THE USE OF VIBRATION EXERCISE IN CLINICAL POPULATIONS

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LEARNING OBJECTIVES

- Describe whole body vibration exercise.
- Understand the rationale for the use of vibration exercise.
- Understand current evidence in support of vibration exercise in clinical populations.
- Understand the basic guidelines for prescription of vibration exercise.

Key words:
Whole Body Vibration, Training, Rehabilitation, Neurological Disorders, Osteoporosis

Performing exercise on a vibrating platform has gained popularity over the past decade among athletes. The potential therapeutic benefit of vibration also has been studied recently in clinical populations, although its clinical use began much earlier, in the 1940s, with the use of a special bed that delivered mechanical vibration to prevent bone loss in immobilized subjects (43). Further development was undertaken more than 30 years later in Eastern Europe, with "biomechanical stimulation" being used with Russian cosmonauts to prevent muscle atrophy and osteopenia while in space. At about the same time, localized vibration was applied in gymnasts to enhance strength and flexibility (17). Subsequently, the physiological effects of recreational whole body vibration (WBV) were studied, and efficacy trials were conducted to assess its influence on muscular strength. Despite its history, the mechanisms underlying vibratory exercise and its advantages over regular exercise remain unclear. Recent reviews offer contradictory conclusions, suggesting "no or only minor additional effects on muscle strength and jump performance" (26) to "greater strength improvement compared with conventional resistance training" (23). Methodological problems, common to almost every study, hinder internal validity and the variability among protocol limit comparisons.

Recently, there has been growing interest in the use of vibration in clinical populations to improve health and functional capacity, moving beyond the focus on elite athletes and strength. Clinical trials have been developed in patients with neurological, musculoskeletal, and metabolic diseases and outcomes other than strength (*e.g.*, balance, proprioception, pain, body composition, quality of life, and disease severity) have been studied.

WHAT IS VIBRATION EXERCISE?

Vibration training relies upon application of a mechanical oscillation to the body using a vibrating platform. This vibration is usually delivered with

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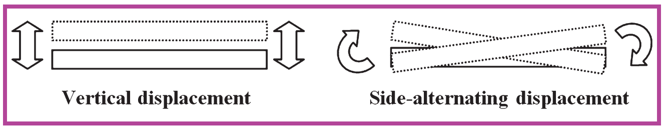

Figure. Types of whole body vibration platforms.

the person standing, although special devices have been used when the person is unable to stand, such as a standing frame or a chair. In the standing position, the vibratory wave propagates from the feet to the legs, thighs, and upward to the trunk and head. Subjects can perform voluntary muscle contractions (*e.g.*, squats) throughout the exposure. Commonly, the platforms have handle bars for safety or support and a display screen to indicate machine settings.

Vertical platforms, which oscillate synchronously up and down, are used, as are side-alternating platforms, which oscillate on the left and right side of a fulcrum (Figure). To a lesser extent, horizontal and random vibration platforms also are used. With side-alternating platforms, it is important to know that the amplitude of platform displacement changes with foot position. For example, there is an increased displacement when the feet are further apart from fulcrum. Other components of a vibration exercise prescription are listed in Table 1 according to recent guidelines (21,27).

Chronic exposure to vibration has been studied only in the occupational setting. Some negative side effects have been identified, including spinal degeneration, vestibular disturbances, and vascular and neurological conditions (34). Guidelines have been published to limit the exposure to industrial WBV, but intermittent exposure while exercising on a platform has not been addressed (16). Although WBV uses frequencies and amplitudes lower than occupation vibration, a recent study (1) estimated that the vibration dose in typical vibration training regimens (10 minutes a day at 30 Hz, 4-mm displacement) exceed the recommendations (16). They also concluded that vertical vibration, a fully upright position, and full-squat exercises were potentially harmful and that knee flexion of 26 to 30 degrees should be encouraged to minimize head vibration (1). Exercises that involve lying or sitting on the platform (*e.g.*, doing push-ups) should be avoided. In addition, recent work showed that amplitudes above 0.5 mm can lead to unpredictable high peak accelerations and may pose a risk to fragile bone and cartilage (19).

The most common reported side effects are transient itching and tingling (feet, legs, and nose), skin redness (legs), and muscle soreness. Incorrect exercise technique also could result in headache, motion sickness (if too much vibration is transmitted to the head), and anterior knee pain (if squatting is involved). However, no serious adverse effects were reported in recent reviews that included clinical populations (24,35).

Before starting a vibration exercise program, the participant should be screened for possible contraindications. Exclusion criteria used in clinical trials are likely good standards to follow (8,24). A nonexhaustive list is provided in Table 2.

HOW VIBRATION EXERCISE WORKS

Vibration massage and application of local vibration on the muscles have been used extensively in rehabilitation. Vibration massage has documented circulatory effects, whereas applying a vibrating stimulus to a muscle belly has been shown to facilitate motor responses, even under pathological circumstances. This reflex muscle contraction is known as the *tonic vibration reflex* (12). Although it was studied with localized vibration rather than WBV, and with higher frequencies than those usually used in

TABLE 1: **Characterization of Vibration Exercise**

Type of vibration	Vertical (synchronous), side-alternating, random, horizontal
Frequency	Number of cycles (oscillations) per second (6 to 45 Hz)
Peak-to-peak displacement	Extent of the vibration, displacement of the platform from the lowest to the highest point (1 to 14 mm)
Magnitude	Vertical acceleration imposed to the body, usually measured in multiple of Earth's gravity (9.81 m/s^2) (up to 15*g*)
Protocol	Single or multiple application of the stimulus
	Acute exposure or chronic exposure (more than one point in time)
Duration	Exposure to vibration per application (15 seconds to 10 minutes)
Type of exercises	Standing only or exercise
	Static or dynamic exercises
	Lower body: squats (two legged or single legged), lunges, calf raises
	Upper body: push-ups, body plank, triceps dips
	Joint angles of limb (*e.g.*, full squat, half squat) and precise foot position should be predefined (*e.g.*, wide or narrow stance)
	Rest periods between exercises (10 to 60 seconds)
	Number of repetitions per exercise (1 to 3 repetitions)
Frequency	Number of sessions a week (1 to 7 days)
Additional loads	Vest with weights, dumbbells
Footwear	Barefoot, socks, or tennis shoes

TABLE 2: Contraindications for the Use of Vibration Training

Conditions	
Musculoskeletal	Hip or knee endoprosthesis
	Osteosynthesis with metal implant in lower body
	Acute vertebral disk herniation
	Recent fracture
	Acute soft tissue injury
	Joint inflammation
	Osteoporosis with vertebral fracture
Cardiovascular	Recent myocardial infarction
	Pacemaker
	Artificial heart valves
	Uncontrolled hypertension
	Venous thrombosis
	Aortic aneurysm
Neurological	Epilepsy
	Migraine
	Peripheral neuropathy
	Impaired cognition that precludes exercise training
	Deep brain and/or spinal cord stimulation
Other	Pregnancy
	Acute limb edema
	Impaired skin integrity
	Tumors or metastases
	Recent surgery
	Bladder and/or bowel Incontinence

vibration exercise, it is thought to be one of the primary mechanisms to explain the increased neuromuscular activation during and following vibration. There are several ways vibration may potentiate muscular contraction. Together with enhancing the stretch reflex, vibration also stimulates somatosensory areas of the cortex, which can facilitate subsequent voluntary movements (7). Increased muscle temperature, due to better perfusion and dampening of mechanical vibration, also may have a positive effect on force generation (29). Theoretically, with more powerful muscle contractions (during the WBV exercise), the conditioning stimulus would be stronger than conventional resistance training.

Exercise done on a vibrating platform may influence the skeleton in at least two ways. First, it may potentiate muscle contractions that are known to be important osteogenic stimuli. Second, vibration transmitted by the platform is perceived as a strain-activating mechanism that promotes bone formation, ultimately leading to an increase in bone mineral density (BMD) (29). Vibration also has been shown to influence pain perception, possibly by a "gate-control theory"–mediated effect, similar to transcutaneous electric nerve stimulation (22,29).

The improvement of flexibility after stretching while on a vibrating platform can be attributed to diverse causes, namely, heat-related facilitation, circulatory factors, and increased pain threshold (17,29). While on the platform at lower frequencies (up to 12 Hz), one experiences rapid cyclic transition between concentric and eccentric contractions, underlying attempts to maintain balance, and dampen the vibration. The mechanical oscillation provides valuable sensory information to cutaneous and joint receptors, and the vestibular system, likely improving proprioception (25).

Hormonal responses to WBV exercise have been identified but not consistently replicated. Some studies reported acute increases of growth hormone, insulin-like growth factors, and testosterone that could corroborate the anabolic effect of vibration training on muscle and bone (6,9,20).

Little is known about the cumulative effects of WBV exercise, whether "more is better" or whether there is a plateau after which no further benefit is seen. In most studies, follow-up assessments occurred soon after the end of the intervention, so the long-term safety and duration of benefits still have to be established for this type of training regimen. Whole body vibration exercise has the potential to positively influence motor response, strength, proprioception, bone quality, and pain control, which could benefit millions of patients by leading to an overall improvement in quality of life.

NEUROLOGICAL CONDITIONS

Whole body vibration exercise has been studied in patients with different central nervous system disorders such as Parkinson's disease, stroke, multiple sclerosis, cerebral palsy, and spinal cord injury. A recent review of seven trials concluded that "there was weak to moderate evidence for positive effects on postural control, mobility, motor function and strength after a single application of WBV" (44).

No conclusion could be made about long-term treatment as long-term studies are scarce. In Parkinson's disease patients, five acute bouts of 60 seconds of WBV (6 Hz, 6 mm peak-to-peak displacement, random vibration platform) resulted in reduced tremor, rigidity (38), and body sway (15), but no differences in knee proprioception (14). A protocol with 12 sessions over 5 weeks (five bouts of 1 minute at 6 Hz, 26 mm of peak-to-peak displacement, side-alternating platform) failed to show differences in gait, balance, hand dexterity, and disease severity between intervention and control groups (5), whereas a more intense program, with two daily sessions of 15 minutes for 3 weeks (25 Hz, 14 to 28 mm of peak-to-peak displacement, side-alternating platform) had similar effects on equilibrium and gait compared with conventional physiotherapy with a balance board (11).

In a 4-week crossover study, multiple sclerosis patients performed 10 exercises for 30 seconds on the platform (40 to 50 Hz, 4mm of peak-to-peak displacement, vertical oscillating platform) after a "massage"/warm-up period. No differences were detected between exercise with or without vibration for disease severity, spasticity, and functional measures (33). In respect to acute exposure, five 1-minute bouts, (2 to 4.4 Hz, 6 mm of peak-to-peak displacement, random vibration platform) improved "timed-get-up-and-go" test performance and reduced body sway (32). Positive acute effects on postural control also were shown in stroke patients, with four 45-second periods of exposure (30 Hz, 6 mm of peak-to-peak displacement, side-alternating platform) (39). A transient increase in knee extension strength was shown with a similar protocol (six bouts of 1 minute at 20 Hz, 5 mm of peak-to-peak displacement), showing the capability of WBV to influence the motor response of affected limbs (36). A longer regimen of 6 weeks with subacute patients (four bouts of 45 seconds, 5 days a week, at 30 Hz, 6 mm of peak-to-peak displacement, side-alternating platform) failed to show any additional recovery in terms of balance or activities of daily living (40).

In adult cerebral palsy patients, an 8-week WBV regimen (3 days a week, 3 to 8 bouts of 30 to 110 seconds at 25 to 40 Hz, vertical oscillating platform) was as good as leg press for improving quadriceps strength without negative effects on spasticity (2).

A 6-month study (10 minutes a day, 5 days a week at 90 Hz, 0.1 mm of peak-to-peak displacement) of disabled children with cerebral palsy or muscular dystrophy reported a significant increase in tibial BMD, despite poor compliance. However, no significant benefit was found for spinal BMD (42).

MUSCULOSKELETAL CONDITIONS

Whole body vibration exercise has been studied in different joint and musculoskeletal conditions including low back pain, knee osteoarthritis, total knee arthroplasty, fibromyalgia, chronic fatigue syndrome, anterior cruciate ligament-reconstructed knee, low BMD, and osteogenesis imperfecta. Although occupational vibration has been associated with disk degeneration and low back pain (34), WBV decreased low back pain in patients with chronic back

pain and osteoporosis, perhaps by better spinal proprioception and trunk muscle conditioning induced by vibration. An additional reason for the pain relief may be the analgesic effect of mechanical oscillations via a "gate-control theory." One intervention, a 3-month study of vibration exercise versus traditional resistance training (4 to 7 minutes, 1 to 2 times a week at 18 Hz, 12 mm of peak-to-peak displacement, side-alternating platform) used supplementary weight on the shoulders or upper arm while on the platform (30). The protocol involved standing with different foot positions, slow amplitude squatting, and slow movements of the hips and waist such as bending sideways, tilting back and forward, and left and right trunk torsions. Both types of training increased lumbar extension torque and reduced pain sensation.

Improved proprioception after 1 month of whole body vibration training also has been documented in patients recovering from an anterior cruciate ligament reconstruction (25). The vibration exercise group (4 to 16 minutes, 3 days a week at 30 to 60 Hz, 5 to 10 mm of peak-to-peak displacement, vertical oscillating platform) did a variety of static and dynamic exercises such as mini-squats, single leg mini-squat, lunges, and toe standing. Results were significantly better than conventional rehabilitation, consisting of lower body strengthening and tilt/wobble board training.

Vibration training has been used in fibromyalgia and chronic fatigue syndrome patients with promising results. A 6-week randomized controlled trial (4.5 to 18 minutes, 2 times a week at 30 Hz, 4 mm of peak-to-peak displacement, vertical oscillating platform) reported less pain and fatigue with WBV training, whereas with exercise alone, there was no amelioration. The protocol consisted of static and dynamic squats, unilateral squats, and calf raises after 90 minutes of traditional exercise (4). The addition of WBV exercise to a conventional exercise protocol resulted in additional benefits on disease symptoms.

WBV may be a promising modality to enhance bone density and lessen postmenopausal bone loss (28,35,37). Among subjects with low BMD, with diagnosed osteoporosis (18,31) or osteopenia (13), vibration has shown promising results. In patients not using osteoporosis medication, regular WBV exposure at 30 Hz over six (10 minutes, 5 times a week at 30 Hz, 10 mm of peak-to-peak displacement) and 12 months (10 minutes daily, at 30 Hz, 0.05 mm of peak-to-peak displacement, vertical oscillating platform) led to increases in femoral and spinal BMD (13,31). However, in a 12-month study with patients on alendronate, a biphosphonate drug that increases bone mass, there was no additional benefit of 4 minutes of exposure to vertical whole body vibration (12 Hz, once per week, 1.4 to 8.2 mm peak-to-peak displacement, side-alternating platform) (18). In populations known to have increased risk of bone loss (postmenopausal women, disabled patients), there are conflicting results, with some studies reporting benefits in femoral cortical bone, whereas others failed to show benefits (28,35,37).

MEDICAL CONDITIONS

Vibration exercise may be an alternative form of exercise for people who cannot or will not undertake other types of physical activity because of their medical conditions. WBV exercise has been shown to acutely increase oxygen consumption in healthy young and older people and overweight/obese patients, although this increase may not be enough to induce cardiovascular training or weight loss (8,10). Even with the use of additional weight and at higher frequency and amplitude, the oxygen uptake does not approach the values elicited by traditional aerobic exercise. Although perceived exertion may be high and fatigue can occur in just a few minutes, the conditioning stimulus may be insufficient to load the cardiovascular system (8).

IMPLICATIONS FOR PRACTICE

There have been aggressive marketing campaigns advocating for WBV platforms. The cost of a device can range from $200 (home units) up to $12,500 for a fitness/clinical facility unit. The money spent purchasing this device is not currently reimbursed because there is no prototype that is approved by the U.S. Food and Drug Administration as a medical device.

When purchasing a device, one should look for a certified machine, with peer-reviewed published data. Preferably, acceleration, frequency, and amplitude of the prototype should have been confirmed by an independent party. Not all devices allow manipulation of the frequency or peak-to-peak displacement; rather, they are limited to pre-defined "programs," and the characteristics of the vibration being delivered are not well described. A machine that delivers more acceleration is not necessarily better, as too much acceleration can be detrimental. The lowest effective dose should be used.

Practitioners should choose published exercise protocols and vibration settings for their patients/clients, with proven safety and efficacy rather than accept those recommended by vendors, which might not have strong scientific rationale. Some examples of protocols are given in Table 3 (3,4,15,41). The selection of participants should follow rigorous criteria (Table 2), and when working with clinical populations, one should seek medical clearance before participation.

When initiating a training regimen, the fitness professional should advise the client to wear shoes with thin hard soles to avoid

TABLE 3: Guidelines for Vibration Exercise Prescription

	Clinical Populations			
	Parkinson's Disease (15)	Fibromyalgia (4)	Frail Adults (3)	Osteopenia (41)
Goal	Improve motor symptoms	Pain and fatigue control	Improve balance	Increase BMD
Type of vibration	Random	Vertical (synchronous)	Side-alternating	Vertical (synchronous)
Parameters	6 Hz, 6 mm of peak-to-peak displacement	30 Hz, 4 mm of peak-to-peak displacement	5 to 12 Hz, 5 mm of peak-to-peak displacement	35 to 40 Hz, 1.7 to 2.5 mm of peak-to-peak displacement
Duration	1 minutes × 5, with 1-minute rest between bouts	30 seconds each exercise, up to 6 repetitions	5 to 30 seconds each exercise, 3 repetitions	Up to 30 minutes each session
		3 minutes recovery between repetitions	3 minutes recovery between repetitions	
Exercises	Simple standing	Static squat	Simple standing without using the handrails	Squat
		Dynamic squat	Body weight shifts from one leg to the other	Deep squat
		Calf raises	Slight foot lift and hold	Wide stance squat
		Body weight shifts from one leg to the other	One-legged squat	Lunge
Frequency	As needed to control symptoms	Twice a week	Thrice a week	Thrice a week

too much dampening of the vibration by the footwear during the exercise session. The first few sessions should be of shorter duration at a lower frequency and peak-to-peak displacement to ensure that the client can tolerate WBV. Duration of an exercise should not exceed 20 to 30 seconds initially with plenty of time for recovery (this principle may not apply when simple standing is being performed). As with any type of exercise, the progression should consider the client's tolerance and clinical status, being mindful of any preexisting conditions and contraindications. Increases in intensity can be achieved by increasing the frequency, amplitude, duration, and number of repetitions of the exercise and decreasing recovery time.

Correct foot placement is very important. Feet should be placed symmetrically on the platform, with toes pointed slightly outward. Some exercises can be performed with a single leg (squats, calf raises). The handrail should be used to enhance safety; however, some balance exercises may not be useful if performed while holding it. During all exercises, a locked knees position should be avoided to limit transmission of the vibration to the trunk and head.

The provider should look for the more common side effects, such as transient itching and skin redness, muscle soreness, headache, mild knee pain, and forefoot pain, and monitor them closely. In weighing the potential benefits and the known risks, WBV exercise in clinical populations may be useful when other forms of exercise are not feasible (time constraints, lack of motivation for conventional programs, limited human resources, not able to do weight-bearing impact exercise).

SUMMARY

There is no current consensus on the efficacy of vibration exercise, but there have been some very promising results. The potential to improve lower body muscle power, bone strength, proprioception, balance, and pain warrants further investigation. Studies with extended duration and follow-up periods are needed to better define long-term benefits and risk.

This novel type of exercise has been well tolerated by people with chronic conditions and even perceived by some patients as pleasant and easy. This training could be an alternative for people who otherwise would not be able to perform conventional exercise or just want to diversify their training.

Using published protocols when prescribing WBV (*e.g.*, volume, exercises, and device settings) should minimize unwanted side effects and increase the likelihood of effectiveness.

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CONDENSED VERSION AND BOTTOM LINE

Vibration exercise is a type of exercise that has recently gained in popularity and may benefit clinical populations. There have been trials with patients with neurological and musculoskeletal disorders that showed improvements in muscle power, bone strength, proprioception, balance, and pain. Although these results are promising, caution is warranted because of its injurious potential. The use of this type of training should follow published guidelines that have been shown to be safe and efficacious.