Video Article

Whole Body Vibration Methods with Survivors of Polio

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URL: https://www.jove.com/video/58449
DOI: doi:10.3791/58449

Keywords: Behavior, Issue 140, Poliomyelitis, post-polio syndrome, whole body vibration, weight bearing exercise, therapeutic exercise, feasibility

Date Published: 10/17/2018

Citation: Da Silva, C.P. Whole Body Vibration Methods with Survivors of Polio. *J. Vis. Exp.* (140), e58449, doi:10.3791/58449 (2018).

Abstract

The purpose of the original study was to examine the use of whole body vibration (WBV) on polio survivors with and without post-polio syndrome as a form of weight bearing exercise. The goal of this article is to highlight the strengths, limitations, and applications of the method used. Fifteen participants completed two intervention blocks with a wash-out period in between the blocks. Each block consisted of twice a week (four weeks) WBV interventions, progressing from 10 to 20 min per session. Low intensity (peak to peak displacement 4.53 mm, frequency 24 Hz, g force 2.21) and higher intensity (peak to peak displacement 8.82 mm, frequency 35 Hz, g force 2.76) WBV blocks were used. Pain severity significantly improved in both groups following higher intensity vibration. Walking speed significantly improved in the group who participated in higher intensity intervention first. No study-related adverse events occurred. Even though this population can be at risk of developing overuse-related muscle weakness, fatigue, or pain from excessive physical activity or exercise, the vibration intensity levels utilized did not cause significant muscle weakness, pain, fatigue, or sleep disturbances. Therefore, WBV appears to provide a safe method of weight bearing exercise for this population. Limitations included the lack of measurement of reflexes, muscular activity, or circulation, the difficulty in participant recruitment, and insufficient strength of some participants to stand in recommended position. Strengths included a standard, safe protocol with intentional monitoring of symptoms and the heterogeneity of the participants in their physical abilities. An application of the methods is the home use of WBV to reduce the barriers associated with going to a facility for weight bearing exercise for longer term interventions, and benefits for conditions such as osteoporosis, particularly for aging adults with mobility difficulties due to paralysis or weakness. Presented method may serve as a starting point in future studies.

Video Link

The video component of this article can be found at https://www.jove.com/video/58449/

Introduction

Whole body vibration (WBV) is reported to give benefits similar to customary exercise in adults, those who are normal or with medical conditions. A vibration platform provides motorized, oscillatory movement to the whole body while the person stands on it. Improvements in pain[1,2], strength[3,4], balance[5,6,7], bone density[4,6,8,9], and flexibility[5] have been reported. In del Pozo-Cruz *et al.*'s[10] systematic review of WBV studies with people with neurologic conditions, vibration frequencies ranged from 2 to 50 Hz, amplitudes from 0 to 14 mm, 1 to 11 bouts with 1–3 min of rest between bouts, total vibration time per sequence of 0.5 to 15 min, and number of sessions from 1 to 240. WBV acute significant effects were seen in functional balance tests and quadriceps isometric strength in people with multiple sclerosis, postural control and movement items on the Unified Parkinson Disease Rating Scale (UPDRS) in people with Parkinson's disease, and quadriceps isometric and eccentric strength in people post stroke. The only significant change that lasted through the follow-up period was in the UPDRS in people with Parkinson's disease. The reviewers reported that there are few high quality methodological studies available for review and poor consistency of the data between studies[10]. A pilot study with adults with chronic incomplete spinal cord injury showed significantly faster walking speed and improvement in various gait parameters[11]. However, a small study with survivors of polio was discontinued due to preliminary data analysis failing to show significant improvement in walking speed and strength[12].

Because of the large variations of frequencies and magnitudes used in the WBV intervention studies in the neurologic populations[10], the studies reporting the effects of WBV with bone mineral density in post-menopausal women[4,6,8,9], older adults[6,13,14], and people with fibromyalgia[15] were reviewed due to most of the current study's population of survivors of polio being of similar ages, experiencing problems in participating in traditional weight bearing exercises, and having problems with pain and fatigue. In these review studies, 10 to 40 Hz (most in 30 to 35 Hz range) vibration frequencies, with 1-8 mm amplitude, and variable g forces were used[4,6,8,9,10,13,14,15]. In 2010, Rauch *et al.*[16] published a manuscript describing the need for the standardization and recommendations for reporting WBV studies.

Survivors of polio, with or without post-polio syndrome (PPS), may be challenged in their determination of methods in which to exercise in weight bearing positions to maintain bone density or for other wellness purposes because of their residual weakness or other symptoms of PPS. Exercise has been reported to potentially overly fatigue already overused muscles and worsen symptoms of pain, fatigue, and increased weakness[17,18]. Few studies with small sample sizes have shown exercise to be safe and beneficial in this population[19,20,21,22,23,24].

The goal of the previously conducted study was to examine the use of WBV on polio survivors, with and without PPS, as a possible safe form of weight bearing exercise. Only one prior published study had addressed the use of WBV in people with PPS. The post-polio population has unique issues of chronic muscle weakness or paralysis and joint involvement that impacts their ability to participate in weight bearing exercise; therefore, an exploratory limited-efficacy feasibility study was determined to be necessary[25]. This article expands upon and demonstrates the method used in the previously published study[26]. The purpose of this article is to highlight the strengths, limitations, and applications of the method used in that study.

Protocol

The protocol being described in this article follows the protocol used in the previously published study that abided by the ethical standards for human research of the Internal Review Boards of Texas Woman's University and Baylor College of Medicine in Houston, Texas, USA[26].

1. Participant Screening and Study Preparation

1. Screen all participants for inclusion and exclusion criteria by phone, and then ask them again about these criteria while in person during the approved informed consent process.
    1. Ask the participants about their polio history and whether they have been diagnosed with PPS.
    2. Ask if the participants have any concern about being able to bear weight through their lower extremities (LEs) at least 20 min in short blocks of time.

2. Review the exclusion criteria commonly reported in the literature and used in the previously published study[26] for appropriateness for a future study.
   NOTE: Typical exclusion criteria are body weight more than 227 kg (vibration platform maximum), current medical conditions such as cancer, infection, wound, fracture, thrombosis/embolism, epilepsy, severe migraine headaches, severe vestibular conditions, discopathy, spondylolysis, or implanted devices, metal fixators or joints.
    1. Check the weight limit of the selected or available vibration platform, and weigh the participants in person if they appear close to that body weight maximum.
       NOTE: A typical bathroom scale may not measure weights high enough. Many vibration platforms have weight limits of 227 kg or 500 lbs.

3. Determine the inclusion criteria that will be specific to the target population and clinical or laboratory setting. If a physician is not on the study team, consider requiring the participants to seek medical approval from their personal physician, for reasons similar to someone starting a new exercise program.
   NOTE: In the previously reported study[26], the participants were English speaking survivors of polio, with or without PPS, 40–85 years of age, and able to weight bear through their LEs up to 20 min. Note that their ability to walk was not an inclusion criterion.
4. Document the reasons why the individuals do not agree to participate in the study and why they withdraw, if that occurs. Determine if the withdrawals need to be reported to the Internal Review Board of the institution or facility.
5. Explain to the participants what the experimental design is (in lay terms), what to expect in terms of time commitment per session, how many sessions, and how many weeks or months the study will last.
6. Explain to the participants that they will be standing up or weight bearing on the vibration platform for several short bouts for each session and what the vibration will feel like.
    1. Show the participants the vibration platform. If the participants seem hesitant during the informed consent process and baseline testing, offer to turn on the platform to show the participants how it works. Inquire if he or she wishes to try it briefly prior to starting the intervention in the next session.

2. Experimental Design

1. Use random assignment to groups, if possible. If a randomized controlled study is selected, consider offering a delayed-start intervention for the control group to help avoid disappointment or attrition due to the lack of interest.
   NOTE: The previously conducted study used a random-order cross-over experimental design with two weeks for a wash-out period and a two-week follow-up period; therefore, all participants received the same dosage or amount of vibration intervention with treatment block order randomized (low intensity first/high intensity second or high intensity first/low intensity second). No control group was used due to anticipated small sample size[26].
2. If the participants will use any type of written log for the symptoms such as cramping or activity levels, provide the log for them in paper or electronic version, based upon their preference. Request their log each week to help them keep up with their documentation and to avoid recall bias issues.
3. Build in a follow-up period with repeat testing in the study design to see if any changes persist.
4. Be available by email or phone for questions or concerns that may arise during the study period.

3. WBV Interventions

1. Schedule the sessions with at least one day off in between sessions, two to three times per week to avoid undue fatigue or muscle soreness.
    1. Select the number of weeks of intervention based upon the current literature and the outcome measures selected.
       NOTE: Because the previous study was a feasibility study, two four-week intervention blocks with treatment order randomized were used to determine if the WBV would be a safe and tolerable method to achieve weight bearing exercise[26]. Gains in bone mineral density will require months, whereas other gains can occur immediately or in days or weeks.

2. Instruct the participants to stand on the WBV platform with the knees slightly bent and weight as evenly distributed between their two LEs as possible[27,28]. Allow the participants to support themselves with their arms, as needed, for balance during the vibration and when stepping up and down from the platform.
3. If the person is not able to stand at all or stand long enough, allow him or her to sit in a chair or wheelchair, with the feet on the platform, forearms resting on thighs, leaning forward to achieve as much weight bearing through the lower body as possible, still keeping the feet on the platform.
    1. If the motorized wheelchair has a seat elevator, raise the seat as high as possible.
    2. If the person will be sitting in a standard chair, ask him or her to sit on some folded blankets or pillows to raise the hips up into a higher position.
    NOTE: The closer the LEs are to a standing position, the more weight bearing will occur through the LEs to enhance vibration stimulation into the body.

4. Ask the participants to remove their shoes and LE orthoses (braces) and wear socks (for cleanliness) during the vibration. Offer socks with rubber treads on them if the person is not wearing socks or is apprehensive of standing or stepping on the tile floor of the lab.
    1. Explain to the participants that wearing only socks on their feet will enhance their nerve stimulation to their muscles, spinal cord, and brain for peak effectiveness.
    2. Explain to the participants that the orthoses are to be removed because the vibration may cause rubbing between the orthosis and their skin, putting them at risk for skin breakdown. Inform the participants that it may also cause hardware loosening of metal components of the braces.

5. Encourage each person to move into his or her optimal alignment.
NOTE: For people with significant LE weakness on one or both sides, they may not be able to weight bear symmetrically or stand with knees flexed, especially without their orthoses.
6. Use a wedge or cuff weight under the heel to accommodate leg length discrepancies or plantarflexor contractures, if necessary, to allow weight bearing through as much of the plantar surface of the foot as possible.
7. Start with ten 1 min vibration bouts, with 1 min sitting rest periods between the vibration bouts. Increase to ten 2 min vibration bouts, and do not change the rest periods unless needed or requested by the participant. See Table 1 for a typical intervention progression.
    1. Take the person's vital signs.
    2. Observe this person who had polio as a child step up onto the platform used for the low intensity protocol.
    3. Instruct the person to stand with the knees slightly bent, weight as evenly spread between two feet as possible.
    4. Tell the person that he/she can hold onto the handle if he/she needs to balance, but to hold it as lightly as possible.
    5. Inform the person that he/she will feel the vibration in the soles of his/her feet, radiating up into his/her body.
    6. Ask the person if he/she is ready to start, and when he/she says yes, turn on the machine.
    7. Use a timer set for 1 min for the first session if the platform does not have a preset time choice.
    8. After 1 min of vibration has ended, ask the person to sit down for 1 min to rest, setting a timer, offering to answer any questions he/she may have.
    9. After the 1 min rest, ask the person if he/she is ready to step up and resume the vibration. If so, continue for total of 10 repetitions of vibration.
    10. If the person is not ready to continue, ask why, and provide more rest, as needed. Document how much rest time is required, if different than the established protocol.
    11. Repeat this sequence with the higher intensity protocol, but inform the person that the intensity is higher, and he/she may feel it spread higher into his or her body.
        1. Conversely, if using a two-intensity protocol and the person starts with the higher intensity intervention first, warn him/her that the second lower intensity will be quite gentle compared to what he/she is used to.
        Note: The platform used for higher intensity vibration actually elevated a little, and it gradually lowered during the preset time. As it reached the end of the time, returning to the starting position, the vibration intensifies, so inform the participant that this phenomenon will occur beforehand to avoid undue concern.

8. WBV intensity and equipment
    1. Use a medium to higher intensity (peak to peak vertical displacement 8.82 mm, 35 Hz, and g force 2.76) vibration to allow significant effects. Depending on the targeted population and selected outcome measures, choose more or less aggressive settings.
    NOTE: The previously published study[26] used settings in an attempt to simulate that reported for bone mineral density studies, thinking ahead to possible future studies. The second platform listed in the **Table of Materials** was used for this intensity. It is a commercial grade platform that was available in the research lab of Texas Woman's University. The settings used were 35 Hz, "low amplitude", and desired time.
    2. Because low intensity (peak to peak vertical displacement 4.53 mm, 24 Hz, g force 2.21) vibration did not cause any significant changes, do not use this intensity or less unless the targeted study population is very frail, fearful, or both. Then if the participants are able to tolerate this intensity, gradually increase it for each person.
    NOTE: The first platform listed in the **Table of Materials** was used for this intensity. It was purchased for the original study through Post-Polio Health International. It is a unit designed for home or personal use. It has no handles, and a grab rail was installed on the laboratory wall to ensure safety. This platform had a rotating dial, and the lowest setting was selected. A separate timer was used for on and off times.
    3. Ideally, select a vibration platform that the amplitude and frequency can be set independently for individualization to the unique needs of the study population. See **Table of Materials** for the vibration platforms used in the previously reported study[26].
    NOTE: Both units used for the reported study had synchronous vertical displacement during vibration. Some units have asynchronous vertical displacement, rotating over a center; in these, the wider the person's base of support is [feet further from center], the more intense the vibration[16].
    4. Use an independent accelerometer to determine peak to peak displacement, frequency, and g forces.

NOTE: Manufacturers may not provide all required information, and it is needed for accurate reporting of methods and equipment used[16]. G forces reported above were measured by an accelerometer listed in **Table of Materials**.

5. When reporting the amplitude of vibration platforms, be careful with the terminology due to inconsistencies in the literature.
   NOTE: The term amplitude is to be used for equilibrium point to peak displacement. Although the term peak to peak displacement is synonymous with peak to peak amplitude, and this value will be twice that of traditional amplitude, the use of peak to peak displacement is preferred to avoid confusion[16].

4. Participant Testing

1. Take heart rate and blood pressure prior to all testing and intervention sessions, especially if working with people with neurologic conditions. Keep in mind that hypertension is considered a “silent killer” and that many people may have this problem and not be aware of it or fail to take prescribed medications for it.
   1. Take the participants’ vital signs again, after at least the first few sessions to ensure safety, and during sessions if the participants experience symptoms that could indicate excessive exertion or abnormal responses to vibration.
2. Ask the participants to report perceived exertion with a standardized scale, after each intervention session.
   NOTE: Borg’s rating of perceived exertion [RPE] is widely used and has sound psychometric properties[29].
3. To reduce testing bias, have a licensed physical therapist blinded to intervention administer selected outcome measures pre and post each intervention block and at the end of the follow-up period.
   NOTE: A double blinded study with vibration interventions will be difficult to conduct because the participants will be able to feel the vibration.
4. Select reliable and valid outcome measures that address more than one domain (body functions and structure, activities, and participation) of the International Classification of Functioning, Disability and Health (ICF) of the targeted population[30].
   1. When available, use measures that have sound psychometric properties for the population. For less common populations, use more generic measures or ones that have been tested for populations similar in some way. Consider the use of the following outcome measures for survivors of polio, although none were developed specifically for them.
   2. Measure physical performance of gait speed by 10 m walk test (10mWT)[31] and gait endurance by 2 min walk test[32].
   3. Administer surveys to determine pain severity and interference by the Brief Pain Inventory (BPI)[33,34], sleep quality by the Pittsburgh Sleep Quality Index[35], and fatigue by the Fatigue Severity Scale[36,37].
   4. Measure LE strength by manual muscle test and handheld dynamometry[38,39,40].
   5. Provide log forms or calendar for participants to document muscle cramping incidence.
      NOTE: No sensory outcome measures were selected in the previously reported study due to the fact that sensory impairments in polio survivors occur only in the presence of other medical conditions or comorbidities. The original poliomyelitis infection affected the anterior horn cells of the spinal cord (lower motor neurons) impacting motor function while preserving sensory function[17,18].

Representative Results

Fifteen of the 21 survivors of polio who consented completed the study, with 14 of those completing the study having PPS. The six people who withdrew did so for nonstudy-related reasons (five work and/or time issues, one medical concern). See **Table 2** for demographic characteristics of the participants[26].

No significant differences were found between demographic characteristics and pre-intervention outcome measures between the two treatment groups using descriptive statistics and Mann-Whitney *U* tests. Mann-Whitney *U* tests were also conducted between the high and low intensity conditions on measures at pretest, posttest, and follow-up for between subject differences. Within subject changes between pretests and posttests were conducted by Wilcoxon signed-rank tests, and Friedman's analysis of variance test was used to study the change over time from pretest through follow-up due to total of five testing sessions to reduce the risk of committing a Type I error with multiple Wilcoxon signed-rank tests. Nonparametric tests were conducted due to the small sample size and lack of normality[26,41]. Pain severity as measured by the BPI improved significantly after the higher intensity WBV intervention regardless of treatment order (Z = -1.97, p = 0.049, Cohen's d = 0.60), with BPI pain interference trending towards significant improvement (Z = -1.92, p = 0.055, Cohen's d = 0.81). Gait speed significantly improved after the higher intensity intervention, but only for the group that participated in the higher intervention block first, even though both groups experienced both intensities of vibration in intervention blocks (Z = -2.38, p = 0.017, Cohen's d = -1.294). See **Table 3** for the data and results for the 10mWT, BPI pain severity, and BPI pain interference. No significant changes occurred in the other outcome measures and following the low intensity protocol, and no changes that occurred were maintained during the two week follow-up period[26].

No study-related adverse events occurred. Even though this population can be at risk of developing overuse-related muscle weakness, fatigue, or pain from excessive physical activity or exercise, the vibration intensity levels utilized did not cause significant muscle weakness, pain, fatigue, or sleep disturbances[26]. The representative results from the prior study need to be interpreted cautiously because of the small study sample size and the huge variability of muscle weakness, pain, walking patterns, and other issues with which survivors of polio present.

	Day 1	Day 2	Day 3	Day 4	Days 5-8
1 WBV on	1 min	1.25 min	1.5 min	1.75 min	2 min
1 Sitting rest off	1 min	1 min	1 min	1 min	1 min
2 WBV on	1 min	1.25 min	1.5 min	1.75 min	2 min
2 Sitting rest off	1 min	1 min	1 min	1 min	1 min
3 WBV on	1 min	1.25 min	1.5 min	1.75 min	2 min
3 Sitting rest off	1 min	1 min	1 min	1 min	1 min
4 WBV on	1 min	1.25 min	1.5 min	1.75 min	2 min
4 Sitting rest off	1 min	1 min	1 min	1 min	1 min
5 WBV on	1 min	1.25 min	1.5 min	1.75 min	2 min
5 Sitting rest off	1 min	1 min	1 min	1 min	1 min
6 WBV on	1 min	1.25 min	1.5 min	1.75 min	2 min
6 Sitting rest off	1 min	1 min	1 min	1 min	1 min
7 WBV on	1 min	1.25 min	1.5 min	1.75 min	2 min
7 Sitting rest off	1 min	1 min	1 min	1 min	1 min
8 WBV on	1 min	1.25 min	1.5 min	1.75 min	2 min
8 Sitting rest off	1 min	1 min	1 min	1 min	1 min
9 WBV on	1 min	1.25 min	1.5 min	1.75 min	2 min
9 Sitting rest off	1 min	1 min	1 min	1 min	1 min
10 WBV on	1 min	1.25 min	1.5 min	1.75 min	2 min
Total time on	10 min	12.5 min	15 min	17.5 min	20 min

Table 1: Scheduled WBV protocol, assuming no adverse events or problems tolerating intervention.

	Total Sample	Completing Participants
	(N=19*)	(N=15)
Age (yrs, mean & SD)	63.53 SD 8.32	63.80 SD 9.40
Age onset polio (yrs, mean & SD)	3.55 SD 4.03	3.70 SD 4.80
PPS diagnosis (yes/no)	18/1	14/1
Gender (male/female)	8/11	6/9
Race/ethnicity		
African American/Black	2 (1 mixed)	1
Asian/Pacific islander	1	1
Hispanic/Latino	2	2
Native American	1 (mixed)	0
White	13	11
Walking status		
Full-time	12	11
Part-time	6	3
Not able to walk	1	1
Use of orthoses		
None	13	9
1 or bilateral AFOs	3	3
1 or bilateral KAFOs	2	2
Not applicable	1	1
Use of assistive devices		
None	12	8
1 or bilateral canes/walking sticks	5	5
Bilateral Canadian crutches	1	1
Not applicable	1	1
Working status		
Full-time	6	5
Part-time	4	2
Retired	9	8
* 2 females withdrew from original 21 who consented, prior to data collection.		
AFO: Ankle foot orthosis		
KAFO: Knee ankle foot orthosis		
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Physiotherapy Theory and Practice, Da Silva C.P., *et al.*[26]		

Table 2: Demographic characteristics of the participants.

Measure	Lo-Hi Group	Hi-Lo Group	Between Subject Differences *p(d)*	Within Subject Differences *p(dz & eta squared)*
	n=6	n=9		
	Mean (Mdn) & SD	Mean (Mdn) & SD		
	Min-Max	Min-Max		
10mWT (m/s)				
Pre-Hi	1.32(1.07) SD 0.51	1.11(1.03) SD 0.39	0.346(0.46)	
	0.86-2.11	0.69-1.82		
Post-Hi	1.24(1.09) SD 0.49	1.27(1.17) SD 0.47	0.698(0.06)	0.087(0.52)
	0.76-1.96	0.82-2.08		
BPI Interference				
Pre-Hi	3.14(2.50) SD 3.14	3.62(3.57) SD 2.50	0.796(0.17)	
	0.29-7.57	0.00-7.57		
Post-Hi	2.26(.00) SD 3.09	2.39(2.57) SD 2.40	0.862(0.05)	0.055(0.81)
	0.00-5.86	0.00-5.14		
BPI Severity				
Pre-Hi	3.29(2.75) SD 2.57	3.44(3.50) SD 1.74	0.795(0.07)	
	0.75-7.25	0.00-5.50		
Post-Hi	2.68(0.13) SD 3.63	2.61(2.50) SD 2.65	0.674(0.02)	0.049*(0.60)
	0.00-7.25	0.00-5.75		
*Significant difference				
Lo-Hi group: low intensity intervention first, higher intensity intervention second				
Hi-Lo group: higher intensity intervention first, low intensity intervention second				
Hi: Higher intensity intervention				
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Physiother Theory Pract, Da Silva C.P., *et al.*[26]				

Table 3: Representative results from outcome measures.

Discussion

Two different vibration intensities were studied due to the author's clinical experience in working with survivors of polio and hearing their reports of increased muscle weakness, pain, fatigue, and other symptoms of PPS. Little evidence is present in the literature related to safe, effective weight bearing exercise parameters for people with PPS, and only one study[12] was published prior to the current study[26] with WBV and survivors of polio. To date, only two published articles have studied the use of WBV with polio survivors, and both used the platforms with synchronous vertical oscillations[12,26]. Therefore, no scientific literature exists related to the use of asynchronous vertical (rotatory) or horizontal vibration in this population.

This author was concerned about possibly worsening their symptoms during the WBV protocols, thereby selecting one intensity fairly typical of that reported in the bone density studies and one much lower, in case the participants would have difficulty tolerating the higher one. The author was vigilant during each vibration session and regularly asked if new symptoms surfaced or typical ones worsened at the beginning of the next session. Group means of RPE after higher intensity sessions were 9.4 to 9.8, or "very light," although the range extended from "no exertion at all" to "extremely hard." Although significant changes only occurred for pain severity across both groups, polio survivors and those who provide care for them may be encouraged that gait endurance, muscle strength, and typical PPS symptoms of fatigue, sleep disturbances, and muscle cramping did not significantly worsen during participation in the protocols. Therefore, a strength of the presented methods includes the use of a standard protocol with intentional monitoring of symptoms by a consistent health care provider knowledgeable about their condition. Because no significant improvements occurred with the low intensity protocol, this intensity or less could possibly be considered for use in a sham intervention in a future randomized controlled study.

Although the knowledge of the effects of WBV with survivors of polio is limited, some critical steps may exist. Due to their typical "type A", hard-working, and eager-to-please personalities, one must ask them specific questions and give them explicit permission to voice concerns or potential problems, such as muscle or joint discomfort, excessive muscular fatigue, or sense of worsened balance, that may arise during the intervention period. Similarly, limiting the WBV total dosage (frequency and intensity)[16] per session to no more than 20 min (in one to two min bouts with forced rests) and scheduling sessions with at least one day off in between can help reduce risk of muscle overuse-related fatigue, pain, and cramping[17,18].

The mechanisms behind how WBV affects a person's neurophysiological system is poorly understood. The literature has not reported how changes due to WBV in the Hoffman, stretch, and tonic vibratory reflexes of polio survivors who have a depleted alpha motor neuron pool due to initial disease destruction are impacted[42,43,44,45,46,47]. Reported circulatory changes[42], in addition to reports of vibration decreasing delayed-onset muscle soreness after exercise[48], may enhance the polio survivors' weaker muscles to work at safe levels for longer time periods during functional activities, such as walking. A limitation of the presented method in this article is that measurement of reflexes, muscular activity, and circulation did not occur.

A second limitation of the method may be that it was tested on such a small group of polio survivors. Recruitment of people to come to a university research lab in the Texas Medical Center twice a week for three months was challenging due to the time, energy, and transportation costs of commuting within a huge metropolitan city. However, a noteworthy amount of participant diversity in physical mobility existed in the 15 individuals who completed the previously reported study[26], which could be considered a strength. As seen in **Table 2**, they ranged from not being able to walk at all, to walking "5%" of total locomotion, to walking full-time, and using no devices at all to utilizing a pair of knee ankle foot orthoses with crutches. All participants except one were able to independently get onto and off the vibration platforms, using the provided handles or grab bar. Even though the participants were able to use their arms for support as needed or preferred, some were unable to shift their weight onto the weaker leg or stand without mechanically locking their knees because of their weakness. Standing with the knees locked could be a potential joint safety issue for some people, and this could be considered a limitation to this method; however, locking also allows more of the vibration g force to extend more cranially[27,28]. However, this author was surprised by how positively the individuals responded to the vibration during the sessions, with smiles, early arrivals for appointments, requests to "turn it up", and few to no complaints, even with some them dependent on orthoses or assistive devices for safe walking or appearing physically frail. Participants were noted to spontaneously shift weight and change postural alignment, apparently seeking the body position that "felt best" to them. The vibration was truly "whole body" in that it could be heard in their voices while talking during vibration, and dangling earrings or bracelets could be seen or heard to vibrate.

The presented WBV method seems to be a safe, tolerable, and feasible form of weight-bearing exercise for people with weakness or paralysis from polio and PPS. Short lasting improvements in pain and walking speed for some individuals are encouraging for polio survivors who have limited methods to exercise, especially in weight bearing positions. Further research is necessary in order to study long term use and efficacy of WBV in people with PPS and other neurological conditions, particularly to address decreasing barriers to exercise participation and active pursuit of wellness activities. An application of the presented method is the safe use of a WBV platform designed for home use to reduce the barriers of energy, time, and transportation costs associated with going to a health club or therapy clinic. Use within the home can make a longer term intervention feasible, particularly for people with mobility difficulties. Longer intervention studies (at least eight months) will be needed to determine if WBV can significantly impact bone mineral density in female and male polio survivors who have a higher prevalence of osteopenia and osteoporosis than typically aging adults[49,50,51,52]. Additionally, examining the application of WBV in aging adults with neurologic conditions other than post-polio and its effects on bone mineral density will be important, and the presented methods may serve as a starting point in these studies.

Disclosures

The author has nothing to disclose.

Acknowledgements

The original study was funded by Post-Polio Health International in 2013, with no cost extension to 2014. Funding for this article was through Texas Woman's University Libraries' Open Access Fund. The results were presented as a poster at the American Physical Therapy Association Combined Sections Meeting, Anaheim, California, US, 2016, and published as a manuscript in *Physiotherapy Theory and Practice* in 2018 (see reference #26).

The author wishes to acknowledge Elson "Randy" Robertson for his assistance during the filming of the video and participation in the original study. She also wishes to acknowledge the following people for their assistance during the original study: C Lauren Szot, PT, DPT, NCS and Natasha deSa, PT, DPT, NCS as blinded testers and co-authors for original manuscript; Arianne Stoker, PT, DPT, Kelly Hodges, PT, DPT, NCS, Mariana Sanjuan, PT, DPT, and Maggie Strange, PT, DPT for help as DPT students during vibration sessions; and Zoheb Allam, MS and Rene Paulson, PhD for statistical assistance.

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