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Whole Body Vibration Effects on Activation of Lower Extremity Muscles in Recreationally Trained Females

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WHOLE BODY VIBRATION EFFECTS ON ACTIVATION OF LOWER EXTREMITY MUSCLES IN RECREATIONALLY TRAINED FEMALES

by

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ABSTRACT

Purpose: The purpose of this experiment was to measure the differences in activation in four different conditions: maximum voluntary contraction with vibration (MVC + V), maximum voluntary contraction (MVC), vibration only (V), and control group with no vibration (C). Muscles of interest were tibialis anterior (TA), vastus medialis (VM), vastus lateralis (VL), and medial gastrocnemius (MG). This information was obtained for a larger study involving improvement of vertical leap through vibration conditions. **Methods:** A sample of 13 (n=13) recreationally females was studied. EMG electrodes were used to measure activations of the TA, VM, VL, and MG. Vibration was applied at 50 Hz and with displacement amplitudes of 4-6 mm. The data was filtered and normalized to MVC data (MVC = 100%). **Results:** Significant main effects were seen in Condition and Muscle x Condition ($p < .05$). No main effect was seen for Muscle ($p > .05$). Strong trends favoring MVC + V over MVC were seen but were not statistically significant ($p = .051$). T-tests showed that significant differences ($p < .05$) were seen at C for TA, VM, VL, and MG. In the V condition, VM saw significant effect ($p = .001$). VM, VL, and MG saw main effect ($p < .05$) in MVC + V condition, but TA did not ($p > .05$). **Conclusion:** Greatest changes in relative activation were seen in the TA and MG at MVC + V and V. Trends of increased relative activation were seen in muscles during vibration above what was found during MVC.

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INTRODUCTION

Whole Body Vibration (WBV) is a new frontier of research. Many studies have been, and are currently being conducted in several realms as to the benefits and dangers of whole body vibration. Negative side effects have been reported for those who are exposed to high magnitude vibrations on a daily basis (Abercromby, 2007). The effects of brief stimulation with WBV are still relatively unknown. Abercromby et al. (2007) conducted a study on negative side effects of WBVT. This study was particularly concerned with the effects on vibration stimulus on the many internal organ systems of the body as well as the skeletal system. Head acceleration, knee angle and mechanical impedance were of great interest in this study. Vibration was applied in two different ways: vertical vibrations on both feet simultaneously and vertical forces to only one foot at a time at a frequency of 30 Hz. It was concluded that even at low frequencies, the amount of vibration to which the body was subjected during training sessions exceeded the recommended amount by the International Organization for Standardization (ISO). It is also acknowledged that more extensive studies should be conducted on the possible negative effects of vibration training.

Studies have also begun to focus upon the acute effects of Whole Body Vibration (WBV) upon explosive activities such as counter movement jumps and squats (Nordlund, et al. 2007). The improvements noted appear to be dependent upon frequency, amplitude, duration, and number of repetitions utilized (Savelberg, et al. 2007). WBV is usually carried out using a platform upon which the subject stands statically or performs exercises while the platform vibrates (Nordlund, et al. 2007). Modalities such as telemetry surface EMG are a potentially useful tool to help monitor changes in muscle activation in response to differing exposures of whole body vibration while normalizing them to MVC values.

REVIEW OF LITERATURE

Electromyography

Electromyography (EMG) is the study of muscle function through the inquiry of the electrical signal the muscles emanate (Basmajian & DeLuca, 1985.). It is through electromyography that muscles and inherent activation properties may be studied. Luttmann (1996) states that the EMG represents an adequate parameter for the analysis of muscle activation. According to Luttmann, using derivatives from the frequency and amplitude of the EMG signal, statements can be made about the time and characteristics of a muscle contraction as well as the coordination of activities.

EMG may be recorded from the skin surface of muscle or from within a muscle itself. Needle and wire electrode methods are actually inserted into the muscle and are used to record activities from deep muscles and single motor units. This configuration is used for many experimental designs. These procedures are safe, but invasive and may cause discomfort to some subjects. Milner-Brown and Stein (1975) conducted a study comparing voltage of surface unit EMG and needle voltage EMG. They found that voltage contributed by a motor unit to the surface EMG increases approximately as the square root of the threshold force at which it is recruited. For purposes of this study, only surface electrodes and their configurations will be referenced.

During surface EMG, electrodes are generally set up in a bipolar configuration. Two detection surfaces are used to detect two potentials in the muscle tissue of interest, each with respect to a reference electrode (Basmajian and DeLuca, 1985). This configuration allows that outside AC and DC noise to be subtracted from the detected signal before being amplified. One must also take into consideration the area which is being studied by the EMG. Selectivity of the EMG and cross-talk are factors which could affect the EMG signal output. The selectivity of the area is dependent upon the area and the distance between the two electrodes in the case of bipolar configuration (Basmajian and DeLuca, 1985). When sampling EMG, the Nyquist Theorem is the preferred sampling theorem to follow. The voltage/hertz sinusoid we see cannot be correctly constructed if the signal is undersampled. The Nyquist Theorem states that sampling should occur at no less than twice its frequency (DeLuca, 2001). This is true for all complex analog signals.

The output signal of the EMG can be filtered naturally from internal impedance from tissue as well as from the electrode itself. Noise must also be taken into consideration when analyzing the EMG. Noise is defined as any unwanted signal which is detected together with the wanted signal (Basmajian and DeLuca, 1985). Most ambient noise is found at 50-60 Hz since power lines and most electrical devices operate at this frequency (Basmajian and DeLuca, 1985). Another disturbance to consider which could cause noise is motion artifact. This may occur at the actual interface between the electrode and tissue. This has two possible sources: the potential across the skin itself if not properly abrased or from having dissimilar electrical properties coming into contact with one another. (Basmajian and DeLuca, 1985) EMG signal has amplitude which is quasi-random in nature (DeLuca, 2001). It is an inherent instability of the signal due to the random nature of the firing motor units. This usually occurs between 0-20Hz. (DeLuca, 2001).

The first EMG signal investigations were normalized to maximal isometric contraction in relation to isometric conditions. It is important to use one or more contractions of the areas to be studied once electrodes are in place. This helps to provide for the normalization of the signal. Often a maximal voluntary contraction (MVC) is used as a means of normalization. (Selected Topics)

Maximal Voluntary Contraction

Maximal Voluntary Contraction (MVC) is often used as a determination of the peak force or "maximal strength" or a muscle or grouping of muscles. The classic approach is to record changes in average EMG activity during a maximal voluntary contraction (Duchateau, et al. 2006). These measures of MVC are often useful in providing a baseline, or normalization in which to compare the EMG measurements. The idea that the amount of force produced varies directly with the myoelectric output suggests a high correlation between MVC and maximal activation (selected topics). Each MVC provides a baseline for each individual so that multiple contractions may be compared to other individuals and expressed as a relative percentage (MVC = 100% activation).

Whole Body Vibration (WBV)

Whole body vibrations have been proposed as a training intervention to develop strength and flexibility (Annino, 2007). It has been utilized as an alternative exercise modality and is also receiving increasing interest (Erskine, 2007) at low amplitudes as it may improve muscle strength, body composition, balance, and mechanical competence of bones (Paradisis, 2007).

Neuromuscular adaptations are thought to be primarily responsible for the acute changes associated with whole body vibration. The "Tonic vibration" stretch reflex (TVR) is a mechanism commonly cited as leading to reflex up regulation in muscle activity during WBV exposure. The TVR results in the repeated elongation of activated muscles which elicits Ia afferent activity (Savelberg, et al. 2007). While a transient increase in muscle activation has been demonstrated while being exposed to a short bout of high frequency WBV (Nordlund and Thorstensson, 2007), a decrease in voluntary activation has been reported in prolonged exposures utilizing lower frequencies (Nordlund and Thorstensson, 2007). Theoretically, WBV causes an acute improvement in coordination in which there is an increase in the activation of agonist muscles and decrease in excess activation of antagonist muscles via reciprocal inhibition (Nordlund and Thorstensson, 2007). Paradisis and Zacharogiannis (2007) suggest that WBV training renders specific training of Type II, fast twitch muscle fibers which produce the greatest specific tension, (force) and velocity of shortening and are preferentially activated during high-velocity ballistic movements.

Research Studies utilizing whole body vibration

Many studies have been conducted using WBV and utilizing EMG to assess the muscles of interest during the training. EMG can be useful in providing a better estimate of maximum muscle activation strength by studying relationships between amplitudes of the EMG, increasing isometric exertion, and perceived MVC's (Chaffin, et al., 1980). Many studies are focused on the effects of vibration training and the change in activation in lower limbs. The following studies involved a combination of whole body vibration training (WBVT), with some of them using external loads in more extensive training and measurement of activation of various muscles of the lower limbs with EMG.

Abercromby et al. (2007) found that previous studies had not taken into account motion artifact in EMG analysis when studying muscle activation in conjunction with WBVT. Sixteen subjects were recruited to perform unloaded squats in vertical and rotational vibration conditions. Activations from the vastus lateralis, biceps femoris, tibialis anterior and gastrocnemius were recorded. Even after motion artifact was filtered from the raw EMG date, all muscle activations were concluded to have significantly increased during both vibration conditions. The tibialis anterior showed the greatest difference during rotational vibration while the other extensors had greatest activation during vertical vibration.

Moras et al. (2006) studied the activation of the muscles of the quadriceps (vastus medialis, vastus lateralis, and rectus femoris) and medial gastrocnemius muscles under vibration conditions and with external progressive loads. Sixteen male subjects were included in this study and were asked to have had experience in resistance training. The researchers took measurements from the dominant leg and two MVC's were performed in order provide for normalization. Knee angle was held at 100_ while subjects maintained a squat position on the platform for all conditions. There were a total of twenty five conditions measured on each subject: no vibration (control), vibration at 30, 35, 40, and 50 Hz with no external load and with a progressive load of 20, 30, 40, and 50 kilograms. With the exception of the medial gastrocnemius, a significant linear relationship between the increments of the external load and percentage of the EMG activation was found. Moras et al (2006) went on to suggest that different frequencies could have different effects on the muscle activation, but that significantly there were no differences at frequencies of 30, 35, 45, and 50 Hz in this study.

In a six week trial, Lamont et al. (2008) studied vibration and no vibration conditions in conjunction with squat training and jump performance. Thirty six recreationally trained males were divided into three groups: WBV + squat training, squat training alone, and a non-training control group. No significant differences were noted at the beginning of this study for the baseline measures across the groups. Vibration for the first group was applied before and between sets of weight training. Subjects were evaluated at three separate intervals during the trial: week 1, week 3, and week 7 to account for pre-training, training, and post-training. Squat jumps of 20 kg and depth jumps of 30 cm were measured. Significant group differences in peak power and 20 kg squat jump height were noted among all of the three groups. Lamont et al. (2008) found that background training had a lot to do with the responsiveness to the vibration training. The stimulus in this study may have been too strong for less heavily trained individuals, although suitable for more heavily trained individuals.

Mahieu et al. (2006) conducted a study to evaluate whole body vibration in contrast to equivalent resistance training. Thirty-three competitive youth skiers (males and females) were used in this study in order to assess postural control and strength in vibration and non-vibration conditions. This six week study took place three times per week and was divided into two different groups: WBV or equivalent resistance (ER). Subjects receiving WBV carried out exercises on the vibration platform while receiving vibration stimulus. Those in the ER group carried out the exact same exercises but without vibration stimulus. Repetitions and number of exercises increased in both groups over the six week training period. No significant differences were seen between the groups at the beginning of the study. The only significant differences seen between the WBV group and ER group at the conclusion of the study were greater increases in performance on the high box test and better plantar-flexor strength at low speed. Postural control was not affected by either intervention. Mahieu et al. (2006) concluded that although there were not many differences between the two groups, WBV did have a main effect on explosive strength and could be practically applied to supplement other resistance programs for improvement in that area.

While ballerinas are considered artists as well as athletes, Annino et al. (2007) took the opportunity to apply WBV training and its effects on the jumps of these dancers as well as power generation in lower limbs. Twenty-two ballerinas were randomly assigned to an experimental group (those receiving WBV) or control group. The experimental group received WBV training three times a week. They stood on the vibrating platform at 30 Hz for 40 seconds and rested for 60 seconds after treatment. This was repeated five times each session before ballet training sessions. The experimental and control groups attended the same amount of ballet sessions and received no other training during the eight week intervention. It was found that external load strength only improved marginally, but explosive strength (countermovement jump) improved significantly.

In addition to explosive strength, vibration effects on the performance of running kinematics have been studied as well. Paradisis and Zacharogiannis (2007) conducted a study on the effects of vibration on twenty four volunteers for six weeks. Subjects were tested in a sixty meter sprint as well as in the countermovement jumps. The control groups received no training. The WBV group received vibration training three times per week at 30 Hz with displacement of 2.5 mm. The vibration training was conducted in the three sets of eight repetitions. Each repetition lasted for a duration of forty seconds. Each repetition was followed by one minute of rest, and each set was followed by two minutes of rest. There was a significant improvement in step length and running in the sprint tests and a step rate decrease. Paradisis and Zacharogiannis acknowledge that the improvements could have been significant since the volunteers were not currently trained in sprinting and that other more trained athletes might not see such improvement because fast-twitch fibers may already be more targeted and trained.

The effects of vibration on knee extension and strength has also become an issue of interest. Mileva et al. (2006) and Savelberg et al. (2007) both conducted studies on the effects of vibration stimulus on knee extension. Mileva et al. (2006) were more concerned about muscle performance after stimulation with a low frequency vibration. Savelberg et al. (2007) focused the study more on the effects of WBV on the knee extensor, knee angle, and initial strength.

Mileva et al. (2006) studied the musculature above the knee during knee extension exercises. Of particular interest were the rectus femoris and vastus lateralis. Nine subjects completed four different trials on a knee extension exercise machine: two different contraction intensities under a vibration condition or non-vibration condition (control). Vibration stimulus was applied at 10 Hz. It was concluded that at a low intensity of contraction, muscle performance was enhanced significantly. Once again, it was acknowledged that in light-moderate training and those not heavily trained potentially see the most benefit from vibration training.

Savelberg et al. (2007) used three different frequencies (20 Hz, 27 Hz, and 34 Hz) to study if there was a difference in improvement upon initial strength and maximum joint moment when using WBV. Twenty-eight subjects entered into this intervention for four weeks. Subjects were divided into four groups, one for each of the test frequencies with knee angle held at 10_ and one control group trained at 20 Hz in a squat position (knee at 70_). It was concluded that weaker subjects saw the greatest improvement in maximal knee extension joint moments. Subjects who were stronger initially did not see the change that these subjects did.

Through a review of the literature, it can be concluded there is still much to learn from whole body vibration training and vibration stimulus. Many studies are conducted similarly. Some produce similar results while others produce different results. Factors such as previous training and initial strength potentially affect the outcome of vibration training. In this study, different relative activations are analyzed under different vibration and non-vibration conditions.

Purpose

This study was intended to study the differences in muscle activation in 4 different conditions: vibration with maximal voluntary contraction (V + MVC), MVC only, V only, and no MVC or V (control) in recreationally trained females. The muscles of interest in this study included tibialis anterior (TA), vastus medialis (VM), vastus lateralis (VL), and the medial gastrocnemius (MG). The purpose of this study was also to provide a baseline measure of the muscles and conditions for another study involving WBV and countermovement jumps (CMJ). When referring to MVC throughout this study, it should be noted that the vibration plate is not completely stable and therefore should be thought of as maximal voluntary effort (MVE).

Research Questions:

1. How does EMG activation differ in non-vibration control vs. vibration control?

2. How are MVC and EMG activation affected during vibration vs. non-vibration conditions in comparison to their respective baselines?

3. Is EMG activation greater during MVC with vibration or without vibration?

4. What muscles see the greatest effect during each condition?

Research Hypotheses:

1. EMG activation will be greater in a vibration control rather than in a non-vibration control as subjects have not received vibration training before. Muscles in the vibration control will be less coordinated and must activate more in order to remain stable.

2. There will be a greater MVC and EMG activation in a non-vibration condition than in vibration conditions when compared to the respective baselines.

3. EMG activation in an MVC condition will be greater than activation the MVC+ vibration condition as the subjects have not received vibration training and may be more hesitant to give a maximal effort in the vibration condition.

4. The medial gastrocnemius will see the greatest activations during these conditions.

METHODS

This study was presented to, and subsequently approved by the University of Mississippi Institutional Review Board (IRB). Approval may be seen in Appendix C.

Sample:

A sample size of 13 (n=13) recreationally trained females was used for this study. See table below for anthropometric measures and standard deviations.

***	Age (years)	Weight (kg)	Height (cm)
Mean	21.8	64.8	167.9
Standard Deviation	±1.5	±11.5	±7.8

Table 1. Anthropometric data for Age (yrs), Weight (kg), and Height (cm) for 13 female subjects.

In order to be classified as recreationally trained, individuals could resistance train no more than three times in one week. Resistance training could not take place in the lower extremities more than twice a week.

Electrodes and placement:

Noraxon TeleMyo® (Arizona, USA) 16 lead telemetry EMG was used to record muscle activation. All measurements were taken from the left leg on all individuals. Before electrodes were placed, the skin was cleaned and inherently lightly abrased with alcohol pads. Bipolar configuration was used in all sites of interest (TA, VM, VL, and MG). The ground electrode was placed on the bony process below the knee of the left leg, above the electrodes of the TA. After cleaning and light abrasement, two electrodes were placed on the belly of the TA, VM, VL, and MG.

Vibration Plate:

Subjects received vibration at a frequency of 50 Hz on an Airdadaptive Pro 5 vibration platform (Power Plate, Illinois). The displacement was at high amplitude (4-6 mm). The plate had three different settings of air pressure adjustment and was automatically adjusted according to body weight. Setting 1 held up to 120 lbs (54.5 kg). Setting 2 corresponded between 120 – 200 lbs (54.5 kg – 90.9 kg). Setting 3 was adjusted for subjects over 200 lbs (90.9 kg).

Postural position:

Once all electrodes were properly placed, the individual stepped onto the vibration plate. At this point, the individual stood on a strap that allowed her to pull against the vibration place in order to evoke MVC. The strap was adjusted according to the individual's height so that the individual could achieve a 140_ knee angle during MVC. Measurement was made with a hand – held goniometer before testing took place. If performing one of the MVC conditions, subjects were instructed to push through their legs while resisting through their straightened arms, while gripping firmly against the straps in order to achieve MVC targeting primarily the lower extremities.

Procedures:

All individuals completed all conditions during this study. Each condition was performed three separate times and held for five seconds. There was a rest between each hold of 180 seconds during each condition. There was a rest of 300 seconds between each of the conditions tested so that fatigue could not be a factor in the measurements. When it was time to record data, the subject was given verbal instructions to step up. Upon getting into position, the subject was given a "3,2,1" count down and then measurements were taken for five seconds. If performing an MVC condition, the subject was given verbal encouragement for the entire five seconds. Upon completion of the task, the subject sat quietly for the prescribed amount of time. This format was followed for all four conditions.

Data collection and filtering:

Data was recorded for the five seconds during each condition and transmitted to a Dell Laptop. Data was recorded in Microsoft Office Excel and then filtered. The data was first passed through a band pass filter of 20 Hz – 450 Hz (Hamming window). Then notch filters were applied at 49.5 Hz – 50.5 Hz to allow for vibration frequency artifact. Another notch filter was then applied at 59.5 Hz – 60 Hz to allow for ambient noise from surrounding settings. This data underwent full wave rectification and Root Mean Square in 100ms second windows (rms) applications. This information was then averaged and normalized to the MVC condition (MVC = 100%).

Statistical Analysis:

Following EMG data filtering, the data where normalized to MVC (MVC = 100%) using Windows Microsoft Excel. A repeated measures ANOVA (Condition (4) x Muscle (4)) was run on the data to assess any Condition x Muscle interaction and/or main effects for Condition or Muscle. A Bonferroni correction was included to correct the potential for an inflated alpha due to multiple comparisons. Bonferroni Post hoc pair wise comparison analyses where used to highlight the nature of any significant differences.

Further, multiple T-tests (paired samples test) were run to highlight the nature of any Condition x Muscle interactions. Alpha was set at $p = .05$.

<u>**RESULTS**</u>

There was a significant main effect seen for the Condition (p = .000) and Condition x Muscle interaction (p = .036). However, there was no significant main effect seen for Muscle (p >.05). MVC + V was significantly greater than control and vibration (p <.05). Although not statistically significant, a strong trend was seen favoring MVC+V greater than MVC (p = .051).

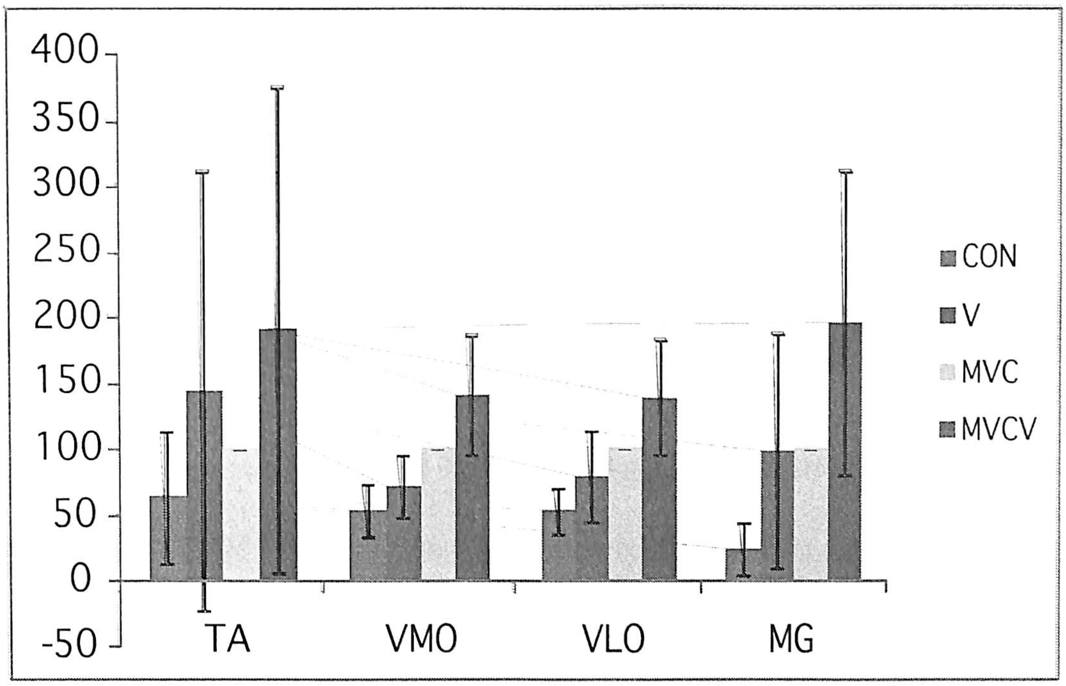

Figure 1. Muscle activation for all muscles (4) (TA, VM, VL, MG) during all conditions (4) (CON, V, MCV, MVCV) normalized too, and then expressed as a relative percentage of MVC (MVC = 100%). Significant main effect for the Condition (p = .000) (Condition 4 > Condition 2, Condition1) and Condition x Muscle interaction (Condition 4, Medial Gastroc > Condition 1 and Condition 2, Medial Gastroc) (p = .036). Measures expressed as means ± SD.

Each condition and muscle was run in comparison with each muscle at MVC (no vibration). TA, VM, VL, and MG at control were compared to their respective muscles at MVC, all were significantly less ($p = .021$, $p = .000$, $p = .000$, $p = .000$). Significant difference was seen in VM for the vibration only condition when normalized to MVC ($p = .001$). It should be noted that while not statistically significant, the VL p value, for the V condition, was only slightly above .05 (.058) which suggests a strong trend towards being significantly less than VL activation during MVC. When TA, VM, VL, and MG activation at MVC (100%) was compared with MVC + V, all but TA activation was significantly less for VM, VL, and MG ($p = .007$, $p = .007$, $p = .010$).

<u>Discussion</u>

In comparing the vibration condition to the MVC condition, activation varied between 79- 144% of MVC activation, the greatest of these being the tibialis anterior (144%, 44% greater MVC) and the medial gastrocnemius (99%, 1% less than MVC). Again in the MVC+V condition, the tibialis anterior and the medial gastrocnemius had the greatest percentage increase in activation at 190% (90% greater than MVC) and 196% (96% greater than MVC) respectively. The TA and MG potentially saw the greatest changes in activation due to the proximity of these muscles to the vibration plate. In response to the vibration stimulus there may have been alternating between dorsi-flexion and plantar flexion as the plate vibrated, potentially creating greater relative activation in these muscles. Mileva et al. (2006) stated that vibration also potentially inhibits the activation of antagonist muscles which could potentially lead to greater activation in the TA and GM as well.

As the knee is flexed at 140_, the plate's transmission of the vibration from the lower extremities to upper body is potentially dampened which may account for reduction in relative muscle activation of the vastus medialis and vastus lateralis. Abercromby et al. (2007) found that mechanical energy from vibration is dampened by the legs through joint angles of the ankle, knee, and hip. The knee angle in this study was at 140_, and the researchers of the Abercromby study found that a similar angle was effective enough to produce significant dampening of vibration transmission to the upper extremities.

Another reason for this increase in relative activation could be due to post activation potentiation (PAP). The twitch magnitude or force/velocity characteristics of a muscle are affected after a brief, intense stimulus such as vibration. These changes could be responsible for creating the greater relative activation seen in these two muscles (TA, MG) during the vibration conditions. Mileva et al. (2006) also found that median frequency of EMG power after training was significantly elevated when testing for dynamic strength.

This increase could also potentially be attributed to tonic vibration reflex (TVR). Paradisis and Zacharogiannis (2006) suggest that there is an increase in recruitment of motor units. They go on to propose that threshold of these motor units are lower which could result in more rapid activation of and training of high-threshold units. Although their study included an element of running, they also saw a significant improvement in explosive strength through measurements of countermovement jumps. This potentially suggests that TVR may help to create a higher activation than a voluntary action is capable of producing.

Some studies have seen trends in the force/velocity relationship and force/power relationship shifting to the right after vibration training. Annino et al (2007) saw such changes in well trained ballerinas, which is a shift in the trends of other studies as untrained subjects had seen significant improvement, and well trained subjects tended not to see a significant improvement. While Annino et al. (2007) only studied the short term effects of whole body vibration on lower limb strength, the findings of this study are particularly useful and may be used in cross-over to other athletic applications because ballerinas do undertake physically demanding movements which require high levels of muscle activation.

Limitations

There were a few limitations to this study. Previous training could have potentially affected the effects of the vibration training as Paradisis (2007) notes. This sample was also limited to strictly recreationally trained female with no comparisons to a male group.

Conclusion

The greatest relative activation changes were seen in the tibialis anterior and medial gastrocnemius in both vibration conditions (V and MVC+V). There was also a strong trend seen in the relative change of activation in the vastus lateralis in the vibration only condition. With vibration, there is a trend of increased muscle activation, even above what is found in an MVC alone. This subset of information provides a valuable baseline for a more extensive ongoing study looking at how varying acute vibration exposure affects muscle activation during counter movement vertical jumps (CMVJ's). With the results of this study, a greater understanding of how acute vibration exposure effects more explosive, ballistic movements could be deemed. The trend of greater activation above that seen during MVC's indicates that whole body vibration could be applied to MVC's in an attempt to increase levels of activation within a targeted musculature, above that produced solely under volitional control.

Research Hypotheses:

1. EMG activation will be greater in a vibration control rather than in a non-vibration control as subjects have not received vibration training before. Muscles in the vibration control will be less coordinated and must activate more in order to remain stable.

1a. This hypothesis is accepted as EMG activation was significantly greater for all muscles during vibration exposure when compared to the control condition.

2. There will be a greater EMG activation during an MVC when compared to the vibration only condition when compared to the respective baselines.

2a. This hypothesis is rejected as TA activation was significantly higher for the V compared to MVC condition.

3. EMG activation in an MVC condition will be greater than activation the MVC+ vibration condition as the subjects have not received vibration training and may be more hesitant to give a maximal effort in the vibration condition.

3a. This hypothesis is accepted as relative muscle activation was shown to be significantly higher for the MVC+V compared to the MVC condition

4. The medial gastrocnemius will see the greatest activations during these conditions.

4a. This hypothesis was rejected as there was no significant main effect found for muscle

Practical Implications

There are several applications in which WBV could be studied in the future. Most studies have focused on lower frequencies and the effects on ballistic movements. There is potential to study how higher frequency vibrations could possibly affect ballistic movements. Previous training could also be studied more extensively to see how it influences the effects of WBV. These applications could be studied in not just an athletic setting but additionally in a therapeutic setting.

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APPENDIX A

	TACON	VMCON	VLCON	MGCON	TAV	VMV	VLV
1	123.28	56.99	68.15	72.71	106.55	71.84	111.99
2	157.27	44.16	60.22	35.73	161.85	76.06	81.10
3	32.90	64.83	61.35	14.91	143.10	79.44	70.56
4	83.34	35.52	34.90	9.49	160.55	65.93	63.54
5	48.38	80.48	67.87	26.31	660.27	107.69	167.29
6	12.48	38.52	35.56	5.60	55.71	103.89	72.67
7	74.82	57.36	37.94	28.54	134.28	29.50	45.75
8	137.07	58.93	63.11	26.97	144.88	60.31	78.64
9	32.27	35.36	55.11	7.96	46.50	68.45	71.70
10	31.46	80.70	83.58	43.08	207.49	96.39	117.59
11	70.49	86.54	62.70	35.66	11.25	32.69	38.03
12	17.64	25.75	27.05	1.65	30.83	72.81	68.61
13	3.38	32.24	32.23	7.19	16.53	62.38	48.57

Maggie Thesis data normalized to MVC.sav

	MGV	TAMVC	VMMVC	VLMVC	MGMVC	TAMVCV	VMMVCV
1	142.26	100.00	100.00	100.00	100.00	147.43	162.78
2	144.34	100.00	100.00	100.00	100.00	162.21	110.22
3	102.14	100.00	100.00	100.00	100.00	173.16	113.50
4	75.09	100.00	100.00	100.00	100.00	120.55	172.17
5	268.30	100.00	100.00	100.00	100.00	727.40	148.37
6	33.02	100.00	100.00	100.00	100.00	67.32	224.82
7	69.24	100.00	100.00	100.00	100.00	160.33	51.00
8	75.02	100.00	100.00	100.00	100.00	415.45	123.83
9	54.01	100.00	100.00	100.00	100.00	121.58	201.46
10	279.04	100.00	100.00	100.00	100.00	117.75	133.26
11	4.76	100.00	100.00	100.00	100.00	120.30	165.79
12	9.80	100.00	100.00	100.00	100.00	84.99	132.58
13	30.34	100.00	100.00	100.00	100.00	64.08	98.30

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

condition	Muscle	Dependent Variable
1	1	TACON
	2	VMCON
	3	VLCON
	4	MGCON
2	1	TAV
	2	VMV
	3	VLV
	4	MGV
3	1	TAMVC
	2	VMMVC
	3	VLMVC
	4	MGMVC
4	1	TAMVCV
	2	VMMVCV
	3	VLMVCV
	4	MGMVCV

Descriptive Statistics

	Mean	Std. Deviation	N
TACON	63.4446	49.86519	13
VMCON	53.6433	20.26953	13
VLCON	53.0593	17.49204	13
MGCON	24.2927	19.82243	13
TAV	144.5982	167.49056	13
VMV	71.3364	23.42091	13
VLV	79.6953	34.87266	13
MGV	99.0284	88.96416	13
TAMVC	100.0000	.00000	13
VMMVC	100.0000	.00000	13
VLMVC	100.0000	.00000	13
MGMVC	100.0000	.00000	13
TAMVCV	190.9649	183.68327	13
VMMVCV	141.3915	45.50275	13
VLMVCV	139.0142	43.79144	13
MGMVCV	196.8942	115.18829	13

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
condition	Sphericity Assumed	368637.249	3	122879.083	15.679
	Greenhouse-Geisser	368637.249	1.658	222358.900	15.679
	Huynh-Feldt	368637.249	1.891	194992.732	15.679
	Lower-bound	368637.249	1.000	368637.249	15.679
Error(condition)	Sphericity Assumed	282135.596	36	7837.100	
	Greenhouse-Geisser	282135.596	19.894	14181.819	
	Huynh-Feldt	282135.596	22.686	12436.433	
	Lower-bound	282135.596	12.000	23511.300	
Muscle	Sphericity Assumed	36778.462	3	12259.487	1.830
	Greenhouse-Geisser	36778.462	1.343	27380.561	1.830
	Huynh-Feldt	36778.462	1.451	25348.526	1.830
	Lower-bound	36778.462	1.000	36778.462	1.830
Error(Muscle)	Sphericity Assumed	241205.882	36	6700.163	
	Greenhouse-Geisser	241205.882	16.119	14964.266	
	Huynh-Feldt	241205.882	17.411	13853.701	
	Lower-bound	241205.882	12.000	20100.490	
condition * Muscle	Sphericity Assumed	53963.881	9	5995.987	2.100
	Greenhouse-Geisser	53963.881	2.020	26718.093	2.100
	Huynh-Feldt	53963.881	2.430	22203.010	2.100
	Lower-bound	53963.881	1.000	53963.881	2.100
Error(condition*Muscle)	Sphericity Assumed	308418.714	108	2855.729	
	Greenhouse-Geisser	308418.714	24.237	12725.116	
	Huynh-Feldt	308418.714	29.166	10574.703	
	Lower-bound	308418.714	12.000	25701.560	

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Sphericity Assumed	.000	.566	47.037	1.000
	Greenhouse-Geisser	.000	.566	25.994	.995
	Huynh-Feldt	.000	.566	29.642	.998
	Lower-bound	.002	.566	15.679	.952
Error(condition)	Sphericity Assumed				
	Greenhouse-Geisser				
	Huynh-Feldt				
	Lower-bound				
Muscle	Sphericity Assumed	.159	.132	5.489	.435
	Greenhouse-Geisser	.196	.132	2.458	.276
	Huynh-Feldt	.194	.132	2.655	.288
	Lower-bound	.201	.132	1.830	.238
Error(Muscle)	Sphericity Assumed				
	Greenhouse-Geisser				
	Huynh-Feldt				
	Lower-bound				
condition * Muscle	Sphericity Assumed	.036	.149	18.897	.851
	Greenhouse-Geisser	.144	.149	4.241	.390
	Huynh-Feldt	.132	.149	5.103	.435
	Lower-bound	.173	.149	2.100	.266
Error(condition*Muscle)	Sphericity Assumed				
	Greenhouse-Geisser				
	Huynh-Feldt				
	Lower-bound				

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	2231817.706	1	2231817.706	96.988	.000	.890
Error	276136.437	12	23011.370			

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Noncent. Parameter	Observed Power[a]
Intercept	96.988	1.000
Error		

a. Computed using alpha = .05

Estimated Marginal Means

1. Grand Mean

Measure: MEASURE_1

Mean	Std. Error	95% Confidence Interval	
		Lower Bound	Upper Bound
103.585	10.518	80.668	126.502

2. condition

Estimates

Measure: MEASURE_1

condition	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	48.610	5.894	35.768	61.452
2	98.665	20.078	54.919	142.410
3	100.000	.000	100.000	100.000
4	167.066	21.373	120.498	213.634

Pairwise Comparisons

Measure: MEASURE_1

(I) condition	(J) condition	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-50.055	18.822	.125	-109.395	9.286
	3	-51.390*	5.894	.000	-69.972	-32.808
	4	-118.456*	18.849	.000	-177.880	-59.032
2	1	50.055	18.822	.125	-9.286	109.395
	3	-1.335	20.078	1.000	-64.634	61.963
	4	-68.402*	14.295	.003	-113.468	-23.335
3	1	51.390*	5.894	.000	32.808	69.972
	2	1.335	20.078	1.000	-61.963	64.634
	4	-67.066	21.373	.051	-134.449	.317
4	1	118.456*	18.849	.000	59.032	177.880
	2	68.402*	14.295	.003	23.335	113.468
	3	67.066	21.373	.051	-.317	134.449

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Bonferroni.

3. Muscle

Estimates

Measure: MEASURE_1

Muscle	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	124.752	24.478	71.419	178.085
2	91.593	4.229	82.379	100.807
3	92.942	5.882	80.127	105.757
4	105.054	13.320	76.032	134.075

Pairwise Comparisons

Measure: MEASURE_1

(I) Muscle	(J) Muscle	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	33.159	23.871	1.000	-42.099	108.417
	3	31.810	20.099	.837	-31.557	95.176
	4	19.698	17.757	1.000	-36.284	75.680
2	1	-33.159	23.871	1.000	-108.417	42.099
	3	-1.349	4.797	1.000	-16.472	13.773
	4	-13.461	12.700	1.000	-53.499	26.577
3	1	-31.810	20.099	.837	-95.176	31.557
	2	1.349	4.797	1.000	-13.773	16.472
	4	-12.112	8.531	1.000	-39.008	14.785
4	1	-19.698	17.757	1.000	-75.680	36.284
	2	13.461	12.700	1.000	-26.577	53.499
	3	12.112	8.531	1.000	-14.785	39.008

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

4. condition * Muscle

Measure: MEASURE_1

condition	Muscle	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	63.445	13.830	33.311	93.578
	2	53.643	5.622	41.395	65.892
	3	53.059	4.851	42.489	63.630
	4	24.293	5.498	12.314	36.271
2	1	144.598	46.454	43.385	245.812
	2	71.336	6.496	57.183	85.490
	3	79.695	9.672	58.622	100.769
	4	99.028	24.674	45.268	152.789
3	1	100.000	.000	100.000	100.000
	2	100.000	.000	100.000	100.000
	3	100.000	.000	100.000	100.000
	4	100.000	.000	100.000	100.000
4	1	190.965	50.945	79.966	301.964
	2	141.392	12.620	113.894	168.889
	3	139.014	12.146	112.551	165.477
	4	196.894	31.947	127.287	266.502

APPENDIX B

Pre participation health screening and existing physical activity questionnaire

Name ____
Date____________

Home Address

____

Work Phone ____________________ Home Phone
____

Person to contact in case of emergency
____

Emergency Contact Phone ___________________ Birthday (mm/dd/yy)____/_____/_____

Personal Physician ________________________ Physician's Phone_____________

Gender_______ Age _____(yrs) Height _____(ft)_____(in) Weight_____(lbs)

Does the above weight indicate: a gain____ a loss____ no change____ in the past year?
If a change, how many pounds?_________(lbs)

A. JOINT-MUSCLE STATUS (✓Check areas where you currently have problems)

Joint Areas
- ( ) Wrists
- ( ) Elbows
- ( ) Shoulders
- ( ) Upper Spine & Neck
- ( ) Lower Spine
- ( ) Hips
- ( ) Knees
- ( ) Ankles
- ( ) Feet
- ( ) Other__________________

Muscle Areas
- ( ) Arms
- ( ) Shoulders
- ( ) Chest
- ( ) Upper Back & Neck
- ( ) Abdominal Regions
- ( ) Lower Back
- ( ) Buttocks
- ( ) Thighs
- ( ) Lower Leg
- ( ) Feet
- ( )

Other_________________

B. HEALTH STATUS (✓Check if you currently have any of the following conditions)

( ) High Blood Pressure
( ) Heart Disease or Dysfunction Abnormality
( ) Peripheral Circulatory Disorder
( ) Lung Disease or Dysfunction
( ) Arthritis or Gout
( ) Edema
( ) Epilepsy
( ) Multiply Sclerosis
( ) High Blood Cholesterol or Triglyceride Levels
( ) Allergic reactions to rubbing alcohol
( ) Acute Infection
( ) Diabetes or Blood Sugar Level
( ) Anemia
( ) Hernias
( ) Thyroid Dysfunction
( ) Pancreas Dysfunction
( ) Liver Dysfunction
( ) Kidney Dysfunction
( ) Phenylketonuria (PKU)
( ) Loss of Consciousness

* *NOTE: If any of these conditions are checked, then a physician's health clearance will required.*

C. PHYSICAL EXAMINATION HISTORY

Approximate date of your last physical examination______________________________

Physical problems noted at that time______________________________________

Has a physician ever made any recommendations relative to limiting your level of physical exertion? _________YES _________NO

If YES, what limitations were recommended?___________________________________

____

D. CURRENT MEDICATION USAGE (List the drug name and the condition being managed)

MEDICATION	CONDITION
____________________	____________________
____________________	____________________
____________________	____________________

E. PHYSICAL PERCEPTIONS (Indicate any unusual sensations or perceptions. ✓Check if you have recently experienced any of the following during or soon after *physical activity* (PA); or during *sedentary periods* (SED))

PA	SED		PA	SED	
( )	( )	Chest Pain	( )	( )	Nausea
( )	( )	Heart Palpitations	( )	( )	Light Headedness
( )	( )	Unusually Rapid Breathing	( )	( )	Loss of Consciousness
( )	( )	Overheating	( )	( )	Loss of Balance
( )	( )	Muscle Cramping	( )	( )	Loss of Coordination
( )	( )	Muscle Pain	( )	( )	Extreme Weakness
( )	( )	Joint Pain	( )	( )	Numbness
( )	( )	Other____________________	( )	( )	Mental Confusion

F. FAMILY HISTORY (✓Check if any of your blood relatives . . . parents, brothers, sisters, aunts, uncles, and/or grandparents . . . have or had any of the following)

( ) Heart Disease
( ) Heart Attacks or Strokes (prior to age 50)
( ) Elevated Blood Cholesterol or Triglyceride Levels
( ) High Blood Pressure
( ) Diabetes
( ) Sudden Death (other than accidental)

G. EXERCISE STATUS

Do you regularly engage in aerobic forms of exercise (i.e., jogging, cycling, walking, etc.)? YES NO

How long have you engaged in this form of exercise? ______ years ______ months

How many hours per week do you spend for this type of exercise? _______ hours

Do you regularly lift weights? YES NO

How long have you engaged in this form of exercise? ______ years ______ months

How many hours per week do you spend for this type of exercise? _______ hours

Do you regularly play recreational sports (i.e., basketball, racquetball, volleyball, etc.)? YES NO

How long have you engaged in this form of exercise? ______ years ______ months

How many hours per week do you spend for this type of exercise? _______ hours

Baseline EMG Data. (Raw data Peak and mean units)

Subject information.

Name.
Age.
Height.
Weight.

CMVJ

VMO	1.	2.	3.
VLO	1.	2.	3.
TIB ANT	1.	2.	3.
MED GAST	1.	2.	3.

MVC 3 X 5

VMO	1.	2.	3.
VLO	1.	2.	3.
TIB ANT	1.	2.	3.
MED GAST	1.	2.	3.

MVC + V 3 X 5

VMO	1.	2.	3.
VLO	1.	2.	3.
TIB ANT	1.	2	3.
MED GAST	1.	2.	3.

V 3 X 5

VMO	1.	2.	3.
VLO	1.	2.	3.
TIB ANT	1.	2	3.
MED GAST	1.	2.	3.

CONTROL 3 X 5

VMO	1.	2.	3.
VLO	1.	2.	3.
TIB ANT	1.	2.	3.
MED GAST	1.	2.	3.

APPENDIX C

The University of Mississippi
Oxford • Jackson • Tupelo • Southaven

Office of Research and
Sponsored Programs
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February 25, 2008

Dr. Hugh Lamont
HESRM
University, MS 38677

Dr. Jay Garner
HESRM
University, MS 38677

IRB Protocol #: ***08-096***
Title of Study: ***The Acute Effects of Maximal Voluntary Contractions with and Without Whole Body Vibration upon Jump Performance in Athletic and Non-athletic Male and Female Subjects***
Approval Date: ***February 13, 2008***
Expiration Date: ***February 12, 2009***

Dear Dr. Lamont and Dr. Garner:

This is to inform you that your application to conduct research with human participants has been reviewed by the Institutional Review Board (IRB) at The University of Mississippi and approved by Full Board Review.

Research investigators must protect the rights and welfare of human research participants and comply with all applicable provisions of The University of Mississippi's Federalwide Assurance 00008602. Your obligations, by law and by University policy, include:

- Research must be conducted exactly as specified in the protocol that was approved by the IRB.
- Changes to the protocol or its related consent document must be approved by the IRB prior to implementation except where necessary to eliminate apparent immediate hazards to participants.
- ***Only the approved, stamped, consent form may be used throughout the duration of this research unless otherwise approved by the IRB.***
- A copy of the IRB-approved informed consent document must be provided to each participant at the time of consent, unless the IRB has specifically waived this requirement.
- Adverse events and/or any other unanticipated problems involving risks to participants or others must be reported promptly to the IRB.
- Signed consent documents and other records related to the research must be retained in a secure location for at least three years after completion of the research.
- If you wish to continue your study beyond the expiration date given above, please request a renewal when submitting the *Progress Report* which we will send to you in approximately nine months.
- Please include the IRB protocol number and the study title in any electronic or written correspondence.

If you have any questions, please feel free to contact me or Diane W. Lindley, IRB Coordinator, at (662) 915-7482.

Sincerely,

Thomas W. Lombardo, Ph.D.
Member, Institutional Review Board
Director, Division of Research Integrity & Compliance