The Effects of Sling Exercise Using Vibration on Trunk Muscle Activities of Healthy Adults

YOUNGIN CHOI, MSc, PT1), HYUNGKyu KANG, PhD, PT2)*

1) Department of Physical Therapy, the Graduate School, Hanseo University, Republic of Korea
2) Department of Physical Therapy, College of Natural Sciences, Kyungnam University: 449 Woryeong-dong, Masanappo-gu, Changwon-si, Gyeongsangnam-do 631-701, Republic of Korea

Abstract. [Purpose] This study compared the effects of sling exercises with and without vibration on the muscular activity of the internal oblique (IO), rectus abdominis (RA), multifidus (MF), and erector spinae (ES) muscles of healthy adults. [Methods] Eleven healthy university students (11 men) with a mean age of 22.8 years were enrolled in this study. Subjects performed supine and prone bridge exercises with the knees flexed using a sling suspension system with and without vibration. The amplitudes of the EMG activities of selected trunk muscles (internal oblique, rectus abdominis, erector spinae, multifidus) were recorded. Two types of exercise conditions were executed in a random sequence for 5 seconds each. The signals detected from the middle 3 seconds (after discarding the signals of the first and the last one seconds) were used in the analysis. A 3-minute break was given after each exercise to minimize muscle fatigue. [Results] During the supine bridge exercise with vibration, the activities of the IO, RA, MF, and ES muscles were significantly higher than those of the supine bridge exercise without vibration. Additionally, during the prone bridge exercise with vibration, the activities of the IO, RA, MF, and ES were significantly higher than those of the prone bridge exercise without vibration. [Conclusion] Sling exercises with vibration improved the trunk muscle activities of healthy adults compared to the sling exercises without vibration. The information presented here is important for clinicians who use lumbar stabilization exercises as an evaluation tool or a rehabilitation exercise.

Key words: Sling exercise, Vibration, Trunk muscle

INTRODUCTION

Stabilization exercises are exercise methods that focus on co-contraction of deep trunk muscles and improvement of spinal stability1). Stabilization exercises not only the improve strength and endurance of deep trunk muscles, but also have the effect of maintaining dynamic stability by improving neuromuscular control2). Consequently, they are used in a wide range of rehabilitation therapies for individuals with low back pain3–5). Coordination promotions between local and global muscles are necessary factors of efficient lumbar stabilization6). Activities of a single muscle do not systematically influence trunk stabilization6–9). Therefore, for an adequate level of stability maintenance, integration of local and global muscle is required10, 11).

Sling therapy is performed by suspending part of body in a sling12). It was reported that sling therapy has the advantage of facilitating exercise by decreasing the load on the body12, 13). Sling therapy also facilitates neuromuscular control of the extremities14). Vibratory stimulation can improve muscle contraction by stimulating muscle hypertrophy, thereby affecting the muscle spindles15). Type Ia af-

*To whom correspondence should be addressed.
E-mail: hhkkang@kyungnam.ac.kr

(This article was submitted Apr. 8, 2013, and was accepted May 20, 2013)
In this study, we measured trunk muscle activation in two sling exercises with and without vibration. A surface electromyography (sEMG) system (Telemyo 2400T-G2 Telemetry EMG system; Noraxon, USA) with disposable bipolar surface EMG electrodes and MyoResearch Master Edition 1.06 XP software were used for data collection. We used 4 active electrodes and a reference electrode. The maximum spacing between recording electrodes was 2.0 cm. The sampling frequency was 1,024 Hz. The raw data were band-pass filtered between 20 and 500 Hz and full-wave rectified by the analysis software. During each exercise with and without vibration, the root mean square was calculated over 3 seconds. For normalization, EMG signals were recorded during maximum voluntary isometric contraction (MVIC). The EMG signal of each muscle was measured for 5 seconds and the average value of the middle 3 seconds (excluding the first and last one seconds) was used in the analysis after normalization. EMG signals were recorded during maximum voluntary isometric contraction (MVIC). The EMG signal of each muscle was measured for 5 seconds and the average value of the middle 3 seconds (excluding the first and last one seconds) was used in the analysis after normalization to %MVIC. Surface EMG of the internal oblique (IO), rectus abdominis (RA), multifidus (MF), and erector spinae (ES) were measured on the subjects’ dominant side. Hair was removed from the measurement sites, and the skin was cleaned with alcohol before electrode placement to reduce skin impedance. The reference electrode was placed over the superior aspect of the left iliac crest. The electrode placement for the muscles was as follows: IO, midway between the anterior iliac spine and symphysis pubis and above the inguinal ligament; RA, 3 cm lateral to the umbilicus; MF, lateral to the midline of the body and above and below the line connecting both posterior superior iliac spines; ES, 2 cm lateral to the L2 level.

For the quantification of RA, IO, ES, MF muscles action potential, MVIC was measured. Measurement of MVIC was performed using the method of Daniels and Worthingham(7) and measurements lasting 5 seconds were performed 3 times. The maximum value of the 3-second signal excluding first and last one seconds was used.

Table 1. General characteristics of the subjects

| Gender | Age (years) | Height (cm) | Weight (kg) |
|--------|-------------|-------------|-------------|
| Subjects (n=11) | 11 males | 22.83 ± 1.65 | 173.67 ± 6.86 | 69.48 ± 14.55 |

All values are mean±standard deviation (SD).

Table 2. Comparison of trunk muscle activities during supine bridge exercise with and without vibration

|        | SBE (M ± SD) | SBEV (M ± SD) |
|--------|--------------|---------------|
| IO**   | 11.52 ± 9.25 | 17.90 ± 12.61 |
| RA*    | 2.46 ± 1.99  | 3.78 ± 3.12   |
| MF**   | 30.05 ± 5.13 | 36.53 ± 6.05  |
| ES**   | 24.87 ± 8.02 | 31.01 ± 8.56  |

All values are mean±SD. SBE: supine bridge exercise. SBEV: supine bridge exercise with vibration. * p<0.05, ** p<0.01

Table 3. Comparison of trunk muscle activities during prone bridge exercise with and without vibration

|        | PBE (M ± SD) | PBEV (M ± SD) |
|--------|--------------|---------------|
| IO*    | 37.04 ± 9.25 | 49.21 ± 22.65 |
| RA*    | 17.82 ± 12.81| 23.44 ± 16.00|
| MF**   | 12.53 ± 5.75 | 21.77 ± 18.01|
| ES*    | 9.49 ± 4.06  | 10.55 ± 5.15  |

All values are mean±SD. PBE: prone bridge exercise. PBEV: prone bridge exercise with vibration. * p<0.05, ** p<0.01

Two sling exercises were performed as follows. Supine bridge exercise with the knees flexed: Subjects had their heels suspended in sling in the supine position. With the palms on the ground, the shoulders in 30° abduction and the pelvis maintained in the neutral position, subjects raised their hips on the auditory cue “go”. When the flexion angle of both knees as measured by a goniometer was 90°, subjects maintained this position. Prone bridge exercise with the knees flexed: Subjects had their ankles suspended in slings in the prone position. They raised their hips on the auditory cue “go” and maintained the pelvis in the neutral position. When the flexion angle of both knees as measured by a goniometer was 90°, subjects maintained this position.

To get used to the exercise method, the subjects practiced after being given an explanation of how to perform the exercise. The exercises were performed in a random manner. Each exercise was performed 3 times. Measurements lasted for 5 seconds. The middle 3 seconds of data, after discarding the first and last one seconds, were used in the analysis. In order to minimize muscle fatigue, a 3-minute break was taken after each exercise. Manual vibration was applied for 5 seconds with amplitude with cord within 5 cm when expert physical therapist maintains exercise position. The SPSS 12.0 program was used for data analysis. Wilcoxon’s signed-rank test was used to compare the differences in trunk muscle activities of each sling exercise with and without vibration. The significance level was chosen as p<0.05.

RESULTS

The mean EMG amplitudes of the different trunk muscle activations during the supine bridge exercise with and without vibration are presented in Table 2. The mean EMG amplitudes of the different trunk muscle activations during the prone bridge exercise with and without vibration are presented in Table 3.

During the supine bridge exercise with vibration, the muscle activities of the IO, RA, MF, and ES were signifi-
cantly higher than those during the supine bridge exercise without vibration (p<0.05). Moreover, during the prone bridge exercise with vibration, the muscle activities of the IO, RA, MF, and ES were significantly higher than those during the prone bridge exercise without vibration (p<0.05).

**DISCUSSION**

Sling therapy is performed with the pelvis suspended in a sling. Since the load of gravity is reduced, subjects are better able to control the level of exercise, and can carry out the exercise to suit themselves for a more effective approach. The principle of the therapy is to carry out each treatment pain free, and in order to maintain balance, the stabilization muscles are activated according to the increase in physical demand. Many previous studies have provided empirical evidence that vibratory stimulation is effective for pain relief and enhancement of muscle activation. Pain relief occurs through the secretion of enkephalin from inhibitory interneurons, which are stimulated by vibration, which suppresses the pain. The enhancement of muscle activation occurs through effects on the muscle spindle system. The muscle spindle is contained in the muscular fiber and consists of two afferent and one efferent fiber. Not only is it sensitive to muscle stretch, but it also senses the γ-motor signal during contraction. The type Ia afferent fiber is connected in monosynaptic form to the motor neuron, which can change muscle contraction depending on the rate of firing, and due to the co-activation of alpha-gamma motor neurons, type Ia fibers can be aroused even during isometric contraction.

Therefore, when doing sling exercises, the added vibratory stimulation increases the firing rate of type Ia fibers and allows additional muscle contraction.

Sling therapy and vibratory stimulation are recognized as effective methods of physical muscle activation; however, previous research has experienced difficulties in reproducing effects induced in clinical practice by mechanical vibration. This study was carried out to test what effect vibration has on trunk muscles during sling exercise. Rolands et al. carried out a study with 15 healthy adults. They measured their leg muscle activation in three different squat postures, with and without the application of vibration. Vibration increased leg muscle activation in all of the postures. Another study showed that resistance exercise using heavy load with vibration is effective for decrease of the muscle atrophy generating by a bet rest during a long time. Bosco et al. proposed that vibratory stimulation has a positive influence on the power of the upper limbs of boxers. The present study showed that during each exercise, vibration stimulation significantly enhanced the activation of all the trunk muscles. Therefore, manual vibration has a better intervention effect in clinical practice, rather than mechanical vibration. In addition, the present study used bridging exercises with the knees flexed, and compared to the typical bridging posture, as performed in a study by Stenvens, we showed that the multifidus, internal abdominal oblique and abdominal rectus muscles were much more activated. Compared with Lehman’s research, there was a difference of activation in the internal abdominal oblique and erector spine muscles. Therefore, the exercise in the bridging posture with the knees bent and vibratory stimulation enables the trunk muscles to be effectively activated and is a method proposed to patients suffering back pains for mediation.

A limitation of this study was the use of surface EMG to measure the activity of the multifidus muscle. Also, the effect of the movement of muscles on the EMG signals, due to the, could not be eliminated. In addition, the lack of kinematics equipment made it difficult to control the spinal posture, and there could have been additional effects, because the frequency of vibration was not consistent. Therefore, in further studies, the vibratory stimulation and spine posture need to be controlled and during sling exercise, the effect of vibration duration on the activity ratio of the trunk muscles should be researched.

**REFERENCES**

1. Richardson CA, Jull GA: Muscle control-pain control what exercises would you prescribe? Man Ther, 1995, 1: 2–10. [Medline] [CrossRef]
2. Standaert CJ, Weinstein SM, Rumpeljes J: Evidence-informed management of chronic low back pain with lumbar stabilization exercises. Spine J, 2008, 8: 114–120. [Medline] [CrossRef]
3. Lienohw WP, Baumgartner TA, Gagnon LH: Measuring core stability. J Strength Cond Res, 2005, 19: 583–586. [Medline]
4. Hamlyn N, Behm DG, Young WB: Trunk muscle activation during dynamic weight training exercises and isometric in stability activities. J Strength Cond Res, 2007, 21: 1108–1112. [Medline]
5. Willardson JM: Core stability training: applications to sports conditioning programs. J Strength Cond Res, 2007, 21: 979–985. [Medline]
6. Marshall PW, Murphy BA: Core stability exercises on and off a swissball. Arch Phys Med Rehabil, 2005, 86: 242–249. [Medline] [CrossRef]
7. Cholewicki J, VanVliet JI: Relative contribution of trunk muscles to the stability of the lumbar spine during isometric exertions. Clin Biomech (Bristol, Avon), 2002, 17: 99–105. [Medline] [CrossRef]
8. Stevens VK, Boucke KG, Mahieu NN, et al.: Trunk muscle activity in healthy subjects during bridging stabilization exercises. BMC Musculoskelet Disord, 2006, 7: 75–82. [Medline] [CrossRef]
9. Stokes IA, Gardner-Morse MG, Henry SM: Abdominal muscle activation increases lumbar spinal stability: analysis of contributions of different muscle groups. Clin Biomech (Bristol, Avon), 2011, 26: 797–803. [Medline] [CrossRef]
10. Arokoski JP, Kankaanpää M, Valta T, et al.: Back and hip extensors or muscle function during therapeutic exercises. Arch Phys Med Rehabil, 1999, 80: 842–850. [Medline] [CrossRef]
11. Kibler WB: The role of core stability in athletic function. Sports Med, 2006, 36: 189–198. [Medline] [CrossRef]
12. Saliba SA, Croy T, Guthrie R, et al.: Differences in transverse abdominis activation with stable and unstable bridging exercises in individuals with low back pain. N Am J Sports Phys Ther, 2010, 5: 63–73. [Medline]
13. Kirsnesloa G: Neurac –a new treatment method for long-term musculoskeletal pain. J Fysioterapeut, 2009, 76: 16–25.
14. Vikne J, Oedegaard A, Laerun E, et al.: A randomized study of new sling exercise treatment vs traditional physiotherapy for patients with chronic whiplash-associated disorders with unsettled compensation claims. J Rehabil Med, 2007, 39: 252–259. [Medline] [CrossRef]
15. Gojanovica B, Feihlb F, Liaudetb L, et al.: Whole body vibration training elevates creatine kinase levels in sedentary subjects. Swiss Med Wkly, 2011, 141: 1–5.
16. Mikhael M, Orr R, Amsen F, et al.: Effect of standing posture during whole body vibration training on muscle morphology and function in older adults: a randomised controlled trial. BMC Geriatr, 2010, 10: 74–96. [Medline] [CrossRef]
17. Hislop H, Montgomery J: Daniels and Worthingham’s Muscle Testing: Techniques of Manual Examination. St. Louis: Elsevier Saunders, 2007.
18. Liunggren AE, Weber H, Kogstad O, et al.: Effect of exercise on sick leave due to low back pain: a randomized, comparative, long-term study. Spine, 1997, 22: 1610. [Medline] [CrossRef]
19. Rolands M, Verschueren SM, Delecluse C, et al.: Whole body vibration
induced increase in leg muscle activity during different squat exercises. J Strength Cond Res, 2006, 20: 124–129. [Medline]
20) Belavý DL, Miskovic T, Arnbrecht G, et al.: Resistive vibration exercise reduces lower limb muscle atrophy during 56-day bed-rest. J Musculoskeletal Neuronal Interact, 2009, 9: 225–235. [Medline]
21) Lundy-Ekman L: Neuroscience fundamentals for rehabilitation, 3rd ed. Saunders, 2007, p 144.
22) Burke D, Hagbarth KE, Lofstedt L, et al.: The responses of human muscle spindle endings to vibration of non-contracting muscles. J Physiol, 1976, 261: 673–693. [Medline]
23) Ushiyama J, Masani K, Kouzaki M, et al.: Difference in aftereffects following prolonged achilles tendon vibration on muscle activity during maximal voluntary contraction among plantar flexor synergists. J Appl Physiol, 2005, 98: 1427–1433. [Medline] [CrossRef]
24) Bosco C, Cardinale M, Tsarpela O: Influence of vibration on mechanical power and electromyogram activity in human arm flexor muscles. Eur J Appl Physiol Occup Physiol, 1999, 79: 306–311. [Medline] [CrossRef]
25) Lehman GJ, Hoda W, Oliver S: Trunk muscle activity during bridging exercises on and off a swissball. Chiropr Osteopat, 2005, 13: 14–21. [Medline] [CrossRef]