

## Whole body vibration therapy in fracture prevention among adults with chronic disease

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### Abstract

Due to various physical impairments, individuals with chronic diseases often live a sedentary lifestyle, which leads to physical de-conditioning. The associated muscle weakness, functional decline and bone loss also render these individuals highly susceptible to falls and fragility fractures. There is an urgent need to search for safe and effective intervention strategies to prevent fragility fractures by modifying the fall-related risk factors and enhancing bone health. Whole body vibration (WBV) therapy has gained popularity in rehabilitation in recent years. In this type of treatment, mechanical vibration is delivered to the body while the individual is standing on an oscillating platform. As mechanical loading is one of the most powerful stimuli to induce osteogenesis, it is proposed that the mechanical stress applied to the human skeleton in WBV therapy might be beneficial for enhancing bone mass. Additionally, the vibratory signals also constitute a form of sensory stimulation and can induce reflex muscle activation, which could potentially induce therapeutic effects on muscle strength and important sensorimotor functions such as postural control. Increasing research evidence suggests that WBV is effective in enhancing hip bone mineral density, muscle strength and balance ability in elderly patients, and could have potential for individuals with chronic

diseases, who often cannot tolerate vigorous impact or resistance exercise training. This article aims to discuss the potential role of WBV therapy in the prevention of fragility fractures among people with chronic diseases.

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**Key words:** Falls; Vibration; Exercise; Rehabilitation; Balance; Bone density; Muscle

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### FRAGILITY FRACTURES AND CHRONIC CONDITIONS

Individuals with chronic diseases might sustain varying degrees of impairments in different body systems that considerably reduce their capacity to engage in physical activity, which gives rise to secondary bone loss<sup>[1]</sup>. Certain chronic diseases (e.g. stroke and multiple sclerosis) also directly impair muscle function. For example, muscle weakness or atrophy is a common manifestation among individuals with osteoarthritis and chronic obstructive pulmonary disease (COPD)<sup>[2,3]</sup>, whereas spasticity is often observed in patients with stroke or multiple sclerosis<sup>[4,5]</sup>. As it is well known that muscle function is strongly correlated with the integrity of bone tissue<sup>[6-10]</sup>, people with impaired muscle function are particularly prone to secondary osteoporosis.

In addition to the problem of secondary bone loss,

people living with chronic diseases often have a number of fall-related risk factors, such as poor balance, compromised sensory function, impaired vision, and depression<sup>[11]</sup>. The combination of a sedentary lifestyle and impaired functional status could lead to further reduction in physical activity level, thereby triggering a vicious cycle of physical de-conditioning, bone loss, and falls. It is thus not surprising that individuals who live with chronic diseases often sustain an exaggerated fracture risk. For example, in stroke patients, a population that is known to have accelerated bone loss on the paretic side of the body<sup>[6,7,12,13]</sup> and elevated risk of accidental falls<sup>[14-17]</sup>, the risk of fragility fractures is more than seven times higher within the first year post-stroke, when compared with people with no history of stroke<sup>[18]</sup>. At 8 years post-stroke, the excess risk of hip fracture remains 23% higher than in the reference population<sup>[18]</sup>. Among individuals with Parkinson's disease, another population that is highly susceptible to falls<sup>[19-24]</sup> and secondary osteoporosis<sup>[25-28]</sup>, approximately 27% will sustain a hip fracture within 10 years of diagnosis, compared with only 9% among age-matched healthy subjects over the same follow-up period<sup>[29]</sup>. It is also worth mentioning that certain pharmacological agents used in patients with chronic diseases can exacerbate bone loss and increase the risk of fractures. One example is the long-term use of corticosteroids<sup>[30]</sup> in patients with advanced COPD<sup>[31]</sup> and rheumatoid arthritis<sup>[32]</sup>. Research has shown that corticosteroid treatment is associated with increased vertebral fracture risk in COPD patients<sup>[33,34]</sup>.

Fragility fractures have become a major public health issue<sup>[35]</sup>. As the global population is rapidly aging, the number of individuals who live with chronic conditions, and hence the incidence of osteoporosis, falls and fragility fractures can only be projected to increase. Fragility fractures can lead to serious consequences, including increased morbidity, mortality, and health care costs<sup>[36-38]</sup>. The outcomes are even more unfavorable if fragility fracture is superimposed on a pre-existing chronic disease. Di Monaco *et al*<sup>[39]</sup> have demonstrated that patients with a chronic neurological disease (stroke or Parkinson's disease) have a significantly longer period of hospital stay after a hip fracture than their peers without a history of chronic neurological disease. It has also been shown by Ramnemark *et al*<sup>[40]</sup> that the 1-year mortality rate following a hip fracture is significantly higher among patients with a stroke history (29.3%) than those without (16.8%). Moreover, among the hip-fractured patients who were independent in mobility pre-admission, only 38% of those with a stroke history could regain independent mobility status upon discharge from the hospital, compared with 69% of patients without a stroke history<sup>[40]</sup>.

In summary, patients living with chronic illnesses are highly susceptible to falls, bone loss and fragility fractures, which can lead to disabling, and sometimes fatal consequences. Hence, identifying effective intervention strategies to prevent or reduce fragility fractures through modification of fall-related risk factors and enhancement of bone health is of paramount clinical relevance.

## WHOLE BODY VIBRATION: POTENTIAL APPLICATION IN PATIENTS WITH CHRONIC DISEASES

It has long been demonstrated that high-frequency mechanical stimuli can produce a strong osteogenic effect in animal models<sup>[41-45]</sup>. The encouraging findings from animal studies have raised the possibility that the dynamic mechanical stress involved in whole body vibration (WBV) therapy could be a viable method to enhance bone density in humans<sup>[46]</sup>. In WBV therapy, the individual is required to stand on an oscillating platform that is capable of generating mechanical vibration signals of varying frequency, magnitude, and duration. As the vibratory signals also constitute a form of sensory stimulation and can induce reflex muscle activation<sup>[47,48]</sup>, WBV therapy is also proposed to have potential therapeutic effects on muscle strength and other important sensorimotor functions such as postural control<sup>[46]</sup>.

Mounting research evidence has suggested that WBV therapy is an effective treatment method to improve bone health, and modify fall-related risk factors (e.g. muscle strength, and balance ability) in older adults. A number of randomized controlled studies have examined the effects of WBV therapy on hip and lumbar spine BMD in postmenopausal women<sup>[49-55]</sup>. A recent meta-analysis by Slatkowska *et al*<sup>[56]</sup> has shown that WBV has a small but significant effect on hip BMD in postmenopausal women. No overall significant effect on lumbar spine BMD, however, can be identified<sup>[56]</sup>. In addition to the reported positive outcomes on bone health, WBV has also been shown to have a significant effect on improving leg muscle strength and balance performance in several studies<sup>[49-51,54,57-68]</sup>.

Patients living with chronic diseases could be potential beneficiaries of WBV therapy, considering that many of these individuals suffer from impaired muscle function, secondary osteoporosis, physical de-conditioning, and an elevated fracture risk. Research on the application of WBV in people with chronic diseases has flourished in recent years. The following section provides a summary of the findings on the effects of multiple sessions of WBV treatment in patients with chronic diseases. The WBV protocols employed in these studies are outlined in Table 1.

### **Chronic diseases that primarily affect the musculoskeletal system**

A recent randomized controlled study has examined the effect of WBV therapy on muscle strength and proprioception in older women with knee osteoarthritis<sup>[69]</sup>. The subjects were randomly assigned to one of three groups: WBV exercise performed on a stable platform, WBV exercise performed on a balance board, and controls. After 8 wk training, those who underwent WBV exercise on a stable platform had significantly greater gain in isokinetic knee extension/flexion torque and isometric knee extension strength than control subjects. In contrast, those who underwent WBV training on a balance board had signifi-

**Table 1 Application of whole body vibration therapy in chronic diseases: Protocol and results**

Study	Chronic condition	Study design	Sample size	WBV protocol					Main results
				Frequency of vibration (Hz)	Amplitude of vibration (mm)	Duration of WBV exposure per day	Treatment days per week	Duration of program	
Trans <i>et al</i> <sup>[69]</sup> , 2009	Osteoarthritis	RCT	52	24-30	Not reported	3-5 min	2	8 wk	WBV exercise on a stable platform resulted in significantly more gain in isokinetic knee extension/flexion torque and isometric knee extension strength than controls; WBV training on a balance board resulted in significantly more improvement in knee proprioception than controls
Ahlborg <i>et al</i> <sup>[70]</sup> , 2006	Cerebral palsy	RCT	14	25-40	Not reported	6 min	3	8 wk	No significant difference in ambulatory and gross motor function outcomes between the WBV group and resistance training group
Wunderer <i>et al</i> <sup>[71]</sup> , 2010	Multiple sclerosis	Single subject experimental design	3	40	2	30 min	2	6 wk	WBV resulted in increase in knee extensor muscle strength in all three subjects; WBV resulted in improvement in functional mobility (Timed Up and Go test) in two subjects
van Nes <i>et al</i> <sup>[72]</sup> , 2006	Stroke	RCT	53	30	3	4 min	5	6 wk	Gains in balance, mobility and activities of daily living were comparable to that in the conventional exercise group
Ebersbach <i>et al</i> <sup>[73]</sup> , 2008	Parkinson's disease	RCT	27	25	7-14	15 min/session, 2 sessions/d	5	3 wk	Gain in functional balance and gait velocity in WBV group was similar to those in the conventional physiotherapy group
Arias <i>et al</i> <sup>[74]</sup> , 2009	Parkinson's disease	Non-randomized controlled trial	21	6	Not reported	5 min	2-3	5 wk	Balance and mobility outcomes after WBV exercise were similar to those after control exercises without WBV
Baum <i>et al</i> <sup>[75]</sup> , 2007	Type II diabetes	RCT	40	30-35	2	4 min	3	12 wk	No significant difference in maximal isometric torque of the quadriceps and fasting glucose concentration after treatment among the WBV group, the strength training group and the flexibility training group
Roth <i>et al</i> <sup>[76]</sup> , 2008	Cystic fibrosis	Quasi-experimental (no control group)	11	12-26	7.8	6 min	3-5	6 mo	WBV resulted in no significant changes in the trabecular bone density of the tibia or spine; WBV induced an increase in explosive leg muscle strength
Rietschel <i>et al</i> <sup>[77]</sup> , 2008	Cystic fibrosis	Quasi-experimental (no control group)	10	20-25	0.6	9 min/session, 2 sessions/d	5	3 mo	WBV induced significant improvement in performance in the chair-rising test and the two-leg jump test

RCT: Randomized controlled trial; WBV: Whole body vibration.

cantly greater improvement in knee proprioception than the controls had<sup>[69]</sup>. However, it is unclear whether the reported benefits are related to the exercise itself or the addition of vibration during exercise.

**Chronic diseases that primarily affect the neurological system**

A number of studies have examined the effects of WBV therapy in adults with different types of chronic neuro-

logical diseases, including cerebral palsy<sup>[70]</sup>, multiple sclerosis<sup>[71]</sup>, stroke<sup>[72]</sup> and Parkinson's disease<sup>[73,74]</sup>. In a small-scale study that involves 14 adults with cerebral palsy, Ahlborg *et al*<sup>[70]</sup> compared the effects of an 8-wk WBV program and a resistance training program. It was found that WBV was no better than resistance training in enhancing ambulatory function and gross motor skills. Using a single subject experimental design, Wunderer *et al*<sup>[71]</sup> examined the long-term effects of WBV in three patients with mul-

multiple sclerosis. Increase in knee extensor muscle strength was obtained in all three subjects, whereas improvement in mobility as measured by the Timed Up and Go test was observed in two of the subjects. Although this study suggests that the application of WBV in patients with multiple sclerosis has promise, further research using a randomized controlled design is required to establish the clinical efficacy of WBV in this patient group.

Other investigators have examined the effect of WBV in stroke patients. In a randomized controlled trial of 53 patients with subacute stroke, van Nes *et al*<sup>[72]</sup> have reported that their 6-wk WBV program has led to significant improvement in balance, mobility and activities of daily living that was comparable to that produced by the conventional exercise program. The effects of WBV on neuromuscular performance in patients with Parkinson's disease have also been examined by Ebersbach *et al*<sup>[73]</sup>, who showed that their 3-wk WBV protocol did not result in significantly greater gains in functional balance and gait velocity compared with a control group who received conventional physiotherapy. In a non-randomized controlled trial, Arias *et al*<sup>[74]</sup> demonstrated that although improvement in balance and mobility were improved following 5 wk WBV, the treatment effect was similar to control exercises without vibration, which indicates that WBV has no additional effect in improving neuromuscular outcomes in Parkinson's disease patients.

### **Chronic diseases that primarily affect the respiratory and cardiovascular systems**

Few studies have investigated the clinical efficacy of WBV therapy in chronic diseases that affect mainly the cardiovascular or respiratory systems. A randomized controlled study investigated the effects of a 12-wk WBV program in individuals with type II diabetes<sup>[75]</sup>. The 40 subjects were randomly assigned to one of three groups: a WBV group, a strength training group, and a flexibility training group. The results showed no significant difference in maximal isometric torque of the quadriceps and fasting glucose concentration after treatment in the WBV group, the strength training group and the flexibility training group.

In contrast, Roth *et al*<sup>[76]</sup> examined the effect of WBV in adults with cystic fibrosis. The subjects received a home-based WBV exercise program for 6 mo, which resulted in no significant changes in the trabecular bone density of the tibia or spine. Improvements were observed, however, in explosive leg muscle strength, as measured by two-leg jump test (increase in muscle power and velocity) and one-leg jump test (increase in muscle force). The effects of WBV in patients with cystic fibrosis were also studied by Rietschel *et al*<sup>[77]</sup>. In their pilot study of 10 subjects with cystic fibrosis<sup>[76]</sup>, it was found that the 3-mo WBV training program resulted in significant improvement in performance in the chair-rising test (reduced time, increased maximal force, maximal power and velocity) and the two-leg jump test (increased force and velocity). However, these studies did not have a control group, and therefore the interpretation of results warrants caution.

In summary, based on the available research data thus

far, there is no evidence to suggest that WBV is superior to other exercise approaches in improving various neuromuscular outcomes in adults with chronic disease. This is in contrast to a good number of WBV studies in the general older adult population that have demonstrated the positive effects of WBV on balance performance and leg muscle strength<sup>[49-51,54,57-68]</sup>. It is possible that WBV protocols used in the general older adult population are not the optimal for inducing a therapeutic effect on the various outcomes of interest in patients with chronic disease. Perhaps a greater intensity and longer duration of training is required to obtain a significant treatment effect among patients with disabilities. It is also possible the non-significant results were partly due to the fact that small sample sizes were used, which had low statistical power. It would thus be difficult to detect a statistically significant difference, even if a true treatment effect existed. Surprisingly, despite the fact that bone health is a major health issue among patients with chronic disease, only one study has incorporated bone mineral density as the outcome<sup>[76]</sup>. There is a need for more research in this important area.

### **Adverse events**

Similar to studies in older adults and postmenopausal women, very few adverse effects have been reported in WBV studies in patients with chronic disease. There have been isolated cases of head discomfort and increased fatigue<sup>[76]</sup>. One patient with a history of arthropathy developed joint effusion, but the symptoms subsided as training progressed<sup>[76]</sup>. One patient with cystic fibrosis and a history of venous thrombosis developed new thrombosis of the superior vena cava<sup>[75]</sup>. It is unclear how closely the adverse symptoms were monitored during the course of WBV therapy in these studies. It is also uncertain whether long-term adverse effects can result from WBV therapy. Based on the available data, however, WBV therapy seems to be a safe treatment technique when applied to individuals with chronic disease.

## **CONCLUSION**

The research evidence on the clinical efficacy of WBV for improvement of bone health and modification of fall-related risk factors among patients with chronic disease is limited. Good quality randomized controlled trials are scarce. More research is needed to determine whether WBV therapy has a role in fracture prevention in individuals with chronic disease.

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