BOHR International Journal of Neurology and Neuroscience
2023, Vol. 1, No. 2, pp. 87–92
DOI: 10.54646/bijnn.2023.12
www.bohrpub.com

METHODS

Whole-Body vibration therapy: an overview

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Received: 04 July 2023; **Accepted:** 18 July 2023; **Published:** 11 August 2023

Concern has been raised about whole-body vibration training (WBVT), which activates skeletal muscles by employing vibrations rather than a mass load or dynamic exercise. As vibration massage and local vibration applied to muscles show promising benefits, vibration treatment and exercise became widely used in rehab. Studies are still being conducted to fully comprehend the cumulative impacts and long-term safety of this training program. This study gives an outline of WBVT, explaining its physiology and advantages as well as some safety aspects, contraindications, and instructions for applying it in a clinical environment.

Keywords: WBVT, QOL, posture, frequency, tonic vibration reflex, eccentric exercise

1. Introduction

Vibration training (VT), which stimulates the skeletal muscles by using vibrations rather than a mass load or dynamic exercise, has drawn a lot of concern (1). It has acquired popularity as a practical strategy for enhancing muscle function since it is a non-invasive physical therapy that offers vibration platforms for passive exercise stimulation (2). Whole-body vibration training (WBVT) has emerged as an effective approach for improving muscular performance and inducing adaptive neuromuscular changes through biomechanical and physiological effects (3). Whole-body vibration (WBV) has gained popularity as a technique for clinical and performance improvement. Numerous studies have emphasized the advantages of including WBV as a low-intensity exercise because of its capacity to raise bone mineral density (BMD) in osteoporosis patients while also lowering fall risk due to an improvement in balance and strength (4).

Whole-body vibration training effects depend on a number of variables, such as fundamental vibration parameters, vibration mode, training posture, and training frequency (3). The duration of work, rest intervals, number of sets, and sessions are adjusted based on the patient's clinical and physical conditions. For preserving astronauts' skeletal muscle mass and strength and enhancing athletic performance, WBVT is a common training technique that increasingly gains attention in exercise rehabilitation. (2).

Whole-body vibration is a low-intensity exercise that uses a platform that oscillates and generates sinusoidal vibrations. There are two widely used types: (1) a side-alternating (also known as horizontal) oscillating platform that employs a fulcrum to alternately elevate the left and right sides of the body and (2) a vertical platform that delivers tri-axial acceleration with the majority of the vibration in the vertical direction, raising the body equally (4).

2. History

Scientists originally created whole-body vibration technology in the second half of the twentieth century to prevent astronauts from losing bone density and developing atrophy in their muscles, caused by zero-gravity exposure. WBV, often referred to as indirect vibration, involves exposing people to repetitive oscillations produced by a mechanical instrument that produces sinusoidal waveforms with a certain amplitude and frequency. Commercial vibration platforms have proliferated in performance spaces and institutions around the country during the past 20 years. As a result, researchers in sports performance and athletic training have started investigating the use of WBV in trained individuals (5).

JM Granville made a major advancement in the discipline in 1881 when he first presented the idea of employing mechanical vibration to relieve pain. WBVT, however, did not become well-known or widely used as a training method among athletes until the 1980s. Individuals participating in WBVT experience external oscillation vibrations while standing on a vibrating platform. Although the majority of platforms use one or both of the widely used energy transfer technologies, their technical capabilities vary. While some devices use a vertical vibration mode that sends vibrations simultaneously to both feet, others use a seesaw-like side-alternating mode. Since these two methods focus on different neurophysiological movement patterns, there is a continuous discussion concerning whether the strategy is more advantageous (6).

3. Physiological changes

Vibration therapy and exercise were extensively utilized in rehab, with vibration massage and local vibration applied to muscles showing promising results. Vibration massage has been discovered to possess circulatory effects. Moreover, when vibration is applied to muscle bellies, it promotes motor responses, even in cases of pathological conditions. The tonic vibration reflex, a reflexive action triggered by vibration therapy, is widely regarded as one of the primary factors responsible for the increased neuromuscular stimulation observed during and following such therapy. Vibration also stimulates somatosensory regions of the cerebral cortex and amplifies the myotatic reflex, thereby enhancing voluntary movements. Furthermore, the elevation in muscle temperature, improved perfusion, and reduction in mechanical vibration can potentially have a favorable effect on force production (7). Various theories have been proposed to explain the WBV responses, including the tetanic vibration reflex, angiogenic factors promoting capillary growth, hormone secretion, and stem cell activation. These acute effects are attributed to the activation of the "tonic vibration reflex," which induces muscle contractions primarily in the lower limbs. Following a single WBVT session, positive effects have been observed, such as improved blood circulation, enhanced muscle performance and balance, and increased production of human growth hormone. WBVT also shows potential for improving postural control and intermuscular coordination and counteracting muscle atrophy and bone density loss associated with immobility (5, 6).

Exercise performed on vibrating platforms can influence the skeletal system in two ways: by potentiating muscle contractions, which are essential for bone health, and by transmitting vibration as a mechanism for strain activation that encourages bone growth and increases bone mineral density. Vibration has also shown the potential to influence pain perception through a mechanism analogous to transcutaneous electric nerve stimulation (TENS). The combination of rapid cyclic contractions and the valuable sensory information provided by mechanical oscillation on the platform can improve flexibility and proprioception. While hormonal responses to WBV exercises have been identified, their replication has not been consistent. Ongoing studies are being conducted to gain a comprehensive understanding of the cumulative effects and long-term safety of this training regimen (7).

During vibration exercise, the muscle-tendon complex undergoes cyclic changes between elongation and shortening due to the vibration stimulus. This vibration-induced stretching and shortening trigger reflex contraction through the activation of primary and secondary spindle endings and Golgi tendon organs. The stretch reflex and H-reflex are suppressed, whereas corticospinal excitatory pathways are facilitated. Research has shown that vibration can elongate the gastrocnemius muscle-tendon complex by approximately 1% of its total length. Vibration also affects electromyography (EMG) activity, exhibiting vibration-synchronous EMG responses in specific muscles. Additionally, vibration exercise increases energy metabolism and adenosine triphosphate (ATP) turnover (8). The sinusoidal oscillations energize muscle spindle primary endings, leading to the activation of α-motor neurons, and has been recognized as the tonic vibration reaction, fast eccentric-concentric involuntary contractions. Various propositions propose adaptive muscular mechanisms associated with vibration therapy, including muscle activity synchronization, Golgi tendon organ stimulation, activation of antagonistic muscles, and potential modulation of neurotransmitters such as dopamine and serotonin (9).

Vibration exercises elicit acute neuromuscular responses and increase serum anabolic hormone concentrations, similar to resistance exercise (10). The precise mechanism by which the body responds to vibratory stimuli remains uncertain. However, the activation of the neuromuscular system, particularly the tonic vibration reflex, is a commonly proposed mechanism. WBVT optimizes the stretch reflex and motor unit recruitment through sensory stimulation and afferent pathways. The neuromuscular system may also adjust muscle activity to dampen vibrations, contributing to improved motor unit synchronization and overall muscle function. Additionally, there is speculation that WBVT may have a preventative effect on muscle damage by distributing contractile stress more evenly among active muscle fibers through eccentric exercise (11).

The musculoskeletal system relies on dynamic mechanical loading to maintain bone strength and muscle function. Reduced functional loading, often caused by conditions that limit mobility, can lead to bone fragility. Dynamic mechanical loading is necessary for bone development, with varying intervals between loading episodes. Within the bone matrix, dynamic load offers both magnitude and frequency components. Vibration therapy, specifically low-intensity vibration (LIV), delivered as a low-magnitude, high-frequency stimulus, provides a safe and effective means to supply mechanical signals to the musculoskeletal system. In addition, the combination of large- and high-frequency, low-magnitude signals generated from muscle contractions plays a crucial role in maintaining bone strength. Vibration therapy targets various cell types involved in bone remodeling, including mesenchymal stem cells, osteocytes, and osteoclasts. It promotes the differentiation of bone-forming cells (osteogenic differentiation) while reducing bone resorption. Moreover, vibration therapy's low-intensity mechanical signals have anabolic effects on bones, potentially mediated indirectly through extraskeletal tissues. Notably, vibration therapy enhances muscle strength, size, and performance, possibly by improving neuromuscular efficiency. Additionally, it stimulates the expression of anabolic genes in tendons and may increase bone density by reducing fat accumulation. The underlying molecular mechanisms responsible for these responses involve enhanced β-catenin signaling, improved gap junction communication, and acceleration of the cell nucleus. Remarkably, these mechanisms operate independently of traditional factors such as matrix strain or fluid shear. WBVT shows promise in improving bone quality and strength, particularly for individuals unable to engage in high-impact exercises. Low-intensity WBV has demonstrated the ability to increase BMD and enhance muscle function. Combining WBV with exercise has yielded positive outcomes, especially among post-menopausal women and individuals with low bone density (12).

The cutting-edge complete active rehabilitation osteoporosis rehabilitation plan (ICARO), which includes WBV, is essential. The beneficial effects of vibratory treatment on bone formation are supported by the piezoelectric hypothesis. This idea states that when pressure is applied to bones, an electrical potential difference is created that accelerates the process of bone growth. WBV prevents disorders like osteoporosis and sarcopenia by increasing the levels of growth hormone (GH) and testosterone in the blood. The advantages of vibration treatment are explained by the fact that the upright posture is regarded to be a more effective bone-growth stimulator than the horizontal position. Furthermore, vibration therapy enhances neuromuscular coordination and improves muscle strength, which is particularly beneficial for individuals with osteoporosis because it lowers the possibility of falls and consequent fractures (13).

Muscle oxygenation and blood flow are strongly connected. During exercise, blood flow to the working muscle increases as a result of a variety of factors, including increased oxygen and fuel requirements and raised carbon dioxide and hydrogen ion concentrations, among others. Changes in peripheral blood flow due to WBV treatment may disclose a possible mechanism of action for WBV therapy. One typical therapeutic goal of employing treatment approaches is to improve circulation at the site of musculoskeletal injury during the fibroblastic repair and maturation-remodeling phases of healing. These indices, which are numerical assessments of the cardiovascular system's autonomic function, can be a helpful tool for determining operational stress. Physical vibration was shown to be connected to the workload by the percentage of heart rate reserve, but driving duration was not. The construction machine's remote operators, who experienced the least vibration while running it, also had much lower MSEs and HRV indices than the riders, who felt the most vibration. As a consequence, the hypothesis that the physical vibration of construction workers negatively affects the HRV and MSE was confirmed. Furthermore, it was demonstrated that the driving time of the construction machine was inversely connected with the vibration intensity of the operating environment, as well as the HRV and MSE measurements. The operator's various HRV indices are lower in this circumstance because of a greater sympathetic nervous system tone and sympathetic balance in a setting with high vibrations and a lower parasympathetic nervous system tone (14).

4. General effects

Vibration therapy offers promising benefits for individuals with different clinical populations. In Parkinson's disease, the therapy improves motor symptoms by using random vibrations with specific parameters. For fibromyalgia patients, the focus is on pain and fatigue control, employing vertical vibrations at designated frequencies. Frail adults with osteopenia can enhance their balance and increase BMD through side-alternating vibrations. Each clinical population requires tailored exercises and varying frequencies to address their specific needs, showcasing the versatility and potential of vibration therapy in promoting overall well-being and symptom management (7).

Whole-body vibration training is gaining recognition as a viable practice to improve neuromuscular function in physical therapy, particularly for older adults. It offers convenience as it can be easily administered at home or at rehabilitation centers by having participants step on a vibrating surface during training sessions. WBV provides several benefits across multiple organs and systems in the body. In older adults, it has been shown to improve balance, strength, functional mobility, decreased oxygen intake, quality of life, increased blood flow, increased bone mineral density, decreased body fat percentage, and improved cardiovascular, vascular, and pulmonary functions. Its applications span a variety of fields, including the rehabilitation of people with cerebral palsy and stroke, the treatment of musculoskeletal pain, and the monitoring of blood sugar in diabetic patients. Additionally, WBVT has demonstrated its ability to enhance physical capabilities in older adults with sarcopenia, and some evidence suggests that systemic vibration may have even higher rehabilitative benefits for older adults and patients than for the general population (15).

A number of chronic illnesses and ailments, such as fibromyalgia, persistent lower back pain, osteoporosis, and multiple sclerosis, may benefit from WBVT (6). In terms of changes in maximum isometric and isokinetic force, plasma creatine kinase activity, muscle soreness, and pressure point threshold (PPT), the WBVT lessened the effects of exercise-induced DOMS (11). There are several WBVT devices available today that produce WBV using different mechanical concepts. The cardiovascular, musculoskeletal, endocrine, and neurological systems all react to WBV treatment in a thorough manner (9). In order to mechanically engage muscles, WBVT stimulates neuromuscular activity in the form of muscle reflexes. Studies on WBVT's effectiveness are conflicting. There have been reports of both favorable outcomes (increased flexibility, power, muscular strength, and performance) and unfavorable or no outcomes. This uncertainty is a result of various study designs, populations investigated, and WBV devices being employed (11).

5. Characteristics

In vibration training, the body is subjected to mechanical vibration on a shaking platform. However, when the person is unable to stand, specialist equipment has been used, such as a chair or a standing frame. Vertical platforms oscillate synchronously up and down, whereas side-alternating platforms oscillate on the left and right sides of a fulcrum. Horizontal and random vibration platforms are also employed, but to a lesser extent. From the platform's lowest position to its highest point, its displacement might vary from 1 to 14 mm. Vibration training methods may entail applying the stimulus once, several times, or over an extended period of time. The exposure may be acute or chronic in nature. Exposure times per application might range from 15 s to 10 min. Standing exercises or a variety of activities, such as static or dynamic motions, can be used in vibration exercises. Squats, lunges, and calf raises are examples of lower-body workouts. Push-ups, body planks, and triceps dips are examples of upper-body activities. Typical specified joint angles and foot placements are full or half squats and broad or narrow stances. Rest periods between exercises can range from 10 to 60 s, and the number of repetitions per exercise may vary from 1 to 3. The frequency refers to the rate at which cycles or oscillations occur within a second and usually falls within the range of 6–45 Hz. The magnitude of vibration is directly related to the gravitational force acting on the body in the vertical direction. It is commonly quantified in multiples of Earth's gravity (up to 15 g) to indicate the intensity of the vibration experienced. The frequency of sessions is the number of times per week the exercise is performed, ranging from 1 day to 1 week. To increase the intensity of the exercise, participants can incorporate additional weights, such as a weighted vest or dumbbell. Finally, participants may choose to perform vibration exercises barefoot, in socks, or with tennis shoes, depending on their preference and comfort. These factors collectively contribute to the characterization and customization of vibration exercise protocols (7).

Due to the availability of several devices with varying features, the scientific literature on vibration treatment is complicated. While low-intensity vertical vibrations are often accepted successfully, the use of high-intensity exercise equipment may have negative consequences. Devices can produce high-magnitude (> 1 g) or low-magnitude (1 g) forces, depending on the combination of displacement and frequency that causes the body to accelerate. It's vital to remember that equipment promoted as fitness supplements frequently weighs more than 4 g, making it inappropriate for elderly or fragile individuals looking to strengthen their bones. Therefore, while choosing a treatment plan, doctors and rehabilitation professionals are advised to pick tools that give low-intensity (1 g), horizontally directed vibrations at high frequencies (30–100 Hz), and clear information regarding vibration characteristics (12).

Utilizing all of the lower leg muscles while employing personalized WBV on the lower body will maximize the biochemical reaction. As a result, hormone levels rise, which is related to the volume of muscles used during exercise and their intensity. The lack of agreement on the best way to create WBV training programs, however, has produced erratic outcomes. Muscle activation and motor unit recruitment can be enhanced by tailoring WBV by altering its amplitude and frequency. Acceleration, duration, and external load are all WBV size characteristics that have been linked to pain. According to recent studies, the testosterone response is size-independent, whereas the GH response is dramatically increased when WBV is delivered to the upper extremities (10).

Both very high (> 100 Hz) and extremely low (20 Hz) vibrational frequencies might have negative consequences. The entire body's resonance frequency is in the low-frequency band, which causes great transmissibility and negative impacts. To counteract these effects, clinical studies frequently use WBV in the frequency range of 20–60 Hz. High frequencies can strain muscles and damage soft tissues, and those above 60 Hz may worsen the symptoms of hand-arm vibration syndrome (HAVS). In untrained women, knee extensor muscle torque was increased by WBV at 30 Hz frequency and 4 mm peak-to-peak amplitude over the course of 8 weeks. Factors such as load-bearing and exercises during vibration therapy can enhance muscle strength and physical performance. However, the research discrepancies arise due to variations in vibration parameters and subject posture. High-frequency WBV may have negative consequences, and low-frequency and low-intensity vibrations are ineffective. Further investigation is needed to establish optimal WBV protocols with scientific justification for parameter choices (16).

6. Safety aspects

Modifying standards to account for vibration in rehabilitation and exercise is crucial. Vibration transmission varies across the body parts and postures, with resonance at around 5 Hz in the trunk and below 20 Hz in the lower extremities. Adjusting posture and using side-alternating vibration significantly minimize the transmission. Knee flexion and side-alternating vibration can reduce transmission to the head and trunk. While the potential harm from exercise-related resonance is uncertain, caution is advised for frequencies around 5 Hz and below 20 Hz. Novices should be educated about potential risks, and unauthorized access to vibration platforms should be prevented. Hand-transmitted vibration causes vibration white finger disease, which impairs hand function. It remains unclear if similar conditions occur in the lower extremities. Recommendations for occupational exposure to hand-held vibration tools should be considered, and further investigation is required to comprehend the dangers of high vibration during whole-body activities (8).

7. Implications for practice

When selecting a device, it is advisable to choose a validated machine with peer-reviewed published data. Independent confirmation of parameters such as acceleration, frequency, and amplitude is preferable. Some devices have limited options for manipulating frequency and displacement, offering pre-defined programs with poorly described vibration characteristics. Instead of depending simply on vendor recommendations, it's critical to utilize the lowest effective dose, adhere to established training routines, and employ vibration settings that have been shown to be safe and effective. Before participating, it is important to seek medical clearance when working with clinical populations (7).

When initiating a training regimen involving WBV, it is essential for individuals to wear footwear equipped with thin and rigid soles. The purpose of this recommendation is to avoid excessive dampening of vibration resulting from footwear. To make sure the consumer can withstand WBV, it is advisable to begin with a shorter duration, decreased frequency, and displacement from a peak to a peak during the initial sessions. Each exercise should not last more than 20–30 s in the beginning to allow for enough recovery time. However, it is important to note that this principle may not be applicable when performing basic standing exercises. By escalating the exercise's amplitude, frequency, length of time, and repetition count while reducing the recovery period, one can progress in intensity. Proper foot positioning is vital, ensuring that feet are properly positioned on the ground with the toes slightly inclined outward. Certain exercises, such as calf lifts and single-leg squats, can be executed with this proper foot placement. The handrail can enhance safety, but for certain balance exercises, it may not be necessary. It is important to avoid a locked knee position during all exercises to restrict the propagation of vibration from the torso to the head. The healthcare provider should conduct close monitoring of common side effects, such as brief itchiness, skin redness, tightness in the muscles, headaches, mild tenderness in the knees, and discomfort in the front of the foot. When considering the possible advantages and acknowledged risks, WBV exercise can be advantageous for clinical populations in situations where alternative means of exercise are impractical due to time limitations, a lack of interest in participating in traditional programs, a lack of finances, or an inability to perform load-bearing impact activities (7).

8. Contraindications

Whole-body vibration therapy has several contraindications, particularly related to various health conditions. People who have recently had a myocardial infarction, a pacemaker, prosthetic heart valves, hypertension, uncontrolled venous thrombosis, or an aortic aneurysm should avoid participating in WBV training, according to the cardiovascular experts. In the musculoskeletal domain, individuals with hip or knee endoprosthesis, lower body metal implants from osteosynthesis, osteoporosis with a vertebral fracture, an acute spinal disk herniation, recent fractures, an acute soft tissue injury, joint inflammation, or recent fractures should avoid participating in WBV training. In terms of neurological conditions, WBVT is not recommended for those who have deep brain and/or spinal cord stimulation, epilepsy, migraines, peripheral neuropathy, decreased cognition that interferes with exercise training, or any other neurological condition. WBVT is also prohibited in cases of acute limb edema, pregnancy, tumors or metastases, reduced skin integrity, recent surgery, and incontinence of the bowel or bladder. It is essential to take these contraindications into account and seek guidance from healthcare professionals to ensure the safety and appropriateness of WBVT based on individual health conditions and considerations (7).

9. Conclusion

Whole-body vibration training has emerged as a valuable therapeutic approach with multiple physiological benefits. It is an efficient approach for improving muscular performance and inducing adaptive neuromuscular changes through biomechanical and physiological effects. However, more research is needed to optimize protocols, standardize procedures, and further explore its potential in various clinical populations.

Conflict of interest

The authors declare that there were no financial or commercial ties that may be seen as having a possible conflict of interest during the conduct of the research.

Author contributions

All authors have contributed equally to this study.

Funding

This study was supported by the State Commissionerate for Persons with Disabilities, Kerala.

Acknowledgments

We express our gratitude to S. H. Panchapakesan Commissioner, State Commissionerate for Persons with Disabilities, Kerala for his support.

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