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Eletromyographic Activities of Trunk and Lower Extremity Muscles During Bridging Exercise in Whole Body Vibration and Swiss Ball Condition in Elderly Women

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Abstract

The purpose of this study was to compare the trunk and lower extremity muscle activity induced by six different conditions floor, intensity 0, 1, 3, 5 of whole body vibration (WBV), and Swiss ball during bridging exercise. Surface electromyography (EMG) was used to measure trunk and lower extremity muscles activity. Ten elderly women were recruited from Hong-sung Senior Citizen Welfare Center. The collected EMG data were normalized using reference contraction (during floor bridging) and expressed as a percentage of reference voluntary contraction (%RVC). 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 abdominis muscles were not significantly different between six different conditions of during bridging exercise ($p>.05$). However, there were significantly increased EMG activity of the rectus femoris ($p=.034$) in the WBV intensity 0, 1, 3, and 5 conditions compared with the floor bridging condition. EMG activity of the medial gastrocnemius were significantly increased in the WBV intensity 0, 1, 3, 5 and Swiss ball conditions compared with the floor bridging condition. Future studies are required the dynamic instability condition such as one leg lifting in bridging.

Key Words: Bridging exercise; Elderly; Electromyography; Swiss ball; Whole body vibration.

Introduction

Spinal stability can be enhanced by facilitating a co-contraction of the muscle surrounding the lumbar spine (Richardson et al, 1990). The stabilization exercises have been designed enhance to neuromuscular control system and correct the dysfunction (Noris, 2000; Richardson et al, 1999).

Klein-Vogelbach (1990) began using balls for postural training and exercise to increase mobility and stability of the spine and extremities. The term 'Swiss ball' probably originated from American physiotherapist who had learned about Klein-Vogelbach's teaching of ball exercises when working or studying in Europe (Carrière, 1999). Swiss balls are inflatable vinyl balls of various size and are commonly employed in physical therapy and athletic conditioning setting core stability. However, empirical data to support the claims made by clinicians, trainers and users of Swiss balls are lacking. Data from Swiss ball studies conducted thus far indicate greater activation of the abdominal musculature, when compared to other forms of abdominal training.

Lehman et al (2005) suggested that modifying trunk muscle activity could be important in the safety and efficacy of rehabilitation exercises when a low level of trunk muscle activity is desired. He was performing bridging exercise on a Swiss ball rather than the ground resulted in increases in trunk muscle activity.

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Several studies (Bosco et al, 1999; Cardinale and Lim, 2003; Roelants et al, 2006) have shown that the application of vibration increased muscle electromyographic activity to a much greater degree than the same activity without vibration. Controlled whole body vibration is a type of physical therapy thought to activate muscle via reflexes (Rittweger et al, 2000). Clinical studies suggest that controlled mechanical WBV may improve muscular performance (Bosco et al, 2000; Issurin and Tenenbaum, 1999; Torvinen et al, 2002a) and body balance in young healthy adults (Torvinen et al, 2002b). The subject performed exercises on a platform that generates vertical sinusoidal vibrations. The mechanical stimuli are 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). Importantly, the acute physiologic reponses to WBV have been investigated in the young but no adult. One might speculate that the responses to WBV are mitigated in older people (Cochrane et al, 2008).

Advancing age is associated with impaired postural stability due to deficits in sensory function, central processing, and neural pathways for motor control and musculoskeletal integrity (Horak et al, 1989). Research suggested that aging and disuse attenuates motorneuron excitability and causes structural changes to the muscle spindle (Scaglioni et al, 2002; Józsa et al, 1988). Therefore, the muscle spindle more in older individuals may be less sensitive to the vibration because of fiber composition and reflex deterioration that occurs with natural aging (Lexell, 1997; Liu et al, 2005). But, the elderly are possible beneficiaries of WBV because they have poor muscular performance and low bone quality (Hung et al, 2005; Leung et al, 2004; Qin, 2002). Bruyere et al (2005) reported that short training sessions using controlled WBV 3 times a week for 6 weeks improved gait, body balance, motor capacity in elderly nursing home residents. Rees et al (2008) shown that 8 weeks of WBV training produced a significant improvement in plantar-flexor strength and power for a group of older adults who a healthy. Despite the benefit on muscular performance, the efficacy of WBV on balancing ability is still uncertain, which may be dependent of age, physical conditions (Cheung et al, 2007).

The mechanism responsible for WBV benefit is not conclusive (Cardinale and Rittweger, 2006; Cardinale and Wakeling, 2005). Madau and Cronin (2008) reviewed that neurologic patients and the elderly, WBV seems to have positive effects. Based on this review, WBV has proven to have more beneficial effects on balance, stability, gait, muscle strength, physical and physiological properties as compared with conventional treatment (resistance training and physiotherapy). Exposure to WBV reported that to have negative effects on the human body (Chen et al, 2005; Jordan et al, 2005; Sherwin et al, 2004a; 2004b). 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. Kim and Choi (2009) compared that the trunk and lower extremity muscle activity induced by three different WBV intensity during bridging exercise. This study showed that EMG activity of the trunk muscles between three different intensity conditions of WBV during bridging exercise. However, lower extremity muscles were significantly increased EMG activity high intensity condition. This result can be interpreted that vibration was absorbed through the distal muscles, plantar flexor and knee flexor.

There are many studies on trunk stability exercises on unstable surfaces using a Swill ball, and studies using a WBV was undertaken in the standing or the squat position. Studies using a WBV and Swiss ball during bridging with elderly was not found in the literature as well as 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 on Swiss ball and WBV in elderly women was investigated in this study.

Methods

Subjects

Ten healthy elderly subjects (10 females) were recruited from Hong-sung Senior Citizen Welfare Center. Exclusion criteria were disease or medication known to affect bone metabolism or muscle strength. People suffering from diabetics, serious heart conditions were also excluded from the study. The subject had a mean age of 71.2±3.9 (range 63∼76) years, a mean height of 153.5±4.6 ㎝, a mean weight of 56.1±3.4 ㎏, and a mean body mass index of 23.8±1.2 ㎏/㎡. Before the study, the principal investigator explained all the procedures to the subjects in detail.

Surface Electromyographic Recording

We collected and amplified electromyographic data using a Biopac MPWSW[1]. EMG signals of the dominant leg were collected. Electrode skin area were shaved and cleaned before electrode placement, conductive paste was used. Surface electrode pairs were placed in a bipolar configuration over the seven muscle sites, and distance between two electrodes were 2 ㎝. The seven sites 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 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 (lying supine bridging on the floor) was used and EMG data were expressed as a percentage of reference voluntary contraction (%RVC).

Whole Body Vibration

Intensity for WBV was controlled from stage 15 (1,200 vibrations per minute). The maximal amplitude was 15.4 ㎜. In this study, stage 0, 1, 3, and 5 was chosen for the experiment.

Swiss Ball

The tools described are inflated rubber balls originally fabricated in Italy under the name of Pezzi

Table 1. General characteristics of subjects (N=10)

Subjects	Age (yrs)	Height (㎝)	Weight (㎏)	BMI (㎏/㎡)
Ten Females	71.2±3.9[a]	153.5±4.6	56.1±3.4	23.8±1.2
	(63∼76)[b]	(146.5∼161)	(50∼60)	(21.49∼25.16)

[a]Mean±SD, [b]Range.

1) MPWSW, Biopac System Inc., Goleta, CA, U.S.A.

BALL[2], now available through various companies in different qualities and sizes and even different shapes. The most commonly used sizes 45, 55, and 65 ㎝ diameter. Most of the balls can take a weight of 400 lb or more (Oetterli and Larsen, 1996). Since the balls roll very easily, therapists have to consider the safety of patients at all times, adjust and modify the exercises accordingly and observe common precautions (Carrière, 1999). We used a size of 45 ㎝ diameter for Swiss ball exercise. All subjects were familiarized with the device and the proper position.

Procedures

Subjects began by lying supine on the floor with their feet on the WBV platform[3] and Swiss ball, knees bent 90 degrees, toes facing forward and hands on the floor by their sides, palms facing down, pushing through the heels. Subjects lifted their pelvis off the ground to assume a bridging posture (Figure 1) (Figure 2). Feedback from instructor was given in order to achieve a consistent trunk and lower limb posture during each 6 conditions (floor, 0, 1, 3, 5 intensity on WBV, and Swiss ball). Subjects were 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 condition during bridging posture with their feet on the floor, WBV platform and Swiss ball. Three trials of each of these exercise were recorded.

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 was set at $\alpha=.05$.

Results

The study showed that EMG activity of the trunk muscles (RA, EO, IO, and ES) and MH muscles were not significantly different among 6 different conditions during bridging exercise ($p>.05$). However, there were significantly increased EMG activity of the RF ($p=.034$) in the WBV intensity 0, 1, 3, and 5 conditions compared with the floor bridging condition (Table 2) (Figure 3). EMG activity of the MG were significantly increased in the WBV intensity 0, 1, 3, 5 and Swiss ball conditions compared with the floor bridging condition (Table 2) (Figure 4).

Discussion

This study compared EMG activity of trunk and lower extremity muscles according to 6 different conditions (floor, 0, 1, 3, 5 intensity of WBV and

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

Figure 2. Supine bridging exercise on ball condition.

2) Swiss ball, LEDRAGOMMA, Osoppo, Italy.
3) BBSliner, SECO Inc., Bucheon, Korea.

Table 2. Comparison of the %RVC of the muscles intensity induced on WBV and Swiss ball during bridging exercise

Muscles	WBV0	WBV1	WBV3	WBV5	Ball	F
RA	113.40±27.48[a]	105.13±25.69	103.41±23.95	130.17±49.82	102.86±29.81	5.03
EO	111.68±45.74	103.77±41.60	113.49±48.66	108.65±51.02	106.88±28.73	.562
IO	133.97±32.90	130.00±38.27	131.00±26.04	140.15±29.62	118.80±26.84	2.958
ES	117.76±27.82	105.07±46.83	104.20±32.93	110.55±49.77	112.39±47.68	1.591
RF	125.25±16.89	107.98±9.03	130.97±34.66	125.19±14.07	102.31±13.46	11.970*
MH	147.86±107.30	126.81±65.01	114.29±67.82	156.16±102.10	117.26±47.25	.466
MG	213.11±86.76	244.70±140.39	188.75±97.38	195.16±100.14	334.05±109.52	11.115*

[a]Mean±SD, *$p<.05$.
RA: rectus abdominis, EO: external oblique, IO: internal oblique, ES: erector spinae, RF: rectus femoris, MH: medial hamstring, MG: medial gastricnemius.

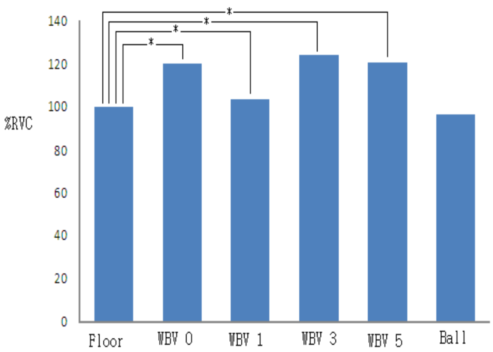

Figure 3. The %RVC data of the rectus femoris muscle among different 6 conditions of WBV and Swiss ball during bridging posture (*$p<.05$).

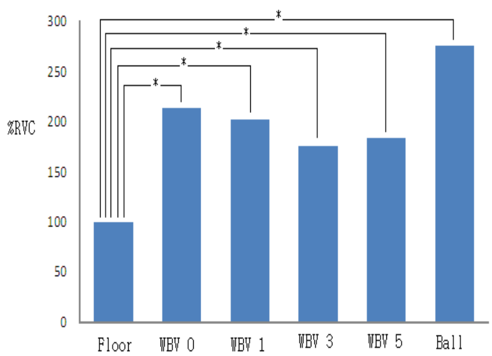

Figure 4. The %RVC data of the medial gastrocnemius muscle among different 6 conditions of WBV and Swiss ball during bridging posture (*$p<.05$).

Swiss ball during bridging). The study showed that EMG activity of the trunk muscles (RA, EO, IO, and ES) were not significantly different among 6 different conditions during bridging exercise ($p>.05$). 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. Duncan (2009) reported that muscle activity was greater when exercises were performed on a Swiss ball in comparison to a stable surface and lower rectus abdominis muscle activity was maximized during the Swiss ball. Kim and Kim (2009) studied that the effect of bridging using Swiss ball, whole body vibration (WBV), and mat on trunk and lower extremity muscle activity. And they found EMG activity of internal oblique increased significantly in WBV condition compared with mat condition ($p<.05$). However, Kim (2009) also reported that the IO, EO, and ES with feet on ball bridging and calf on ball bridging exercise showed significantly higher muscle activity than the floor bridging exercise. A significantly higher level of eletromyographic activity appears in muscles during WBV treatment with respect to a rest condition whereas at the same time specific WBV frequencies also seem to produce a higher EMG-RMS signal than others (Cardinale and Lim, 2003). 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 and Swiss ball 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.

This study found significantly increased EMG activity of the RF ($p=.034$) in the WBV intensity 0, 1, 3, and 5 conditions compared with the floor bridging condition. EMG activity of the MG was significantly increased in the WBV intensity 0, 1, 3, 5 and Swiss ball conditions compared with the floor bridging condition.

Kim and Kim (2009) reported that EMG activity of rectus femoris and medial gastrocnemius increased significantly in Swiss ball condition and WBV condition compared with mat condition ($p<.05$). The muscle activity of medial hamstrings increased significantly in Swiss ball condition compared with mat condition ($p<.05$).

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. Especially, the EMG activity of MG on the Swiss ball condition was the highest compared to other WBV conditions. This result showed that Swiss ball condition was due to the distal instability.

This study showed that EMG activity of low extremity was not significantly different among four intensity (0, 1, 3, 5) conditions of WBV during bridging exercise ($p>.05$). However, Kim and Choi (2009) showed that EMG activity of the trunk muscles was not significantly different among three intensity conditions (1, 3, 5) of WBV during bridging exercise ($p>.05$). However, there were significantly increased EMG activity of the medial hamstring muscle ($p=.001$) and medial gatrocnemius muscle ($p=.027$) in the intensity 3 condition compared with the intensity. These two different results of similar studies seems that participants were heathy young men and elderly women. Scaglioni et al (2002) suggested that aging and disuse attenuates motorneuron excitability and causes structural changes to the muscle spindle. Therefore, the muscle spindle most older individuals may be less sensitive to the vibration because of fiber composition and reflex deterioration that occurs with natural aging (Lexell, 1997; Liu et al, 2005). Bogaerts et al (2007) reported that there were no changes in response strength in any WBV condition, suggesting that training has no effect on central processing, including encoding direction and amplitude of the translation and initiating the appropriate response.

In this study, the effect of stability exercise was investigated by inducing trunk instability with WBV and Swiss ball during bridging in elderly women. There were no significant trunk muscle activity differences with six different exercise conditions. EMG activity of the RF in the WBV intensity 0, 1, 3 and 5 conditions compared with floor bridging condition. EMG activity of the MG was significantly increased in the WBV intensity 0, 1, 3, 5 and Swiss ball conditions compared with the floor bridging condition. This results can be interpreted that the effect of stability by inducing instability with WBV and Swiss ball was lager for distal muscle than more proximal and trunk muscle. This results can be interpreted that the effect of stability by inducing instability with WBV and Swiss ball was larger for distal muscle than proximal and trunk muscle.

Future studies are required using various vibration intensity including trunk instability such as one leg lifting in bridging during WBV and Swiss ball. Because muscle activity was measured only in dominant lower extremity, the change of muscle activity in non-dominant lower extremity was not determined. Consistency of EMG activity varied in elderly women. These limitation should be considered in future studies.

Conclusion

This study compared EMG activity of trunk and lower extremity muscles according to 6 different conditions (floor, 0, 1, 3, 5 intensity of WBV and Swiss ball during bridging). The study showed that EMG activity of the trunk muscles (RA, EO, IO, and ES) and MH muscles were not significantly different between 6 different conditions during bridging exercise (p>.05). However, there were significantly increased EMG activity of the RF in the WBV intensity 0, 1, 3, and 5 conditions compared with the floor bridging condition (p=.034). EMG activity of the MG were significantly increased in the WBV intensity 0, 1, 3, 5 and Swiss ball conditions compared with the floor bridging condition. This study indicates that distal muscle rather than proximal and trunk muscle was affected greatly by inducing instability with WBV and Swiss ball. Further studies are required the dynamic instability condition such as one leg lifting in bridging. It is suggested that long term functional outcome rather than EMG muscle activity of trunk and low extremity should be considered in the future study.

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