Acute Effects of Whole-Body Vibration on Lower Extremity Muscle Performance in Persons with Multiple Sclerosis

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Background and Purpose: Whole-body vibration (WBV) is a relatively new form of exercise training that may influence muscle performance. This study investigated the acute effects of high- (26 Hz) and low- (2 Hz) frequency WBV on isometric muscle torque of the quadriceps and hamstrings in persons with multiple sclerosis.

Participants and Method: Fifteen individuals (mean age = 54.6 years, SD = 9.6) with multiple sclerosis and Expanded Disability Status Scale scores ranging from 0 to 6.5 (mean = 4.2, SD = 2.3) participated in this randomized, crossover study. After baseline measures of isometric quadriceps and hamstring muscle torque, subjects were exposed to 30 seconds of WBV at either 2 or 26 Hz. Torque values were measured again at one, 10, and 20 minutes after vibration. Subjects returned one week later to repeat the same protocol at the alternate vibration frequency.

Results: There were no significant differences in isometric torque production between the 2- and 26-Hz WBV conditions. There was also no significant difference between baseline torque values and those measured at one, 10, and 20 minutes after either vibration exposure. However, there was a consistent trend of higher torque values after the 26-Hz WBV when compared with the 2-Hz condition for both quadriceps and hamstring muscles.

Discussion and Conclusion: Although not statistically significant, peak torque values for both quadriceps and hamstring muscles were consistently higher after 30 seconds of WBV at 26 vs 2 Hz. Whether WBV presents a viable treatment option as either a warm-up activity or a long-term exercise intervention is yet to be determined. Future studies should include a wider variety of WBV parameters and the use of functional outcome measures.

Keywords: *multiple sclerosis, whole-body vibration, strength, exercise, isometric*

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INTRODUCTION

Multiple sclerosis (MS) is a chronic inflammatory, demyelinating disease of the central nervous system. The most prevalent symptoms of MS include sensory changes, visual disturbances, fatigue, and micturition disorders.[1] Motor weakness, including a loss of muscle power, strength, and endurance, is another common symptom that can impair functional performance.[2–4] Moderate intensity strength training has been shown to improve strength and mobility in persons with MS.[5,6] Unfortunately, some individuals with MS have difficulty performing traditional strength training exercises because of problems with balance, coordination, fatigue, and generating a maximal voluntary contraction.[2,3] Because of these difficulties, there is need to explore alternative methods of improving muscle performance in persons with MS. One potential option is the use of a relatively new form of exercise called whole-body vibration (WBV) training.

WBV, or vibration training, has become increasingly popular over the past several years in both health clubs and clinic settings. As its name implies, WBV involves the application of a vibratory stimulus to the entire body as opposed to local stimulation of specific muscle groups. This is typically performed by having a person stand on a vibrating platform. As a training device, WBV has most commonly been used in one of two ways. First, WBV has been used as a warm-up procedure that is thought to transiently increase muscle activity, strength, and power associated with traditional neuromuscular training.[7,8] When used for this purpose, the client/patient typically stands on the platform with the knees slightly flexed for a brief (30 seconds to two minutes) period with the goal of enhancing muscle performance during an activity (eg, jumping) performed immediately after the vibration. A second common use of WBV is for long-term training. When used for this purpose, clients/patients generally train on the vibration unit several times per week while gradually increasing the time and intensity of the stimulus. In addition, common exercise movements such as squats and heel raises are usually performed It has been hypothesized that improvements in muscle strength and power after WBV may be related to an increase in neuromuscular activation during and after WBV.[9] In a recent study by Abercromby et al,[10] neurologically intact subjects who were exposed to WBV at a frequency of 30 Hz and 4 mm of amplitude demonstrated a significant increase in electromyographic (EMG) activity in the knee flexors and extensors as well as the ankle plantar flexors and dorsiflexors during the vibration stimulus.

Several researchers have also evaluated the acute effects of a single exposure to WBV in normal younger adults

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and have shown transient improvements in muscle performance after vibration,[11–13] whereas others have found little or no effect.[14,15] Training studies involving longer term (three times per week for 11–12 weeks) exposures to WBV in younger adults have also shown mixed results.[16,17]

Recently, there has been an increased interest in the use of WBV in clinical populations including those with neurological disorders.[18–22] Several studies have demonstrated improved postural control for individuals with MS[19] and Parkinson's disease[20] after a single exposure to WBV. However, these studies used a low-frequency (2–6 Hz) multidirectional vibration that is distinctly different from the higher frequency (20–40 Hz) vertical or rotational vibration used in most other WBV research. In a recent randomized, controlled trial, subacute stroke patients exposed to 4 one minute bouts of WBV (20 Hz) in a single session demonstrated significant improvements in isometric and eccentric muscle torque as well as EMG amplitude in the quadriceps muscle of their affected leg immediately after WBV.[23] However, there are currently no studies that have evaluated the effects of higher frequency (20–40 Hz) WBV on muscle performance in persons with MS.

Therefore, the purpose of this current investigation was to evaluate the acute effects of a brief exposure to WBV on quadriceps and hamstring muscle performance in persons with MS. Our hypothesis was that a short, nonfatiguing exposure to high-frequency (26 Hz) vibration compared with a low-frequency (2 Hz) may lead to temporary improvements in the ability to generate isometric muscle torque. If the results confirmed our hypothesis, then WBV could possibly be used as a neuromuscular warm-up activity before performing more traditional exercise and functional rehabilitation training. In addition, if the vibration parameters used in this study were found to show transient benefit, using similar parameters in future long-term training studies may be warranted.

METHODS

Subjects

A convenience sample of 15 subjects (three men, 12 women; age = 54.6 ± 9.6 years) with MS was recruited from the community using local support groups and their publications (Table 1). After an explanation of the protocol, subjects signed an informed consent that had been approved by the University of Dayton of Human Subjects Review Board. Inclusion criteria included the following: a confirmed diagnosis of MS, the ability to ambulate 10 m with or without assistive device with no more than contact guard assistance, and the ability to stand for a minimum of five minutes with upper extremity support. Exclusion criteria included thrombosis, acute inflammation, acute tendinopathy, recent (less than six months) fractures, gallstones, implants, surgery, wound/scar, hernia or discopathy, diabetic retinopathy, epilepsy, pacemaker, pregnancy, total joint replacement, or the presence of any other neurological condition. For safety, blood pressure and heart rate were monitored before and after all testing.

During the initial visit, demographic and anthropometric information were recorded and a neurological examination was performed by a physical therapist with extensive experience in neurological rehabilitation. Using findings from the neurological examination, subjects were scored on the Kurtzke Expanded Disability Status Scale (EDSS) to characterize disease severity.[24] EDSS scores can range from 0 to 10, with a higher score indicating greater disability. The mean EDSS score was 4.2 ± 2.3 (range, 0–6.5) (Table 1). This means that our subjects' level of disability varied consider-

TABLE 1. Subject Characteristics

Subject	Age (yr)	Gender	Diagnosis[a] (yr)	EDSS Score	Baseline Quadriceps Muscles[b] (N·m)	Baseline Hamstring Muscles[c] (N·m)
1	52	F	11	6	120.8	36.5
2	44	F	3	6	113.1	31.7
3	73	F	10	6	66.4	31.0
4	51	F	15	2	80.5	37.6
5	43	M	3	1.5	219.9	69.4
6	49	F	7	0	143.3	43.9
7	61	F	10	6	126.4	51.4
8	58	M	4	2.5	131.1	50.5
9	69	F	22	6	72.5	24.0
10	43	F	3	1.5	65.2	26.8
11	47	F	9	2	88.1	42.6
12	66	F	13	4	85.6	31.5
13	57	F	11	6	103.3	66.8
14	47	M	20	6.5	88.1	41.6
15	59	F	19	6	107.5	24.9
Mean ± SD	54.6 ± 9.6	12 F/3 M	10.6 ± 6.2	4.2 ± 2.3	107.5 ± 39.4	40.6 ± 14.0

Abbreviations: EDSS, Expanded Disability Status Scale.
[a] Time since diagnosis of multiple sclerosis.
[b] Baseline isometric torque values for quadriceps and hamstrings as measured on second visit.

ably, from no overt symptoms to walking only limited distances with a cane or walker. Although the EDSS was used for general descriptive purposes, it was not considered an important factor in the data analysis because of its questionable reliability and validity.[25]

Study Design and Protocol

Using blocked randomization, subjects were assigned to receive either a low-frequency 2-Hz WBV exposure or a higher frequency 26-Hz stimulus on their first visit. Subjects then received the alternate WBV frequency on their second visit in this repeated-measures crossover study. At the initial visit, subjects were familiarized with the testing procedures and baseline performance of the quadriceps and hamstring muscles on the subject's more impaired leg were assessed using the Biodex System-3 dynamometer (Biodex Medical Systems, Shirley, NY). Average isometric peak torque (Newton meter) was calculated over three repetitions with the knee held at 60 degrees of flexion. After a 15-minute rest period, subjects then received either the 2-Hz WBV (6-mm amplitude, 30 seconds) or the 26-Hz WBV (6-mm amplitude, 30 seconds). Isometric torque was assessed again at 1, 10, and 20 minutes after the vibration stimulus. These time frames were chosen because they are similar to previous WBV research protocols.[13–15] Subjects returned one week later at the same time of day, which was initially determined by each subject to optimize performance. Subjects then repeated the same protocol, receiving a second baseline assessment of muscle performance and then either the 2- or 26-Hz WBV depending on group assignment. The investigator responsible for performing the muscle testing was blinded to the type of treatment given by remaining in separate room until immediately after the vibration exposure. This researcher also used a consistent phrase of encouragement during the isokinetic testing.

Equipment

Subjects received WBV using the Maxuvibe platform (Fitgroup BV, Hoogstrat, Holland) (Figure 1). The Maxuvibe unit provides a rotational form of vibration. With rotational vibration, the platform rotates in a sinusoidal manner about an anteroposterior axis so that positioning the feet further apart results in increased amplitude of movement and applies force asynchronously to the left and right feet, similar to standing near the middle of a seesaw (Figure 1). We chose to use a unit that provided rotational vibration instead of vertical vibration because it is easier to dampen the mechanical energy that is transferred to the spine and head by alternately flexing and extending the lower extremities.[26] This type of vibration has also been shown to elicit a significantly great response of the knee extensors than vertical vibration.[10] Vibration frequencies of 2 and 26 Hz with a 6-mm peak-to-peak amplitude were used because these parameters are consistent with previous WBV research demonstrating increased muscle activity and muscle performance during and after WBV exposure.[10,23] Subjects were asked to wear thin-soled shoes and to use the same shoes on each visit. Foot position was standardized at a width of 13 cm. This foot position ensured that each patient experienced the same amplitude of movement (6 mm peak to peak), which is determined by foot width when using a rotational vibration unit. A knee flexion angle of approximately 25 degrees was maintained, and subjects were asked to shift their weight slightly toward the balls of the feet without lifting their heels. This position was chosen because it has been shown to minimize head vibration during WBV.[26] All subjects were asked to hold on to the vibration unit for safety, but their arms were positioned to minimize any upper extremity weight-bearing (Figure 1).

Isometric torque of the knee flexors and extensors was assessed using the Biodex System-3 dynamometer. Subjects were positioned sitting in the dynamometer with their more involved lower extremity held at 60 degrees of flexion. For all testing, the trunk was stabilized with a seat belt and shoulder harness and the thigh was also held in place with a belt. Subjects performed three maximal isometric contractions of both the knee flexors and extensors that were held for five seconds each. Isometric muscle testing in persons with MS using dynamometry has previously demonstrated excellent test-retest reliability (Interclass Correlation Coefficient = 0.97).[27]

Statistical Analyses

A power test was not performed before data collection because of the newness of this pilot study and the lack of

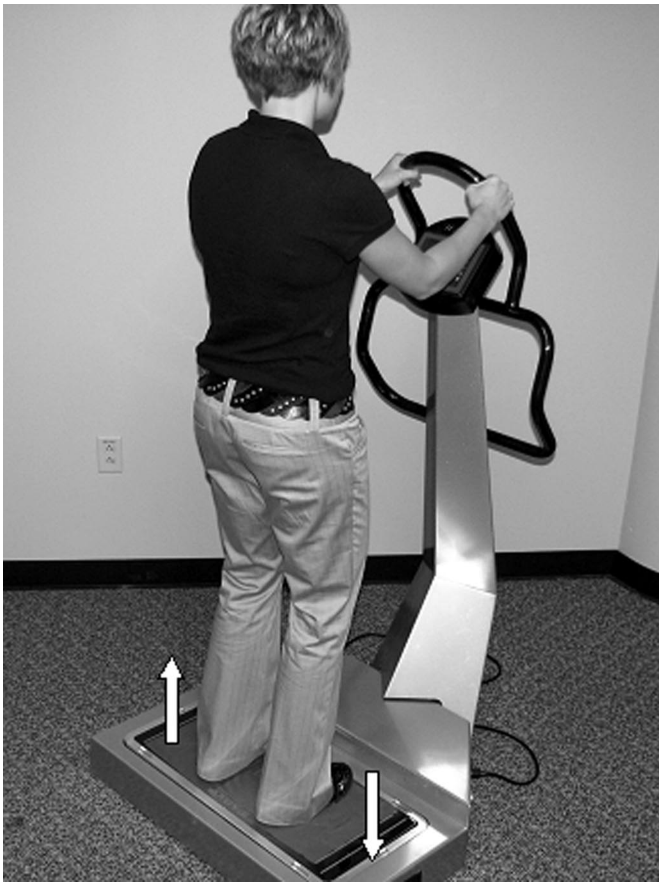

FIGURE 1. Maxuvibe vibration platform (Fitgroup BV, Hoogstrat, Holland).

previous data with this patient population. However, a subsequent power test revealed that, to detect a relatively modest effect size of 0.5, given an α of 0.05 and power of 0.80 using the repeated-measures design of our study, the minimum sample size would be 15. Therefore, we believed that our study likely had sufficient power to minimize the risk of a type II error.

A repeated-measures analysis of variance was used to determine mean quadriceps and hamstring muscle torque value differences between the 2- and 26-Hz conditions as well as differences between the baseline values and those measured at one, 10, and 20 minutes after vibration. The statistical design was a 4×2 with repeated measures across both independent variables: treatment (2 vs 26 Hz) by time (baseline, one, 10, and 20 minutes post-treatment). Therefore, each subject was measured in every condition. In the repeated-measures design, the presence of main effects and interaction terms (time $\times$ treatment) were evaluated. A main effect for time, for example, would indicate that, regardless of treatment, torque values tended to change with time. A significant interaction term would indicate that the effect of time on torque would depend on the treatment or the effect of treatment on time on torque would depend on time. Dependent variables were peak isometric quadriceps and hamstring muscle torque. Only the baseline values obtained on the second visit were used in the analyses because the baseline testing during the first visit was considered primarily a familiarization procedure to reduce possible early learning effects of the isometric testing. A priori statistical significance was set at an α level of 0.05. In addition, a Pearson product-moment correlation was used to determine whether there was any relationship between EDSS scores and baseline torque values.

RESULTS

Table 2 and Figures 2 and 3 show torque values at one, 10, and 20 minutes after WBV for the 2- and 26-Hz conditions for the quadriceps and hamstring muscles, respectively. For the quadriceps muscle, only the main effect for time was statistically significant ($P < 0.05$), suggesting that, regardless of treatment, torque values tended to change with time. For the hamstrings, there were no statistically significant main effects or interaction term. Post hoc analyses indicated that quadriceps torque increased significantly from the first to the 10th minutes for both the 2- and 26-Hz conditions ($P < 0.05$).

TABLE 2. Mean ± SD Isometric Peak Torque (N·m) Values for Quadriceps and Hamstrings at Baseline, One, 10, and 20 Min After Vibration

	Quadriceps Muscles		Hamstring Muscles	
	2 Hz	26 Hz	2 Hz	26 Hz
Baseline[a]	107.5 ± 39.4		40.6 ± 14.0	
1 min	102.5 ± 37.2	107.3 ± 34.4	39.6 ± 13.7	40.9 ± 13.9
10 min	108.5 ± 34.4	111.5 ± 36.5	40.7 ± 12.6	41.5 ± 12.1
20 min	107.9 ± 29.6	111.8 ± 34.8	39.4 ± 12.1	42.0 ± 14.2

[a] Baseline values as measured on the second visit.

However, there was no significant difference between the baseline values and those measured at one, 10, and 20 minutes after vibration for either WBV condition or muscle group. In both the hamstring and quadriceps muscles, the visual trends shown in Figures 2 and 3 suggest that the 26-Hz condition elicited higher torque responses than the 2-Hz condition at all time points, although the analyses indicate that this trend did not achieve statistical significance. Both the 2- and 26-Hz vibration conditions were well tolerated. There was no significant relationship between EDSS scores and baseline torque values for the quadriceps ($r = -0.32$, $P = 0.24$) or hamstring ($r = -0.21$, $P = 0.45$) muscle. There were no adverse events (pain, anxiety, loss of balance, cardiovascular, or neurological changes) encountered during testing, and all subjects completed the study.

DISCUSSION

This is the first study we are aware of that has evaluated the effects of WBV on muscle performance in persons with MS. The main finding of our study, although not statistically significant, was that mean quadriceps and hamstring muscle

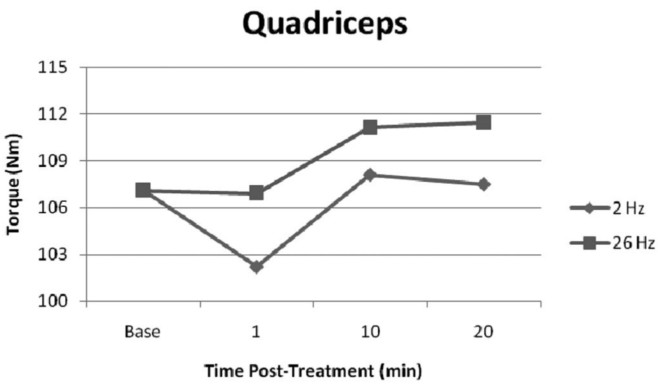

FIGURE 2. Quadriceps torque between 2 and 26 Hz whole body vibration conditions as measured 1, 10, and 20 minutes post-treatment. Note: Values on x-axis are not proportional to time.

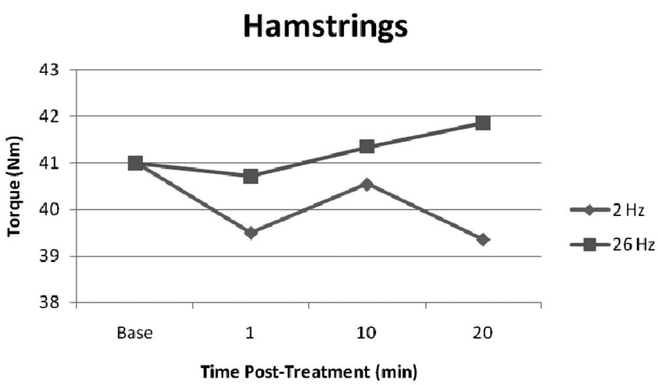

FIGURE 3. Hamstrings torque between 2 and 26 Hz whole body vibration conditions as measured 1, 10, and 20 minutes post-treatment. Note: Values on the x-axis are not proportional to time.

torque values were consistently greater after 30 seconds of WBV at 26 vs 2 Hz. In addition, quadriceps and hamstring muscle torque values continued to show a trend for improvement at 20 minutes after the 26-Hz vibration while performance began to decline by the 20-minute mark after the 2-Hz stimulus. The only previous WBV study involving persons with MS evaluated the effects of a lower frequency (2–4.4 Hz) multidirectional type of vibration on postural control (dynamic posturography, functional reach), and functional performance (Timed Up and Go).[19] Although there were temporary improvements in postural control and functional performance after a brief (five × one minutes) vibration exposure, changes were small and the clinical importance of the findings may be questionable. Because of the profound differences in vibration parameters and outcome measures between this study and ours, it was difficult to make any direct comparisons.

However, a recent study[23] involving subjects with subacute strokes, used WBV parameters (20 Hz, 5-mm amplitude) and outcome measures (isometric/eccentric torque) that were similar to those of the present study. In this investigation, the authors reported significant improvements in isometric and eccentric knee extensor torque, 36.6% and 22.2% ($P < 0.05$), respectively, immediately after WBV. They also reported a postvibratory increase in EMG activity of the knee extensors with a corresponding decrease in EMG activity of the knee flexors. We did not find similar improvements in our study, but several important differences must be pointed out. First, and most important, is the difference in patient populations. Although both MS and stroke can cause upper motor neuron lesions, the pathology is quite different. It is possible that the loss of myelin in the cerebrum and spinal cord associated with MS and the potential for impaired nerve conduction could limit the motor response to vibration as well as afferent transmission of the vibration stimulus to multilevel polysynaptic spinal reflexes and supraspinal centers involved in the vibratory reflex.[9] Second, the subjects with stroke were exposed to four consecutive one-minute bouts of WBV, whereas our subjects received a single 30-second exposure. It is conceivable that in our attempt to ensure that we provided a nonfatiguing stimulus, we did not use an optimal or even adequate vibration dose to see significant effects.

Several other factors also need to be considered when evaluating the results of our study. First, our decision was to measure only the strength of knee flexors and extensors. Previous researchers have shown that during WBV, the vibration stimulus is attenuated in a distal to proximal manner, with muscles such as the gastrocnemius, soleus, and anterior tibialis showing greater activation and training responses than more proximal muscles of the knee and hip.[10,28] Perhaps if we had measured ankle plantar flexion and dorsiflexion torque, changes in muscle performance would have been more apparent. The primary reason that we chose to assess the knee flexors and extensors was because of the established test-retest reliability in persons with MS[27] and the potential to compare our data with those of previous research demonstrating changes if knee muscle function after WBV.[13,23] A second issue was our decision to position the knee at 60 degrees of flexion for isometric testing. In hindsight, it may have been better to position the knee at the same joint angle (25 degrees) that was maintained during the WBV exposure in accordance with principles of training specificity.

As mentioned previously, there is conflicting evidence for both the short- and long-term use of WBV in active younger adults. However, there is a growing body of evidence showing potential benefits of longer term WBV training (two to three weeks × eight to 12 weeks) in sedentary individuals and older adults.[17,28,29] The results of these studies also show that it is important to perform some type of exercise activity (squats, lunges, calf raises) while using WBV and that distal musculature maybe preferentially affected.[28] Because many patients with MS are sedentary and have difficulty with voluntary activation of distal lower extremity muscles, studies involving longer term WBV combined with simple exercises maybe warranted.

Although this study demonstrated no significant changes in muscle performance after a single brief exposure to WBV, the information gained may help in the design of future research studies on both the short- and long-term effects of WBV in persons with MS. Another potentially useful finding of this research was that a single brief exposure to WBV was well tolerated by persons with MS who had a wide range of disability.

CONCLUSION

The main purpose of this study was to determine whether a brief 30-second exposure to WBV transiently improves knee muscle performance in persons with MS. The results of this study showed no significant difference in isometric torque production after WBV at frequencies of 2 and 26 Hz. However, there was consistent trend for improved torque production in both the quadricep and hamstrings muscles after the 26-Hz stimulus that continued for at least 20 minutes that was not evident in the 2-Hz condition. Whether WBV presents a viable treatment option as either a neuromuscular warm-up activity or as a long-term exercise modality for persons with MS is yet to be determined. Future short- and long-term studies should include a wider variety of vibration parameters, the evaluation of additional muscle groups and the use of functional outcome measures.

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