muscle contraction affect somatosensory evoked potentials. *Neurology*, 1985, 35: 691–698. [Medline] [CrossRef]
- Oliver GD, Sola M, Dougherty C, et al.: Quantitative examination of upper and lower extremity muscle activation during common shoulder rehabilitation exercises using the Bodyblade. *J Strength Cond Res*, 2013, 27: 2509–2517. [Medline] [CrossRef]
- Sugimoto D, Blanpied P: Flexible foil exercise and shoulder internal and external rotation strength. *J Athl Train*, 2006, 41: 280–285. [Medline]
- Lister JL, Del Rossi G, Ma F, et al.: Scapular stabilizer activity during Bodyblade, cuff weights, and Thera-Band use. *J Sport Rehabil*, 2007, 16: 50–67. [Medline]
- Eom MY, Chung SH, Ko TS: Effects of bridging exercise on different support surfaces on the transverse abdominis. *J Phys Ther Sci*, 2013, 25: 1343–1346. [Medline] [CrossRef]
- Ekstrom RA, Donatelli RA, Soderberg GL: Surface electromyographic analysis of exercises for the trapezius and serratus anterior muscles. *J Orthop Sports Phys Ther*, 2003, 33: 247–258. [Medline] [CrossRef]
- Sánchez-Zuriaga D, Vera-García FJ, Moreside JM, et al.: Trunk muscle activation patterns and spine kinematics when using an oscillating blade: influence of different postures and blade orientations. *Arch Phys Med Rehabil*, 2009, 90: 1055–1060. [Medline] [CrossRef]