

Original Article

The effects of whole-body vibration on EMG activity of the lower body muscles in supine static bridge position

Pedro J. Marín¹, Darryl J. Cochrane²¹CYMO Research Institute, Valladolid, Spain;²School of Sport, Exercise & Nutrition, Massey University, New Zealand**Abstract**

Objectives: The purpose of the current study was to firstly examine the effects of different whole-body vibration (WBV) frequencies in the lower-body muscles when applied simultaneously during a bridge exercise. Secondly, determine if there were any sex differences in the lower-body muscles of WBV during the bridge. **Methods:** Seven females and 7 males completed 2 familiarization and 1 test sessions. In the test session participants were randomized to complete one 30 s bout of a bridge exercise for 3 separate conditions followed by 3-min of rest. The 3 conditions (a) No-WBV (without WBV); (b) WBV-30 (30 Hz, low amplitude); (c) WBV-50 (50 Hz, low amplitude) were performed on a WBV platform. Muscle activity of the biceps femoris (BF), semitendinosus (ST), gluteus maximus (Gmax), multifidus muscle (MF) muscles were measured. **Results:** Muscle activity was increased with WBV in the BF and ST muscles at WBV-30 and WBV-50 conditions ($p < 0.05$) vs. no-WBV. During No-WBV and WBV-50 conditions, males had a higher biceps femoris activity compared to females for ($p < 0.05$) 45 and 27 %, respectively; however, during all conditions females had a high level of Gmax activity (57%) than males ($p < 0.05$). **Conclusion:** Additional vibration at 30 and 50 Hz during the bridge exercise could be a useful method to enhance hamstring muscle activity.

Keywords: Emg, Hamstring, Hip exercise, Gluteus maximus, Neuromuscular activity

Introduction

Whole-body vibration (WBV) is commanding a lot of attention, due to its ease of use, time efficiency, minimal effort and positive results, it is considered an attractive training device and therapeutic modality for physical rehabilitation¹⁻³. There are three types of vibrating machines. The most common are singular platforms that either move synchronously up and down or asynchronously like a seesaw to produce vertical sinusoidal vibration⁴. In contrast, stochastic resonance vibration has two separate platforms, one for each foot that vibrate in three different planes⁵.

A single session of WBV has been shown to increase

muscular strength⁶⁻⁸ and muscular power⁹⁻¹², while other studies have reported no changes^{13,14}. Through the rapid eccentric-concentric muscle action caused by the vertical sinusoidal oscillations of the vibrating platform, the transient effect to enhance muscle performance is probably due to rapid stretch reflexes¹⁵, which in turn increases muscle activity^{15,16} and enhances cortical motor excitability¹⁷. Previously it has been reported that a temporal association exists between electromyography (EMG) activity and muscle contractile tissue displacement, suggesting that muscle lengthening may be a prerequisite to eliciting stretch reflexes from vibration frequency^{15,18,19}. Previous studies used EMG to examine the acute neuromuscular responses of WBV and reported an increase in EMG activity of the lower-limbs during different static squat positions of 100°^{20,21}, 90° and 125°²² and 120°²³ with 60° knee flexion providing the highest EMG for knee extensors²⁴. Further, WBV exposure through the feet increases EMG activity of the upper-body^{12,25,26}.

The bilateral-leg supine bridge is a common body-weight exercise that activates the gluteal and hamstring muscle groups, it is primarily used as strengthening exercise for the gluteals²⁷. Earlier studies of bilateral-leg supine bridge have

The authors have no conflict of interest.

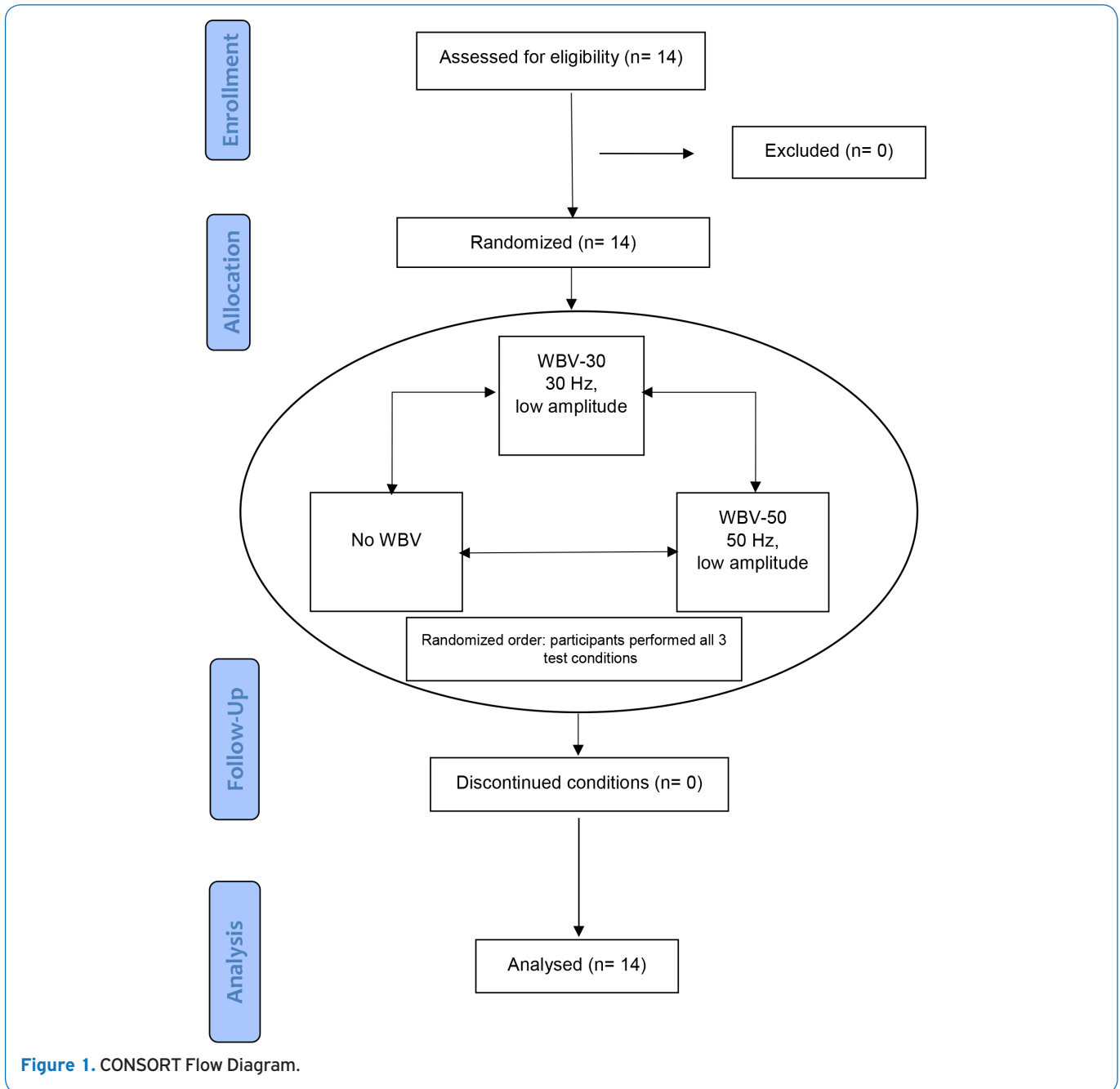
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Edited by: G. Lyritis

Accepted 8 October 2020





reported EMG activation (% maximum voluntary isometric contraction [MVIC]) ranging from 16 to 27% MVIC for gluteus maximus and 15 to 35% MVIC for hamstrings²⁷⁻²⁹.

Progression is a key principle in any strengthening exercise ensures continual improvement in muscle adaptation. There are various approaches that can achieve this, for instance, additional load (weight), volume, intensity are a few that can be modified. Additionally, a change in body position can elicit further challenges that may modify the muscle activation profile of the target muscle(s). For example, an external apparatus i.e., Swiss ball, Bosu ball, or wobble board may be acquired as an interim measure in progressing to a

traditional loading paradigm. Due to the unstable surface of these devices it may challenge the individual's neuromuscular system to increase muscle activity. Previously it has been reported that the addition of a Swiss ball to a bilateral-leg supine bridge had little effect on gluteus maximus activation (13 vs. 16% MVIC) but increased hamstring activation (42 vs. 15% MVIC) compared to conventional bilateral-leg supine bridge²⁷.

The clinical relevance of the bilateral supine bridge is to improve lumbo-pelvic function and reduce lower-limb injury through the activation of the gluteus maximus³⁰. In addition, the bilateral supine bridge has been prescribed for

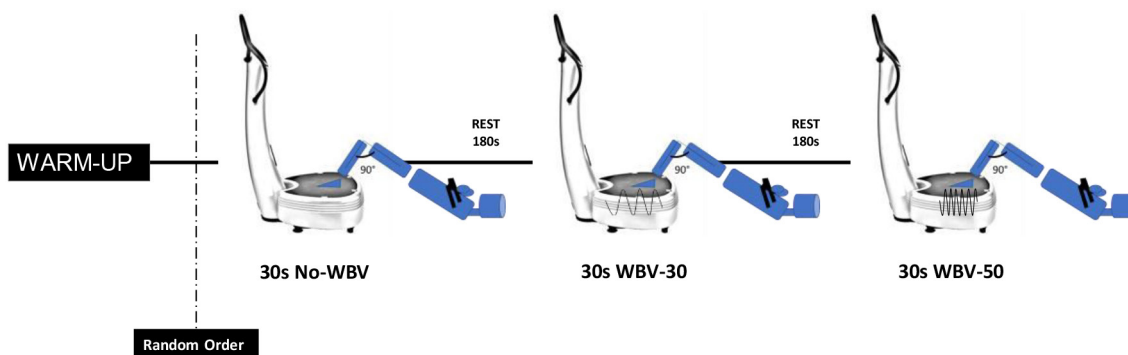


Figure 2. Experimental setup. All sets were performed on the WBV platform in random order of the 3 different conditions: No-WBV (without WBV); WBV-30 (30 Hz, low amplitude); and WBV-50 (50 Hz, low amplitude).

the rehabilitation of other muscles, such as, the hamstrings and lumbar multifidus²⁸. Gaining a greater understanding of the muscle activation profile of the bilateral supine bridge is of importance to assisting intervention progression for rehabilitative and strengthening programs²⁷. Given WBV ease of use and minimal effort required, it has the ability to increase muscle activity, however it is unknown whether WBV can increase EMG activity of lower-body muscles of the bilateral-leg supine isometric bridge. Therefore, the primary aim of this study was to determine if an acute bout of WBV could increase EMG activity of key muscles during bilateral-leg supine isometric bridge at 30 and 50 Hz WBV compared to no WBV. The secondary aim was to evaluate if there were any differences between males and females when performing bilateral-leg supine bridge. It was hypothesized that during bilateral-leg supine bridge the higher vibration frequency would elicit greater changes in EMG activity and males would show a similar trend compared to females.

Materials and methods

Experimental Design

Prior to data collection participants were informed of the requirements associated with participation and provided written informed consent. Participants were encouraged to maintain their dietary, sleeping, and drinking habits during participation in the study. The research project was conducted according to the Declaration of Helsinki and was approved by the CyMO Research Institute granted Ethical approval to carry out the study (1.200.521). To improve the quality of reporting, the current study adheres to the CONSORT (Consolidated Standards of Reporting Trials) guidelines (Figure 1) for randomised trials³¹.

Participants

Fourteen undergraduate students (7 females and 7 males, mean \pm standard deviation [SD]: age: 23.1 \pm 1.5 years; height: 170.6 \pm 9.6 cm; body mass: 67.9 \pm 12.2 kg), participated in the

study during October and November 2019. All participants were recreationally active, which was defined as participating in exercise, sport or physical activity for at least 30-min twice per week and were not involved in a systematic training program at the time of data collection or for at least 2 months prior to the investigation. Participants suffering from epilepsy, gallstones, kidney stones, neuromuscular or neurodegenerative diseases, stroke, serious heart sicknesses or having an implant, bypass or stent were excluded. The sample size of 14 was calculated to detect a minimal clinical significant change of 10% MVIC (standard deviation 12%) between conditions with a statistical power ($\beta=0.8$) at $\alpha=0.05$.

Procedures

Familiarization Sessions

Before testing, each participant performed two familiarization sessions. During these sessions a demonstration of correct bridge technique occurred and practice was undertaken until performance was faultless. To accustom the participants to the sensation of the vibrating platform, each participant performed the bridge exercise³² with WBV for 30 s.

Experimental Sessions

In a laboratory setting, every participant completed a 5-min warm-up of 2:30-min slow jog and dynamic warm up exercises (10 repetitions of pull-backs, butt kicks, knee to chest, squats, and lateral lunges). Participants were then randomly assigned to complete 3 test conditions using a sealed opaque envelope method issued by an independent researcher. Each condition lasted 30 s, with 180 s of rest between each condition to prevent the acute vibration-induced fatigue effect and possible post-activation potentiation³³. For the bridge exercise participants were instructed to lie on their back, with feet shoulder-width apart on the vibration platform (Pro5 Power plate, Power Plate International Ltd.,

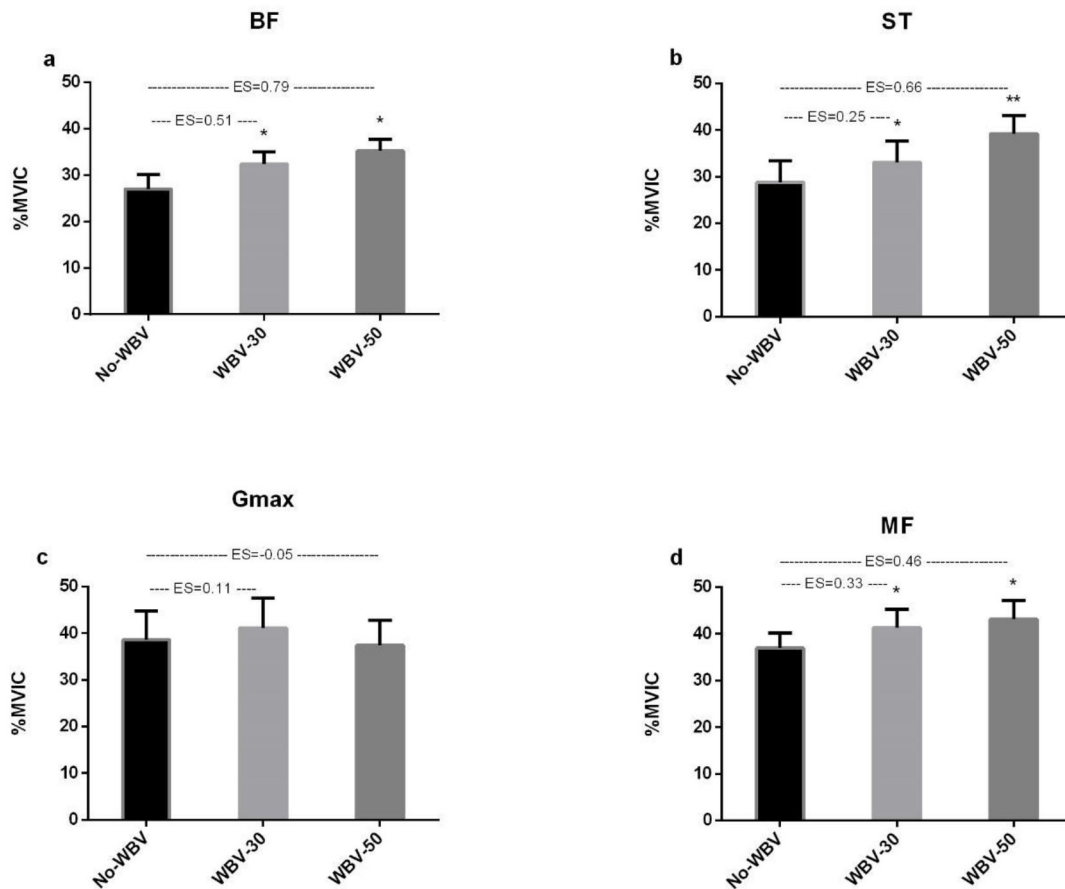


Figure 3. Normalized a) biceps femoris (BF), b) semitendinosus (ST), c) gluteus maximus (Gmax), d) multifidus (MF) electromyographic activity during the bridge exercise. *Significant difference in comparison with No-WBV. **Significant difference in comparison with WBV-30. (n=14).

London, UK) at 90° knee flexion (considering 0° as the anatomical position; measured by a goniometer). With arms crossed over chest, participants lifted the hips off the floor to reach a neutral hip flexion angle. All 3 conditions (a) No-WBV (without WBV); (b) WBV-30 (30Hz, low amplitude); (c) WBV-50 (50 Hz, low amplitude) were performed on the WBV platform in random order (Figure 2). A researcher provided verbal feedback to ensure knee joint angles were maintained during all test conditions.

The acceleration was measured on both the vibrating platform using two triaxial USB Impact X250-2 accelerometers (Concepts of Gulf Coast Data, LLC, Waveland, MS). The accelerometer was set on high gain (± 28 g), resolution of 16 bits, sample rate of 512 Hz, and automatically initialized. Accelerometer data were analyzed using XLR8R software (version 2.1. Gulf Coast Data Concepts, LLC, Waveland, MS). Vibration platform settings included a frequency of 30 Hz (low amplitude) or 50 Hz (low amplitude). The peak-to-peak vibration amplitudes across the range of participant body masses were mean 1.52 ± 0.08 mm (at 30 Hz; low amplitude) and 1.69 ± 0.07 (at 50 Hz; low amplitude).

The vibration acceleration across the range of body masses were mean 27.43 ± 0.22 m·s⁻² (at 30 Hz) and 52.94 ± 0.35 m·s⁻² (at 50 Hz). During all conditions, participants wore the same athletic shoes to standardize the damping of the vibration²¹.

Surface electromyographic activity (EMG)

Muscle activity of the biceps femoris (BF), semitendinosus (ST), gluteus maximus (Gmax), multifidus muscle (MF) muscles were measured using EMG. Prior to electrode placement, the area was shaved and cleaned with isopropyl alcohol to reduce skin impedance³⁴. The electrodes (inter-electrode distance = 10 mm) were placed over the mid-belly of the muscle parallel to the direction of the fibres according to recommendations by the SENIAM project (Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscle)³⁵. Muscle activity was analyzed in the dominant leg, which was defined by the participant's preference leg for kicking a ball.

The double differential technique was used to detect myoelectric raw signals. The surface electrodes were

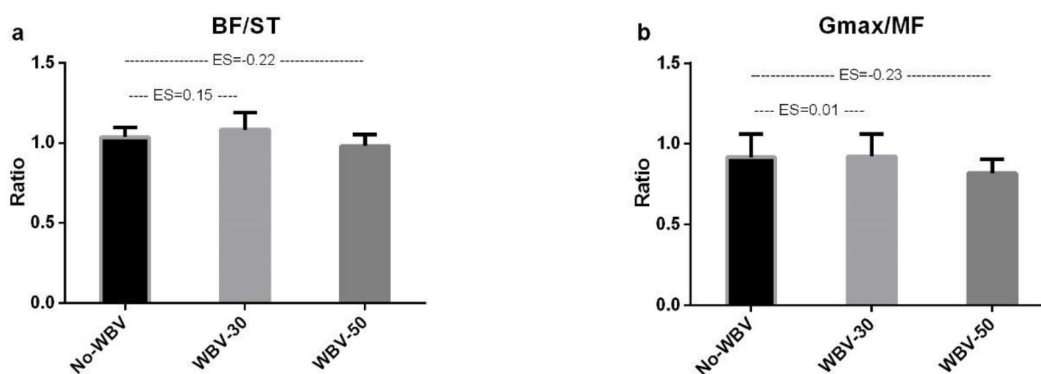


Figure 4. The EMG ratio between a) biceps femoris and semitendinosus (BF/ST); and b) Gluteus maximus and multifidus (Gmax/MF). (n=14).

connected to a 16-bit AD converter (TrigoTM Wireless System, Delsys Inc., Boston, MA, USA). Raw EMG signals were pre-amplified close to the electrodes (signal bandwidth of 20-450 Hz), sampled at 4000 Hz, and stored on a laptop computer. EMG data analysis were performed using specific software (Delsys EMGworks Analysis 4.0. Delsys Inc. Boston, Massachusetts, USA). Only 20 s of the test condition were utilized (from 5 to 25 s), where the EMG data were average by root mean square (rms) and normalized relative to maximal voluntary isometric contraction (MVIC). The participants were instructed to obtain maximal force as quickly as possible and maintain it for at least three seconds. The MVIC of the hamstring muscles was performed in the prone position, with the knee flexed 45° with resistance applied just above the ankle³⁶. For gluteus maximus, MVIC was performed in the prone position with the knee flexed to 90° and the hip extended with resistance applied just above the knee³⁶. For the MVIC of the multifidus muscle, resistance was applied to the posterior aspect of the scapula in the prone position with the legs strapped to the table to prevent them from moving, and the individual was asked to perform trunk extension³⁷.

Statistical analyses

Data were analyzed using PASW/SPSS Statistics 20.0 (SPSS Inc, Chicago, IL, USA). Friedman's analysis of variance (ANOVA) and a pair-wise Wilcoxon signed-rank (Bonferroni adjusted) post hoc test were used to determine any significant difference in the conditions. The Mann-Whitney U test was used to make comparisons between the sex. Effect sizes (ESs) were analyzed to determine the magnitude of an effect independent of sample size (the difference between the mean values divided by the pooled SD)³⁸. Of note, 0.5 and below was considered a low ES, 0.51–0.8 considered a medium ES, and 0.81 and above a large ES³⁹. The intra-class correlation coefficients (ICC) were calculated for each dependent variable to determine test-retest reliability (between the last familiarization session and the test session), obtaining values were greater than 0.90 (BF ICC: 0.94; ST ICC: 0.91; Gmax

ICC:0.95; MF ICC:0.92). Values are expressed as mean±SD, median and the interquartile range (IQR) in table and mean ± SEM in figures. Statistical significance was set at $p \leq 0.05$.

Results

There was a significant increase in % MVIC activity of the biceps femoris during WBV-30 and WBV-50 compared to the No-WBV ($p < 0.05$; Figure 3a). Males had a higher biceps femoris activity compared to females for No-WBV and WBV-50 conditions ($p < 0.05$; Table 1) 45 and 27%, respectively. There was a significant increase in the semitendinosus during the WBV-50 condition compared to other conditions ($p < 0.05$; Figure 3b). Males had a higher semitendinosus activity than females for No-WBV and WBV-30 conditions ($p < 0.05$; Table 1), 59 and 49%, respectively.

For gluteus maximus there were no differences between conditions. Females had a higher gluteus maximus activity (57%) than males for all conditions ($p < 0.05$; Figure 3c). There was a significant increase in % MVIC activity of the multifidus during WBV-30 and WBV-50 compared to the No-WBV ($p < 0.05$; Figure 3d). There were no differences between sex for multifidus ($p > 0.05$; Table 1).

For biceps femoris, semitendinosus (BF/ST) ratio there were no difference between conditions ($p > 0.05$; Figure 4a). Females had a higher BF/ST ratio (29%) than males during WBV-30 ($p < 0.05$; Table 1). There were no differences between conditions ($p > 0.05$; Figure 4b). Females had a higher gluteus maximus, multifidus (Gmax/MF) ratio than males for no-WBV and WBV-30 conditions 61 and 56%, respectively ($p < 0.05$; Table 1).

Discussion

The main finding of this study indicates that the addition of 50 Hz WBV to supine bilateral-leg supine isometric bridge revealed a large magnitude increase in EMG activity of the biceps femoris, semitendinosus and multifidus

Table 1. Summary of the comparisons between the sex.

Dependent variable	Condition	Sex	Mean SD	Median	IQR	<i>p</i>	ES
BF %MVIC	No-WBV	Male	34.9±8.4	33.6	15.8	0.009	-1.85
		Female	19.2±8.4	18.7	12.1		
	WBV-30	Male	36.8±7.0	36.7	12.6	0.064	-1.00
		Female	28.1±10.4	29.3	17.7		
	WBV-50	Male	40.7±4.8	42.2	7.3	0.018	-1.52
		Female	29.8±9.5	32.8	20.9		
ST %MVIC	No-WBV	Male	40.8±14.9	39.3	15.6	0.006	-2.01
		Female	16.8±9.0	17.2	11.8		
	WBV-30	Male	43.8±13.5	37.6	16.2	0.018	-1.56
		Female	22.2±14.3	21.8	25.3		
	WBV-50	Male	46.5±11.1	43.5	13.3	0.064	-1.13
		Female	32.0±14.6	30.9	31.6		
Gmax %MVIC	No-WBV	Male	21.9±12.2	22.4	19.8	0.004	2.11
		Female	55.2±19.3	59.3	38.7		
	WBV-30	Male	24.9±12.2	25.6	26.3	0.025	1.95
		Female	57.4±21.0	65.6	34.3		
	WBV-50	Male	23.5±10.7	21.9	16.7	0.006	2.06
		Female	51.4±16.4	49.5	12.1		
MF %MVIC	No-WBV	Male	38.9±14.6	39.1	21.0	0.749	-0.32
		Female	35.0±9.8	34.6	14.0		
	WBV-30	Male	46.4±18.3	46.3	37.0	0.180	-0.75
		Female	36.4±8.3	36.3	10.6		
	WBV-50	Male	42.4±18.3	47.2	37.5	0.949	0.09
		Female	43.9±12.2	46.5	24.5		
Ratio BF/ST	No-WBV	Male	1.0±0.2	0.9	0.2	0.654	0.34
		Female	1.1±0.3	1.2	0.3		
	WBV-30	Male	0.9±0.1	0.9	0.2	0.048	1.16
		Female	1.3±0.5	1.2	0.3		
	WBV-50	Male	0.9±0.1	0.9	0.2	0.277	0.56
		Female	1.1±0.3	1.1	0.6		
Ratio Gmax/MF	No-WBV	Male	0.5±0.2	0.6	0.3	0.006	2.61
		Female	1.3±0.5	1.3	0.5		
	WBV-30	Male	0.6±0.3	0.5	0.5	0.005	1.94
		Female	1.3±0.5	1.2	0.6		
	WBV-50	Male	0.7±0.2	0.7	0.4	0.125	0.92
		Female	1.0±0.3	0.9	0.1		

SD: standard deviation; IQR: the interquartile range; ES: effect size.

muscles. To the best of our knowledge, this is the first study to report an increase in EMG activity of combining WBV to supine isometric bridge exercise. This is in agreement with other studies that have reported increased EMG activity of the lower-limb with the addition of WBV during isometric squat position²⁰⁻²⁴, isometric leg press⁴⁰ and isometric unilateral squat⁴¹. The use of 50 Hz WBV to increase muscle activity is further supported by previous research that reported increased biceps femoris activity when WBV was administered through the supine bilateral-leg bridge during a barbell decline press bench¹². Currently, the mechanism

of acute WBV remains equivocal but several theories exist to explain the mediated response of WBV to increase muscle activity. One theory of WBV suggests a temporal association between EMG activity and muscle contractile tissue displacement¹⁸ - it propounds muscle lengthening as a prerequisite to eliciting stretch reflexes/monosynaptic reflexes^{15,19} that may heighten muscle spindle sensitivity⁴². Further, it is plausible that increased motor unit recruitment threshold¹⁹ and/or increased motor unit synchronization⁴³ may be responsible for increased muscle activity. Although EMG activity from this current study indicates that a

higher vibration frequency is more advantageous for the hamstrings during supine isometric bridge, further examination into the possible mechanism(s) is required to gaining a better understanding in muscle activity from variants of bridge exercises when exposed to acute WBV.

In the current supine isometric bridge without WBV we observed an overall EMG activity of 27.1, 28.8, 38.6, and 36.9% MVIC in biceps femoris, semitendinosus, gluteus maximus, and multifidus, respectively. This is comparable to other research that reported: 1) hamstring EMG activation levels of 15 to 35% MVIC for hamstrings²⁷⁻²⁹; 2) EMG activity of gluteus maximus from 16 to 27% MVIC²⁷⁻²⁹ and 3) multifidus EMG activity of 29 to 39% MVIC²⁷⁻²⁹. The slight discrepancy between studies of the same muscle groups can be explained by participant activity levels, electrode placement or MVIC procedures. The likely explanation that biceps femoris and semitendinosus activity was enhanced from 50 Hz WBV is probably due to the knee angle of the supine isometric bridge. Recent research observed that during a unilateral supine bridge when knee flexion decreased from 135 to 90° biceps femoris activation increased from 24 to 75% MVIC⁴⁴. Hip extensor torque of the bridge exercise is largely acquired from the gluteus maximus and hamstrings. In the present study the hip was placed in full extension and the knee angle at 90° knee flexion, thereby reducing the hip extensor torque of the gluteus maximus and placed more emphasis on hamstring hip extensor torque. Further, the positioning of the present knee angle may have reduced the net knee extensor torque to increase the activation and force-generating capability of the hamstrings⁴⁵. It is plausible; therefore, the current bridge exercise was positioned to preferentially target the hamstrings whereby 50 Hz WBV was able to augment EMG activity of the biceps femoris and semitendinosus through optimizing the pre-muscle stretch of the hamstrings that increased primary afferent discharge. However, further research is required to ascertain if reducing flexion knee angle in the supine isometric bridge causes greater pre-stretch of the hamstrings during each vibration cycle.

Apart from the main finding a novel result of the present study revealed a higher level of EMG activity of biceps femoris and semitendinosus of 32 and 46% MVIC, respectively in males compared to females. This is in agreement with previous studies that females are more quadriceps dominant and males are more hamstring dominant in single leg squat^{46,47}, running and change direction⁴⁸. The concept of a sex-specific response is further supported by the present study. In the current bridge exercise, the gluteus maximus activity was higher (57% MVIC) in females than males suggesting that males and females use different neuromuscular strategies. This is highlighted by observed changes in hip kinematics and muscle activity during running where peak and average gluteal muscle activation was 40 and 53% MVIC respectively, higher in females compared to males⁴⁹. This is in agreement with early work that observed greater gluteus maximus activity during walking and running in females compared to males⁵⁰. Correspondingly, females in the present study

had a higher gluteus maximus/multifidus ratio than males during no-WBV and WBV-30 of 61 and 56%, respectively. The difference in EMG of hamstrings and gluteus maximus has implications for strengthening and rehabilitation and highlights the importance of exploring sex-specific muscle activity differences in future research.

In considering the limitations of the current study, the rest period between the three conditions were 180 s. It is plausible there may have been a residual effect that could have influenced the subsequent condition. However, the current rest period is sufficient and would have little influence on homosynaptic depression⁵¹ and post-activation potentiation³³. The small sample size may have incurred a type II error (false negative finding) and although the statistical power and effect size were reported a larger cohort would have ensured a stronger statistical analysis. Finally, recreationally active participants were recruited, limiting the application of findings to other populations, especially those rehabilitating from a hamstring injury.

Conclusion

The results of this study suggest that the application of WBV-50 during a bilateral isometric bridge acutely increases EMG activity of the biceps femoris and semitendinosus muscles. Compared to a conventional supine bridge, WBV avoids the use of external overload to providing a simple and effective strategy in targeting specific neuromuscular training and/or rehabilitation for the hamstrings.

Acknowledgments

The authors would like to thank all the participants for their excellent cooperation. This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

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