한국전문물리치료학회지 제 16권 제 4호
PTK Vol. 16 No. 4 2009.

# EMG Activities of Trunk and Lower Extremity Muscles Induced by Different Intensity of Whole Body Vibration During Bridging Exercise

**Tack-hoon Kim, Ph.D., P.T.**
**Houng-sik Choi, Ph.D., P.T.**
Dept. of Physical Therapy, Hanseo University

## Abstract

The purpose of this study was to investigate the trunk and lower extremity muscle activity induced by three different intensity conditions (intensity 1, 3, 5) of whole body vibration (WBV) during bridging exercise. Surface electromyography (EMG) was used to measure trunk and lower extremity muscles activity. Eleven healthy young subjects (6 males, 5 females) were recruited from university students. The collected EMG data were normalized using reference contraction (no vibration during bridging) and expressed as a percentage of reference voluntary contraction. To analyze the differences in EMG data, the repeated one-way analysis of variance was used. A Bonferroni's correction was used for multiple comparisons. The study showed that EMG activity of the rectus abdominis, external oblique, internal oblique, erector spinae and rectus femoris muscles was not significantly different among three intensity conditions of WBV during bridging exercise ($p>.05$). However, there were significantly increased EMG activity of the medial hamstring muscle ($p=.001$) and medial gastrocnemius muscle ($p=.027$) in the intensity 3 condition compared with the intensity 1 condition This result can be interpreted that vibration was absorbed through the distal muscles, plantar flexor and knee flexor.

**Key Words:** Bridging exercise; Electromyography; Vibration intensity; Whole body vibration.

### Introduction

Trunk muscle co-activation is considered necessary in achieving adequate spinal stability to prevent and treat low back injury (Axler and McGill, 1997). Vera-Garcia et al (2000) reported that performing curl-ups on a labile surface changed the muscle activity amplitude required to perform the movement. Trunk bridging exercises are often used as therapeutic exercises for lumbopelvic stabilization. Lehman et al (2005) suggested that performing bridging exercise on a Swiss ball rather than the ground resulted in increases in trunk muscle activity. During three bridging exercises (single bridging, ball bridging and unilateral bridging), the ratio of the internal oblique to the rectus abdominis was high due to relatively decreased activity of the rectus abdominis (Stevens et al, 2006). Stevens et al (2007) reported that local internal oblique abdominal muscle was increased on both sides during bridging exercises and after training the activity of the rectus abdominis was significantly higher during the symmetric bridging exercises.

The vibration exercise platform, which vibrates between 1 and 50 ㎐, was originally developed by biomechanical engineer in Europe for use in the space program to prevent bone density changes in astronauts. Recently, whole body vibration (WBV) has emerged as an alternative strength training intervention, with gains reported to be comparable to resistive training in young adults who were healthy (Delecluse et al, 2003). WBV training might potentially be useful to enhance balance. The subject performs exercises on a platform that generates vertical sinusoidal vibrations. The mechanical stimuli are

Corresponding author: Houng-sik Choi *hschoi@hanseo.ac.kr*

transmitted to the body where they stimulate the primary endings of the muscle spindles which in turn activate alpha-motor neuron resulting in muscle contraction (Burke and Schiller, 1976; Hagbarth and Eklund, 1966). Previous studies have shown that WBV has been promoted as a strength training intervention because it could increase motor activity of the lower limbs through reflex-induced muscle contraction (Cardinale and Lim, 2003; Roelants et al, 2006). In most cases, vibration has been shown to positively influence maximal strength and force output (Bosco et al, 1999; Warman et al, 2002), power output (Bosco et al, 1998; 1999; 2000). WBV was reported to improve vertical jump height (Cochrane and Stannard 2005; Torvinen et al, 2002) and muscular contractile properties (van den Tillaar, 2006) in healthy young subjects as well as to increase strength in the elderly (Roelants et al, 2004; Roelants et al, 2006; Verschueren et al, 2004). Additionally, WBV was shown to positively influence the postural control and mobility in multiple sclerosis (Schuhfried et al, 2005) and unilateral chronic stroke patients (van Nes et al, 2004). Cheung et al (2007) reported that despite the benefits on muscular performance, the efficacy of WBV on balancing ability is still uncertain which may be dependent of age and physical condition.

Trans et al (2009) show that the WBV exercise regime (25~30 ㎐) on a stable platform yielded increased muscle strength, while the WBV exercise on a balance board showed improved proprioception. The WBV is time-saving and safe method for rehabilitation of women with knee osteoarthritis. Fontana et al (2005) reported that WBV may induce improvements in lumbosacral repositioning accuracy when combined with a weight bearing exercise. Incorporating vibration exercise into treatment needs to be developed with caution, as prolonged high frequency vibration is known to have detrimental effects on muscles, most particularly increasing fatigue (Bongiovanni et al, 1990), and causing, in some circumstances, disturbances in proprioception (Brumagne et al, 1999; Ribot-Cisar et al, 1998; Rogers et al, 1985).

Harazin and Grezesik (1998) found that the vibration magnitudes being transmitted by the hip, shoulder and head decreased with an increase in frequency above 16~20 ㎐. Crewther et al (2004) investigated gravitational forces and WBV. Gravitational force associated with semi-squat (2.34 g) was significantly greater than the standing postures. Significant damping was observed as the vibratory stimulation was transmitted to the proximal segment. Findings were discussed in terms of safe, progressive and effective prescription of vibratory stimulation.

There are numerous studies on trunk stability exercises on unstable surfaces using a Swill ball, and studies using a WBV were undertaken in standing or squat position. Study using a WBV during bridging was not found in the literature and proper vibration intensity was not studied during bridging exercise. Therefore the effect of bridging exercise and vibration intensity using a WBV on trunk and lower extremity muscle activity during bridging was investigated in this study.

## Methods

### Subjects

Eleven healthy young subjects (6 males, 5 females) were recruited from Hanseo University in Korea. The subjects without intense physical activities or muscle damages within two weeks before the beginning of the study participated. The subjects had a mean age of 22.4±1.7 years, a mean height of 171.7±5.9 ㎝, a mean weight of 64.7±10.0 ㎏, and a mean body mass index of 21.9±2.5 ㎏/㎡ (Table 1). Before the study, the principal investigator explained all the procedures to the subjects in detail.

Table 1. Characteristics of the subjects (N=11)

| Subjects | Age (yrs) | Height (㎝) | Weight (㎏) | BMI |
|---|---|---|---|---|
| 6 males | 23.8±.41[a] | 176.3±2.5 | 71.7±6.2 | 23.1±2.4 |
| 5 females | 20.6±.54 | 166.2±3.1 | 56.4±6.8 | 20.4±1.9 |

[a]Mean±SD.

### Surface Electromyographic Recording

We collected and amplified electromyographic data using a Biopac MP100A System[1]. The skin was prepared by shaving hair and rubbing the skin with an alcohol-water solution to decrease impedance. Surface electrode pairs were placed in a bipolar configuration over the seven muscle sites, and distance between two electrodes were 2 ㎝. The seven sites on the dominant side were as follows: 1) the rectus abdominis (RA) muscle, 2 ㎝ lateral to the umbilicus, 2) the external oblique (EO) muscle, halfway between the anterior superior iliac spine (ASIS) and the inferior border of the ribcage at a slightly oblique angle running parallel with the underlying muscle fibers, 3) the internal oblique abdominal (IO) muscle, approximately 2 ㎝ medial and inferior to the right anterior superior iliac spine, 4) the erector spinae (ES) muscles placed half the distance between the greater trochanter and the sacral vertebrae in the middle of the muscle on an oblique angle at the level of the trochanter or slightly above, 5) the rectus femoris (RA) placed the anterior aspect of the thigh, midway between the superior border of the patella and the anterior superior iliac spine, 6) the medial hamstring muscle (MH), the midway on a line between the medial epicondyle of the femur and the ischial tuberosity, and 7) the medial gastrocnemius (MG) muscle, one hand breadth below the popliteal crease on the medial mass of the calf (Cram et al, 1998; Perotto, 1996). The bandpass filter of 80∼250 ㎐ was used, and data were converted to digital data at a sampling rate of 1000 ㎐. The EMG data was processed into the root mean square (RMS) using a windows of 300 ㎳ data points. For a normalization, reference contraction (no vibration during bridging) was used and EMG data were expressed as a percentage of reference voluntary contraction (%RVC).

### Whole Body Vibration (WBV)

Intensity for WBV consisted of 15 levels (15 level: 1,200 vibrations per minute). The maximal amplitude was 15.4 ㎜. In this study, stage 1, 3, and 5 was chosen for the experiment.

### Procedures

Subjects was positioned in lying supine on the floor with their feet on the WBV platform[2], knees bent 90 degrees, toes facing forward and hands on the floor by their sides, palms facing down. Subjects lifted their pelvis off the ground and pushed through the feet to assume a bridging posture (Figure 1). Feedback from instructor was given in order to achieve a consistent trunk and lower limb posture during each 4 condition (0, 1, 3, 5 intensity). Subjects was aimed to keep their spines neutral position with their leg parallel to their trunk during bridging. EMG data were collected for 5 seconds during the isometric portion of each different intensity condition during bridging posture with their feet on the WBV platform. Three trials of each of these exercise were recorded.

**Figure 1.** Supine bridging exercise on the WBV platform.

### Statistical Analysis

All data were expressed as the mean and standard deviation. To analyze the differences in EMG data, the repeated one-way analysis of variance was used. A Bonferroni's correction was used for multiple comparisons. The analysis of data was performed using SPSS version 12.0 program and significant level set at $\alpha$=.05.

1) MP100A-CE, Biopac System Inc., Goleta, CA, U.S.A.
2) BBSliner, SECO Inc, Bucheon, Korea.

## Results

The study demonstrated that EMG activity of the RA, EO, IO, ES and RF muscles did not show significant difference among three different intensity conditions of WBV during bridging exercise (p>.05). However, there were significantly increased EMG activity of the MH (p=.001) and MG (p=.027) in the intensity 3 condition compared with the intensity 1 condition (Table 2) (Figure 2).

## Discussion

The study indicated that there were no significant differences in EMG activity of the RA, EO, IO, ES and RF muscles between three intensity condition of WBV during bridging exercise (p>.05).

Stevens et al (2007) reported that IO muscle was increased on both sides during bridging exercises and after training, the activity of the RA was significantly higher during the symmetric bridging exercises. However, those studies showed that EMG activity of the RA, IO, EO, and ES muscle were not significantly different between the bridging in supine position condition and ball bridging condition after training. Lehman et al (2005) showed that EMG activity of the RA, EO, IO, and ES muscles were not significantly different during bridging between on the floor and on the ball. However, Kim (2009) reported that the IO, EO, and ES with feet on ball bridging and calf on ball bridging exercise showed significantly higher

**Table 2.** Comparison of the %RVC of the muscles intensity induced on WBV during bridging exercise (N=11)

| Muscles | Intensity 1 | Intensity 3 | Intensity 5 | F |
|---|---|---|---|---|
| Rectus abdominis | 122.61±29.46[a] | 128.81±75.94 | 132.11±89.58 | 2.326 |
| External oblique | 100.60±40.63 | 118.06±35.24 | 115.53±60.15 | 1.530 |
| Internal oblique | 113.53±16.25 | 119.01±27.02 | 114.58±21.55 | 2.345 |
| Erector spinae | 96.83±10.00 | 96.63±11.22 | 102.88±16.14 | 1.279 |
| Rectus femoris | 119.39±31.94 | 133.98±53.36 | 184.84±114.83 | 1.663 |
| Medial hamstring | 90.37±13.60 | 106.29±14.04 | 110.85±34.41 | 16.223* |
| Medial gastrocnemius | 101.32±15.45 | 128.26±33.16 | 143.26±50.87 | 5.522* |

[a]Mean±SD.
*p<.05.

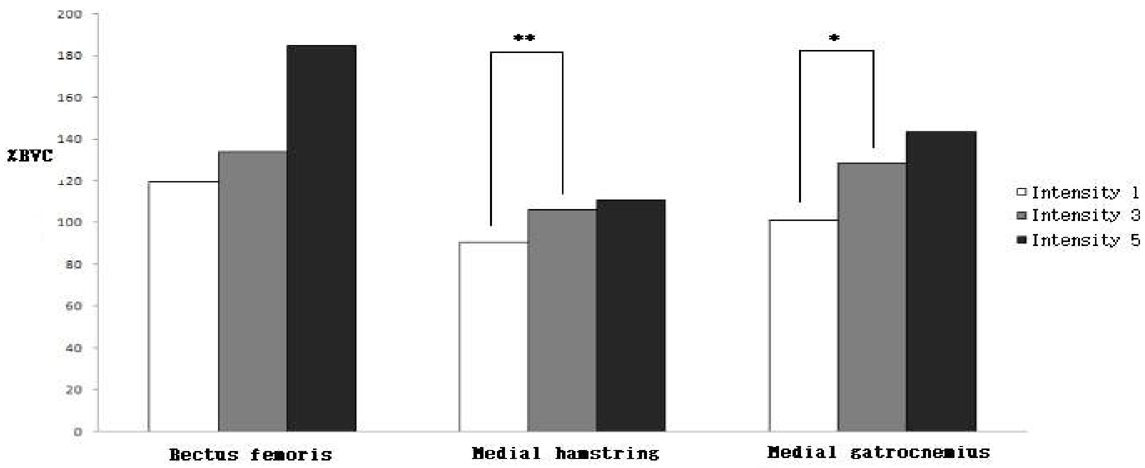


**Figure 2.** The %RVC data of the lower extremity muscles between different 3 intensity condition of WBV during bridging posture (*p<.05, **p<.01).

muscle activity than the floor bridging exercise.

Lifting one leg in supine position requires cocontraction between abdominal and trunk muscle and is used for trunk stabilizing exercise because it prevents trunk and pelvic rotation and maintains vertebral neutral position (Barnett and Gilleard, 2005; Hubley-Kozey and Vizina, 2002; O'Sullivan, 2000). Trunk rotation is controlled by internal oblique, external oblique, and transverse abdominals that runs obliquely or transversely than rectus abdominals that runs longitudinally (Hall and Brody, 1999; Neumann, 2002). This study utilized left-right vibration by WBV during bridging with both feet fixed. Therefore trunk rotation was less than one leg lifting so that no difference in trunk muscle activity was observed.

There were significantly increased EMG activity of the MH (p=.001) and MG (p=.027) in the intensity 3 than those in intensity 1 condition (Table2) (Figure 2). Rees et al (2008) suggested that average strength gains following eight weeks of WBV training were larger for ankle plantar flexors than for knee and hip flexors and extensors. WBV induced larger gains in ankle plantar flexor strength than in more proximal leg musculature. This result is in accordance with research findings of Blottner et al (2006) demonstrating that vibration applied at the foot predominantly recruits the calf musculature to dampen the stimulus. WBV can stimulate a number of muscle groups of the lower body at the same time. However, the muscle group closer to the vibration platform will attenuate more of the vibration stimulus than proximal muscles of the leg (Roelants et al, 2006).

Safety consideration is more important in vibration training than traditional training. This is because too strong vibrations would lead to various damaging effects to the body, ranging from headache to internal bleeding or even death. Particular care should be taken for the head (Mester et al, 2005). High transmission factor to the head should always be avoided. Thus, the frequencies used in vibration training should not be lower than 20 ㎐. Crewther et al (2004) suggested, in general, vibration should be applied with frequencies of 25~50 ㎐ and amplitude ranging from 1 to 10 ㎜, resulting in gravitational forces of 3~7 g.

As vibration frequency increased during WBV in our study, the trunk muscle activity did not show significant differences. This result can be interpreted that vibration was absorbed through the distal muscles, plantar flexor and knee flexor.

In this study, the effect of stability exercise was investigated by inducing trunk instability with different vibration intensity during bridging. There was no significant trunk muscle activity difference with three different vibration intensity. However, MH and MG showed significant difference with increasing vibration intensity. As shown by Rees et al (2008), it was determined that distal muscles, especially plantar flexors was activated. Future studies are required using various vibration intensity and including trunk instability such as one leg lifting in bridging during WBV. Because muscle activity was measured only in dominant lower extremity, the change of muscle activity in non-dominant lower extremity was not determined. Muscle activity was collected for five second period so that muscle activity in one vibration cycle was not assessed. These limitations should be considered in future studies.

## Conclusion

This study compared EMG activity of trunk and lower extremity muscles according to 3 different intensity conditions (1, 3, 5 intensity) of WBV during bridging. We found that EMG activity of the trunk muscles (RA, EO, IO, ES and RF) did not show significant differences among three intensity conditions of WBV during bridging exercise. However, there were significantly increased EMG activity of the lower extremity muscle (MH and MG) of the intensity 3 than those in intensity 1 condition. As vibration frequency decreased during WBV in our study, the trunk muscle activity did not show significant differences. This result can be interpreted that vibration was absorbed through the distal muscles, plantar flexor and knee flexor. Future studies are required using various vibration intensity and including trunk instability such as one leg lifting in bridging during WBV.

## References

Axler CT, McGill SM. Low back loads over a variety of abdominal exercises: Searching for the safest abdominal challenge. Med Sci Sports Exerc. 1997 ;29(6):804-811.

Barnett F, Gilleard W. The use of lumbar spinal stabilization techniques during the performance of abdominal strengthening exercise variations. J Sports Med Phys Fitness. 2005;45(1):38-43.

Blottner D, Salanova M, Püttmann B, et al. Human skeletal muscle structure and function preserved by vibration muscle exercise following 55 days of bed rest. Eur J Appl Physiol. 2006;97(3):261-271.

Bongiovanni LG, Hagbarth KE, Stjernberg L. Prolonged muscle vibration reducing motor output in maximal voluntary contractions in man. J Physiol. 1990;423:15-26.

Bosco C, Colli R, Cardinale M, et al. The effect of whole body vibration on mechanical behaviour of skeletal muscle and hormonal profile, IN: Musculo-Skeletal Interations, 1998.

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(4):306-311.

Bosco C, Iacovelli M, Tsarpela O, et al. Hormonal responses to whole-body vibration in men. Eur J Appl Physiol. 2000;81(6):449-454.

Brumagne S, Lysens R, Swinnen S, et al. Effect of paraspinal muscle vibration on position sense of the lumbosacral spine. Spine. 1999;24(13):1328-1331.

Burke D, Schiller HH. Discharge pattern of single motor units in the tonic vibration reflex of human triceps surae. J Neurol Neurosurg Psychiatry. 1976;39(8):729-741.

Cardinale M, Lim J. Electromyography activity of vastus lateralis muscle during whole-body vibrations of different frequencies. J Strength Cond Res. 2003;17(3):621-624.

Cheung WH, Mok HW, Qin L, et al. High-frequency whole-body vibration improves balancing ability in elderly women. Arch Phys Med Rehabil. 2007;88(7):852-857.

Cochrane DJ, Stannard SR. Acute whole body vibration training increases vertical jump and flexibility performance in elite female field hockey players. Br J Sports Med. 2005;39(11):860-865.

Cram JR, Kasman GS, Holtz J. Introduction to Surface Electromyography. Gaithersburg, An Aspen Pub, 1998.

Crewther B, Cronin J, Keogh J. Gravitional forces and whole body vibration: Implications for prescription of vibratory stimulation. Physical Therapy in sport. 2004;5(1):37-43.

Delecluse C, Roelants M, Verschueren S. Strength increase after whole-body vibration compared with resistance training. Med Sci Sports Exerc. 2003;35(6):1033-1041.

Fontana TL, Richardson CA, Stanton WR. The effect of weight-bearing exercise with low frequency, whole body vibration on lumbosacral proprioception: A pilot study on normal subjects. Aust J Physiother. 2005;51(4):259-263.

Hall CM, Brody LT. Therapeutic Exercise: Moving toward function. 1st ed. Philadelphia, Lippincott Williams and Wilkins, 1999.

Hagbarth KE, Eklund G. Tonic vibration reflexes (TVR) in spasticity. Brain Res. 1966;2(2):201-203.

Harazin B, Grzesik J. The transmittion of vertical whole-body vibration to the body segments of standing subjects. Journal of Sound and Vibration. 1998;215(4):775-787.

Hubley-Kozey CL, Vezina MJ. Muscle activation during exercises to improve trunk stability in men with low back pain. Arch Phys Med Rehabil. 2002;83(8):1100-1108.

Kim MJ. Effect of bridging stabilization exercise on trunk muscle activity on and off a Swiss ball. Physical Therapy Korea. 2009;16(1):18-24.

Lehman GJ, Hoda W, Oliver S. Trunk muscle activity during bridging exercises on and off a Swiss ball. Chiropr Osteopat. 2005;13:14.

Mester J, Kleinöder H, Yue Z. Vibration training: Benefits and risks. J Biomech. 2006;39(6):1056-1065.

Neumann DA. Kinesiology of the Musculoskeletal System. 1st ed. St. Louis, Mosby, 2002.

O'Sullivan PB. Lumbar segmental 'instability': Clinical presentation and specific stabilizing exercise management. Man Ther. 2000;5(1):2-12.

Perotto A. Anatomical Guide for the Electromyographer: The limbs and trunk. 3rd ed. Springfield, Thomas, 1996.

Rees SS, Murphy AJ, Watsford ML. Effects of whole-body vibration exercise on lower-extremity muscle strength and power in an older population: A randomized clinical trial. Phys Ther. 2008;88(4):462-470.

Ribot-Ciscar E, Rossi-Durand C, Roll JP. Muscle spindle activity following muscle tendon vibration in man. Neurosci Lett. 1998;258(3):147-150.

Roelants M, Delecluse C, Verschueren SM. Whole-body-vibration training increases knee-extension strength and speed of movement in older women. J Am Geriatr Soc. 2004;52(6):901-908.

Roelants 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(1):124-129.

Rogers DK, Bendrups AP, Lewis MM. Disturbed proprioception following a period of muscle vibration in humans. Neurosci Lett. 1985;57(2):147-152.

Schuhfried O, Mittermaier C, Jovanovic T, et al. Effects of whole-body vibration in patients with multiple sclerosis: A pilot study. Clin Rehabil. 2005;19(8):834-842.

Stevens VK, Bouche KG, Mahieu NN, et al. Trunk muscle activity in healthy subjects during bridging stabilization exercises. BMC Musculoskelet Disord. 2006;7:75.

Stevens VK, Coorevits PL, Bouche KG, et al. The influence of specific training on trunk muscle recruitment patterns in healthy subjects during stabilization exercises. Man Ther. 2007;12(3):271-279.

Torvinen S, Kannus P, Sievänen H. Effect of four-month vertical whole body vibration on performance and balance. Med Sci Sports Exerc. 2002;34(9):1523-1528.

Trans T, Aaboe J, Henriksen M, et al. Effect of whole body vibration exercise on muscle strength and proprioception in females with knee osteoarthritis. Knee. 2009;16(4):256-261.

van den Tillaar R. Will whole-body vibration training help increase the range of motion of the hamstrings? J Strength Cond Res. 2006;20(1):192-196.

van Nes IJ, Geurts AC, Hendricks HT, et al. Short-term effects of whole-body vibration on postural control in unilateral chronic stroke patients: Preliminary evidence. Am J Phys Med Rehabil. 2004;83(11):867-873.

Vera-Garcia FJ, Grenier SG, McGill SM. Abdominal muscle response during curl-ups on both stable and labile surfaces. Phys Ther. 2000;80(6):564-569.

Verschueren SM, Roelants M, Delecluse C, et al. Effect of 6-month whole body vibration training on hip density, muscle strength, and postural control in postmenopausal women: A randomized controlled pilot study. J Bone Miner Res. 2004;19(3):352-359.

Warman G, Humphries B, Purton J. The effects of timing and application of vibration on muscular contractions. Aviat Space Environ Med. 2002;73(2):119-127.

This article was received October 2, 2009, and was accepted November 3, 2009.