

# Good vibrations: the use of whole body vibration in rehabilitation

## Introduction.

The therapeutic benefits of short duration vibration appear to have been known for centuries. In recent years it has been used in both the medical and exercise arenas, where frequency specific vibration seems to have a variety of positive effects on the body. In the medical profession vibration has been used to treat illnesses such as osteoporosis and kidney stones, while in physical therapy the focus has been on improving postural control and mobility. In exercise science, whole body vibration training (WBVT) has demonstrated improvements in muscular strength, the enhancing of jumping and sprinting performance and flexibility. This relatively new biomechanical intervention has significant potential for a wide range of populations, including sports performers, exercise enthusiasts, older people, astronauts, and those with certain medical conditions; including issues around bone health, which would be an interesting area for physical therapist in increasingly sedentary population. The understanding of how WBV works, and how the signals are transmitted to the body, while also being aware of the potential benefits and dangers, are fundamental with regard to exercise usage and the development of research techniques and treatments parameters

## History of WBV.

It is believed that vibration was being used for therapeutic purposes in ancient Greece and in both the former East Germany and in Russia in the 1960s. It has been reported that scientists were experimenting with the use of cyclic oscillations and their effects on the human body, with increase in flexibility and strength, put to practical uses for athletes [1]. More recently, it is thought that early work by the Russian Space Agency pioneered the use of vibration training, to reduce the effects of microgravity on the musculoskeletal systems of its cosmonauts [2]. Although vibration is now utilised for a variety of purposes in both the medical and sporting arenas, it appears that our understanding of how human systems respond to these vibratory signals lags somewhat behind the availability of the vibration equipment, and inconsistencies and inaccuracies reported regarding vibration have the potential to limit the replication of studies. Despite over 400 papers published on WBV, there is a



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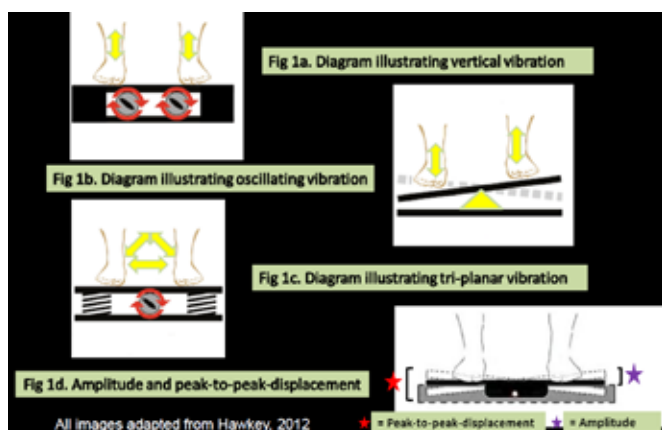
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need for more detailed studies on training parameters for different treatment goals.

## The science behind the shake.

Vibration can be described as a mechanical stimulus characterised by an oscillatory motion back and forth over the same pattern. We experience vibration throughout our daily lives and chronic vibration has been related to discogenic back pain, although results of epidemiologic studies has been mixed<sup>[3]</sup>. To cause bodily damage, the exposure needs to be prolonged. Whole body vibration training (WBVT) is a specific training modality, carried out on a vibration platform, which operate in a variety of movements; either linear (vertically, VV), oscillating (vertically on alternate sides, SV) or tri-planar (Fig. 1a-1c). It has been postulated that from a natural frequency, the lower limb muscles respond to a frequency range from 5 to 65 Hz<sup>[4]</sup>.

By adjusting the frequency and/or amplitude (A), the intensity of the training can be manipulated. Vibration frequency (f), simply quantifies the number of impulses (cycle rate) delivered every second (Hz). The majority of linear and tri-planar platforms have a frequency of 15 to 60 Hz, while oscillating platforms generally operate below 30 Hz. The extent of the vertical displacement from the centre point, corresponds to the amplitude, with platforms typically reporting a range of 1-15mm; although a number have fixed or set amplitude. It is important to stress that amplitude should not be confused with peak-to-peak displacement (Fig. 1d). The magnitude refers to the acceleration of the movement as magnitudes of gravity (G). The acceleration experienced, is equivalent to the acceleration of earth's gravity [9.81 m/s<sup>2</sup>]. The motion of vibration training is sinusoidal, and the peak acceleration ( $\alpha$ ) determines the acceleration transmitted to the body, and is a product of angular frequency ( $\omega$ ) squared and peak-to-peak amplitude (A). A vibration frequency of 26 Hz, with A of 6mm, would produce a peak acceleration of 160m/s<sup>2</sup> (16.3g). Pel et al<sup>[5]</sup> found the application of mass onto a platform, to alter its amplitude, and measurements by accelerometers, were not consistent with theoretical estimations, while Marín et al., [6] reported alterations of maximum muscle activ-



**Fig. 1a-d:** Types of vibration platforms and displacement – amplitude.

ity by wearing shoes. The type of platform utilized, time on the device and the addition of any external loading (e.g. dumbbells) can be manipulation, as well as the frequency, amplitude and positions, which are dependent on the region being trained. The positioning of the feet, on oscillating machines, is important and will have a direct effect on the amplitude, as standing more laterally will expose the body to a greater amplitude and acceleration (Fig. 1a-d)<sup>[7,8]</sup>.

Most studies have either been performed in a single or multiple sessions intermittently for 30–60 seconds, or continuously for 3 – 5 minutes<sup>[9]</sup>. It appears that acute intermittent protocol of 10 repeated exposures of 1 minute, with 1 minute rest, has been a common duration in WBV studies, but presently there is little scientific evidence, on the optimal duration.

There is debate, which vibration type is superior, and a research performed by Abercromby et al.<sup>[10]</sup> reported that vastus lateralis (VL) and gastrocnemius (GS) were activated significantly more during SV than VV, but tibialis anterior (TA) activity was greater during VV. Furthermore, during dynamic (10-35 °) and static squatting (18.5 °), SV produced greater activation of the lower limb muscles than VV. The amount of vibration transmitted to the upper-body and head was 71–189 % greater during VV than SV. The authors concluded that during SV, the pelvic rotations damps the vibration energy more than the VV<sup>[11]</sup>, and during SV, the shift between sides is decreasing the vibration effect reaching the head<sup>[12]</sup>, as well as by increased knee flexion<sup>[10]</sup>. In conventional training, the resistance is the training variable, and the tempo of the movement can vary. During WBVT, the opposite holds true: the mass typically remains constant, during isometric exercise, whereas the acceleration is varied, through manipulating the frequency and amplitude. The addition of functional movements with weights or as single leg training is an area that has shown promising clinical results, but there is a lack of scientific evidence from research studies (Fig. 2).

Modern vibration machines are based on research from the early 1960s, when rhythmic neuromuscular stimulation (RNS) was described. These studies showed that cyclic vibrations, could improve the condition of damaged joints by creating a quick stretch, followed by relaxation<sup>[13]</sup>. It is thought that vibration elicits changes through physiological adaptations to accommodate the vibratory waves<sup>[9, 14, 15]</sup> and by stimulation of neuromuscular pathways<sup>[16]</sup>.



**Fig. 2** Isometrics and squatting with hip external rotation stimulatoin in case of knee instability.



**Fig. 3** Single leg squat – side step downs.

Stimulating the primary endings of the muscle spindle (Ia afferent), will excite the motor-neurons, causing contraction of homonymous motor units. This results in a tonic vibration reflex, which can improve maximum voluntary contraction of muscles, especially when used in conjunction with a standard strength training program<sup>[17]</sup>. Other research has hypothesised that these improvements are due to motor-unit synchronization and the recruitment of previously inactive motor-units.<sup>[18]</sup>

### The scientific bases for WBVT.

As other forms of mechanotherapy, WBVT has been suggested having effects on various neuro and musculoskeletal factors, and some are presented in the following discussion.

### Proprioception.

Proprioceptive training is important in most rehabilitation. The short term effects of using WBVT for a single session did improve balance<sup>[19]</sup>, and the long term effects have improved balance in elderly population, reducing the risk of falls and improving agility and walking speed<sup>[20, 21]</sup>. Balance training on a WBV platform is easy to impliment and during all single leg WBVT for the anterior and posterior chain, the proprioception is also stimulated, and improving strength and stability (Fig. 3). Indirect balance improvement can also be gained by for lateral hip and ankle stability WBVT (Fig. 4). Most people benefit from performing functional movements of the upper arms or torso, while stabilising on the vibration plate, as the focus will be on lower limb stiffness, which is needed in most movements (Fig. 5).

### WBV and bone health.

There are two groups most important in regard to bone health. First, the known loss of bone mineral density (BMD) by increasing age, (more in females) and secondly adolescents, as loss of BMD and has been related to the development of youth overuse injuries like Osgood Schlitters (OS), and WBVT has increased BMD and quality (BMC) in adolescents with Down syndrome<sup>[22]</sup>. It is unclear precisely how the vibrations



*Fig. 4. Side-plank with stimulation of latera hip and ankle.*

actually affect muscle and bone tissue. It may be based through similar physiological effects on bone morphogenetic proteins as extracorporeal shock waves<sup>[23]</sup> or low-level pulsed ultrasound,<sup>[24]</sup> stimulating healing in non-unions. If just the low load high frequency stimulation, has effects on the bone strength and healing process, it is of importance in rehab, since osteoporosis or loss of BMD of the lower extremity is common. This can be from immobilisation and casting or use of corticosteroids. As bone contusions are a serious part of many injuries, all treatments affecting the bone metabolism, as well as of the tendons, are worth attention. As there are definitely positive results on bone strength and architecture in animal studies, WBVT is an exciting field, adding to treatments of stress fractures and bone pathogenesis and insertional tendinopathies, for example of the lower leg and patella. Similarly WBVT may be an option in treatments apophysis like OS, Sever's and Sinding-Larsen disease.

Bones adapt to the imposed mechanical loads, and due to the muscle contractions and increased gravitational (G) forces imposed on the skeleton by WBV training, it provides optimal stimulus for increased BMD, BMC and bone cortical thickness<sup>[25]</sup>. As WBVT has been shown to simultaneously increase circulation of blood and lymphatic fluid,<sup>[26]</sup> the simultaneous axial loading on the bone, and muscular pull, occurring during increased blood flow from vibration, seems to favour increased bone strength. Another factor which may explain the improvement in bone strength is the increase in growth hormone (GH) levels reported after high G-force WBVT, since GH has effects on BMD.<sup>[14]</sup> Similarly up to 31% improvement in bone metabolism has been reported (ie. reduced CTX levels) after 8 weeks, which is better result than reported by medication for osteoporosis, and without side effects!<sup>[27]</sup>

Research on post-menopausal women with osteoporosis, had maximum effects on those with the lowest BMD.<sup>[28]</sup> The control group lost 1.8% of their bone mass during 6 months trial but the WBV group increase their BMD by 5.6%. The participants in the WBVT, stood on the platform without moving, excluding any training effect. This re-gain of BMD was similar, to what may have been lost in 2-3 years. It is promising if such a little time and effort may offer potentials for reduction of bone loss in severely weak individuals, not tolerating regular training.

The amount of G-forces and frequency is of importance as a similar study by Rubin et al.<sup>[29]</sup> of post-menopausal women standing for a longer period, had only 1.8% increase, by using only 0.2G compared to 9G. Encouraging evidence for the application of WBVT in this population have recently shown increase in jumping performance in postmenopausal women, compared to their younger female counterparts; potentially indicating that this intervention could play a part in reducing age-related performance decrements.<sup>[30]</sup>

What we do not use, will be lost, and applied to muscles and bones, suggestions have been made for the inclusion of WBVT devices to be incorporated into space crafts.<sup>[2, 31, 32]</sup> Weightlessness and prolonged bed rest or immobility after injury have been shown to decrease BMD, but modern sedentary lifestyle is also a threat to younger populations as future bone health is partly affected by stimulus, during childhood and adolescence. A recent study found association between duration of playing computer games on BMD in 14-18 years old adolescents.<sup>[33]</sup> This emphasise the importance of regular bone loading in the world of decreased activity levels. This sedentary lifestyle increases in old age, leading to loss of gravitational exposures, similar to the astronauts. Another arena of overuse injuries in adolescence is Mb.Osgood-Schlatters (OS). Quadriceps strength has been estimated as the best predictor of BMD of the tuberositas tibiae in the less active reference groups. But active ice-hockey adolescents showed a significantly higher BMD of the tuberositas tibiae, but not of the proximal tibia. Adolescents with a history of OS, had significantly lower BMD of the tuberositas tibiae. Muscle strength and contractions of the quadriceps, rather than vertical loading, seems to positively affect BMD of the tuberositas tibiae in adolescents, up to a certain level.<sup>[34]</sup>

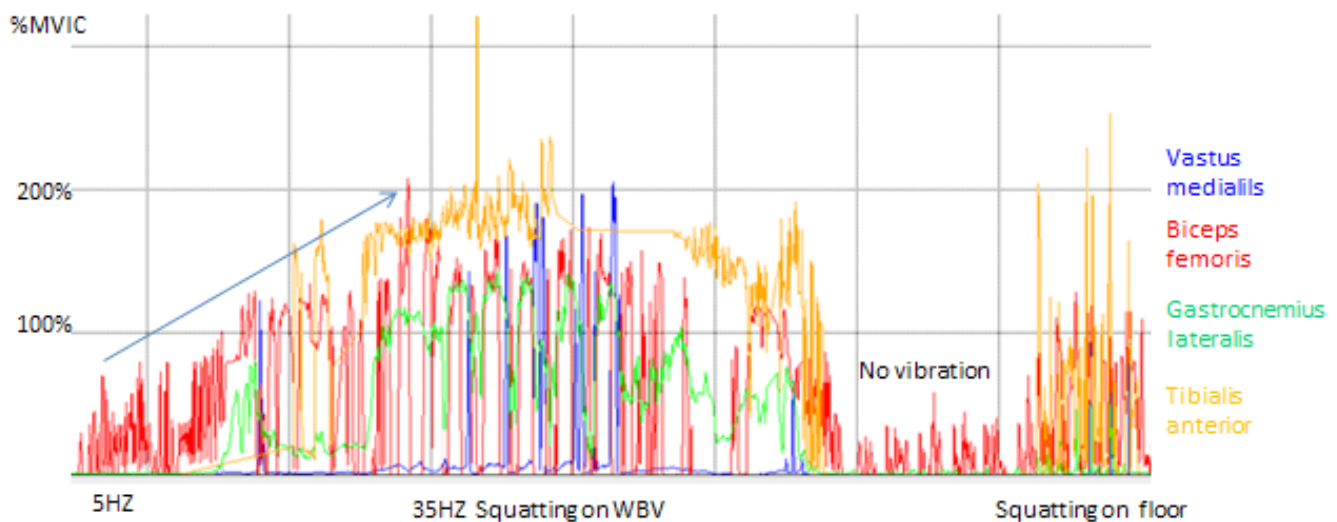
### Strength and power.

A literature review of 6 studies of the effects of WBVT on physical performance on trained athletes, concluded that vibration may provide a small benefit to maximal strength and power, but speed does not seem to be enhanced. What mechanism(s) could be responsible for possible strength and power enhancement is unclear, but it could provide an additional training stimulus for athletes. Further research is required to clarify whether vibration training produces performance benefits greater than those of traditional training methods.<sup>[35]</sup> It seems that most studies have been using bilateral training or just standing, but not adding weights or single leg movement patterns into WBVT, as the authors of this article, find promising in functional training.

The mechanism of upward thrust during WBVT and increased G-loading, increases muscle work during movements, and are



*Fig. 5. Elderly patient training upper spinal rotation or his golf swing.*



**Fig. 6.** Difference in EMG during body-weight WBV squats and squats on floor.

in direct relation to the amount of G-load (force). Vibration of lower than 5G is mainly useful as a massage and recovery measure, but strength, power and hormonal benefits are insignificant. [27, 36-39]

The results of studies of WBVT and muscle power, mimic those of plyometrics, but WBVT suits individuals of all ages.<sup>[9, 40-42]</sup> Higher G-force is loading the skeleton at a very rapid rate, causing reflex muscle contraction, as the ground is moving rather than the athlete. In plyometrics the athlete is moving, causing high loads at a low frequency, but in WBVT, the load is less with higher frequency, with similar cumulative effects.

Some researchers suggest that WBV stimulates the activation of the nervous system, causing both immediate,<sup>[9, 40]</sup> as well as long-term improvements in muscle power<sup>[41, 42]</sup>

### Electromyography and WBVT.

During WBVT at different knee angles, the isometric EMG activity of quadriceps has been from 18.2 to 74.1 % of MVIC and from 5.2 to 27.3 % of MVIC in hamstrings. The highest muscle activation was found at high frequencies and large amplitudes, mainly in the quadriceps. A frequency of 30 Hz, significantly increased the activity, compared to lower frequencies, and the angle had more effect on quadriceps than on hamstrings.<sup>[43]</sup>

A study by Pollock et al.<sup>[44]</sup> investigated the effects of high (5.5 mm) and low (2.5 mm) amplitudes at various frequencies (5–30 Hz) on muscle activity of 6 leg muscles, and acceleration of the lower limb joints and the head, using 3D motion analysis. WBVT increased the muscle activity by 5–50% of MVIC, with the greatest increase in the lower leg. Activity was greater with high amplitude at all frequencies, although not always being significant. The EMG showed a tendency towards linear increase with frequency, in all muscles, except gluteus maximus and biceps femoris. Accelerations throughout the body decreased with distance from the platform, and the greatest acceleration of the knee and hip occurred at 15 Hz and decreased at higher frequencies, where muscle activity increased. There was minimal acceleration at the head which is important in protecting

the neck and brain.<sup>[44]</sup> The knee angle is a critical factor when performing static or dynamic squats during WBVT,<sup>[10]</sup> as static squats at 18.5° have provided greater activation than dynamic squatting from 10–35°. During dynamic squatting the EMG of vastus lateralis, gastrocnemius, and tibialis anterior activity were greater at lower knee angles compared to medium knee angles. However, it remains equivocal whether a greater knee angle elicits a decrement in EMG activity in squatting, or if amplitude or frequency provides the greatest stimulus. Future research needs to focus on different isometric knee angles in WBVT, and its application to muscle performance. In Figure 6, the difference in lower extremity EMG can be seen, with increase in frequency and by performing squats with and without vibration stimulus.

### Effect of WBVT on circulation and recovery.

The constant decrease and increase in G- force has been shown to have a pumping effect on the blood and lymphatic flow, due to intermittent muscle activity, increasing circulation, without a heavy workload.<sup>[45]</sup> These waves of movement through the soft tissues, have been reported to aid in fluid removal.<sup>[26, 46]</sup> These studies have reported from 50-100% increase in peripheral circulation by standing WBV<sup>[47]</sup> and a 40% increase in lymphatic drainage. These fluids have effect on muscular heat, and make WBVT an option in warm-up.<sup>[48]</sup> As a recovery measure, WBV has been proposed to offer all the combined effects of massage, stretches, and light exercise, enhancing performance.<sup>[49]</sup> Its effectiveness in reducing DOMS, has also been reported, possibly due to increase in circulation.<sup>[50]</sup>

### Flexibility.

The rapid vertical movement of the vibration platform leads to repeated stretch, which affects the muscle spindles and golgi tendon organs, forcing the muscles to increase their resting length.<sup>[51]</sup> The oscillation seems to both improve the mobility of the fascia and reduce the tissue stiffness. Another mechanism is the relaxation of muscle tonus, from the vibration, which has been used in massage therapy to reduce the activity of the

nervous system. Bautmans<sup>[52]</sup> reported a significant increase in lower body flexibility in a nursing home residents and Kumari et al.<sup>[53]</sup> reported significant increase in hamstrings flexibility in RA patients. A 13% increase in flexibility of female athletes has also been reported.<sup>[54]</sup> The immediate increase in flexibility from WBVT persisted for at least 15 minutes, without altering jumping performance, irrespective of frequency and amplitude.<sup>[55]</sup> Others have found similar small effect on knee ROM in combination with stretching,<sup>[56]</sup> indicating, mobility exercises during vibration, to be a good addition to the physical therapist's toolbox (Fig.7)



*Fig. 7. Ankle mobility training on WBV platform.*

### The pelvic floor.

Some studies claim that WBVT assists in strengthening the pelvic floor,<sup>[57, 58]</sup> as it stimulates the muscles against gravity, in a rhythmic vertical movement pattern, as in walking. These studies are suggesting that lower intensities, may help to relax overactive muscles, whereas higher intensities, may improve the strength of the pelvic floor and of the pelvic girdle. Zellner<sup>[57]</sup> reported significant reduction of incontinence after 3 weeks of WBVT and Lauper et al.<sup>[58]</sup> concluded that the activation of the pelvic floor muscles, was greater than during traditional pelvic floor exercises.

### Hormonal and metabolic effects.

Bosco et al.<sup>[9]</sup>, reported increase in cortisol and testosterone after 11G WBVT. The greatest effects was of 360% increase in growth hormones (GH), followed by a 20% increase in muscle power. A study by Pritzlaff-Roy et al.<sup>[59]</sup> where 60% of the WBV time was just standing, and 100% without locomotion nor conscious effort, reported decreased stress levels, opposite to an increase, with intense training. Secondly the subjects were not fatigued as in running. High G-Force WBVT has shown up to 800% increase in growth hormones and 48% reduction in cortisol, after 20 minutes post training, and increased metabolism and VO<sub>2</sub> usage has been reported.<sup>[45]</sup> A review paper compiled data from 9 WBVT studies and reported that only 1 of 266 subjects dropped out.<sup>[35]</sup> If this high adherence is related to the potential effectiveness for fat loss still is a question, as the actual exercises done on the platform are BW exercises, known for improving body composition. A study by Wilcock<sup>[35]</sup> reported significant increase in VO<sub>2</sub>, during and following a WBVT, compared to the same exercises done without vibration. Others have reported decreased waist and hip size, and intensity seems to be the key element, for getting the positive results of WBVT.<sup>[27, 60]</sup> Not all of the research on body composition and WBVT has been positive, but these studies used a limited exercise session with lower exercise or vibration intensity and without a control, of the diet.<sup>[61]</sup>

### Low-back pain, ACL and Osteoarthritis.

Despite long hours of vibration has been documented as harmful, some studies have indicated a positive rather than negative effects, from low dose of vibration on low back pain.<sup>[62-65]</sup> Vibration has been shown to have anesthetic effect<sup>[66]</sup> likely due to counter-irritation, and one possible potential of WBVT, is that over time, this may desensitize the nervous system. Exercising on a WBV platform, will lead to increased strength of the pelvic and low back muscles,<sup>[65]</sup> and increase back extensor endurance<sup>[67]</sup> at 25HZ. Probably the most important effects are increased weight-bearing, lumbosacral positional sense.<sup>[62]</sup> WBVT may also reduce muscle tightness, thus leading to improvement in pain and posture.<sup>[63]</sup>

Moezy et al.<sup>[68]</sup> compared a WBVT to a conventional training (CT) on knee proprioception and postural stability, after anterior cruciate ligament (ACL) reconstruction. The error in joint repositioning was significantly less in the WBVT group, for all directional stability indices, and in all averages of absolute angular error. At 60° it was also significant for the healthy knee of the WBVT group. WBVT may be a tool in limb osteoarthritis (OA) rehab,<sup>[61, 69-73]</sup> and even standing WBV has shown comparable strength gains to traditional strength training and less pain in knee OA.<sup>[71]</sup> A systematic review of the WBVT literature on knee OA, concluded that WBVT was effective in reducing knee pain and improving function.<sup>[74]</sup> Increased strength in cases of arthritis, and a positive influence on inflammatory markers in the blood, have also been reported.<sup>[70]</sup> Although fresh joint implants are a contraindication to WBV, positive effects have been reported in total knee arthroplasty rehabilitation,<sup>[68, 73]</sup> and Johnson et al.<sup>[73]</sup> suggested that the unweighted WBV exercises seem to reduce stress in older individuals, and increase the adherence to rehabilitation protocols.

### Neural effects and systemic diseases.

Studies have documented a reflex neural response,<sup>[44, 75]</sup> leading to indications for using WBVT for patients with neuromuscular disorders like parkinsonism.<sup>[76-78]</sup> An increase in peripheral electrical signals via the spinal cord, by 10 minutes of WBVT<sup>[44]</sup> is encouraging, as these responses are not usually found during traditional physical therapy.

Of the systemic diseases being studied with positive effects, are peripheral neuropathies, where symptoms and balance were improved.<sup>[79]</sup> Mason et al.<sup>[77]</sup> reported increased strength and balance in MS patients, and a case study of RA patients reported less inflammation and better function.<sup>[53]</sup> Other studies have reported reduction of inflammatory markers (cytokines)<sup>[72]</sup> and less arterial stiffness and lower blood pressure.<sup>[80]</sup> Muscle spasticity was reduced and strength improved in patients with cerebral palsy<sup>[78]</sup> and reduced pain and fatigue has been reported in Fibromyalgia patients.<sup>[81, 82]</sup>

### Side-effects and contra-indications.

Most exercise vibration studies have been conducted acutely and intermittently with almost no incidences of complications. Erythema and itching as well as oedema, are known temporary side effects, but seem to be limited to stocking-like areas, starting at the bottom of the foot, rendering a likely mechani-

cal explanation.<sup>[47]</sup> Un-common side-effects of the jaw and neck<sup>[83]</sup> have been reported, and highlight the need for therapist to be trained on the use of vibration technology. Certain groups should not be using WBV, like pregnant women, patients with recent or possible thrombosis, valve disorder and pacemakers. Other contraindications are acute or severely rheumatoid or advanced arthrosis, lumbar spine osteoporosis and recent disc problems, recent sutures and fresh wounds, foot, knee, hip and other implants, acute inflammations or infections, migraine headaches and epilepsy.

### Conclusions.

There is still need for high quality papers dealing with WBVT, and the effect on trunk, upper body and neck muscles need further studies. Perchthaler<sup>[84]</sup> in his doctoral thesis, concludes that “WBVT intervention have great potential in older adults”. WBVT may prevent and retain functional strength loss in the lower extremities, as weight bearing exercises, have more carry-over effect than machine based exercises in sitting. WBVT should be an alternative for physical therapists and fitness professionals and can be used for wide range of clinical complaints, such as osteoporosis, osteoarthritis, or sarcopenia, as well as therapeutic application pre and post-operatively. Optimal dosages of WBVT parameters require further evaluation to establish the right period of intervention, number, volume and duration of

exercises. The usage of the Borg scale to rate perceived exertion (RPE), and to modify the training settings, is an alternative for this purpose. As WBVT seems to be a safe and feasible exercise programme for most people, future research needs to establish safe and effective protocols, and establish the long-term effects of WBVT.

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# Hugsaðu vel um fæturna - í vinnunni

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Mikið úrval af sandölum, klossum og öðrum skóm sem henta vel í vinnuna.



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## Skóverslunin iljaskinn

Miðbæ · Háaleitisbraut 58-60 · Sími 553 2300 · [www.iljaskinn.is](http://www.iljaskinn.is)

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Heilsustofnun NLFÍ í Hveragerði býður upp á  
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**Komdu með**  
– hressandi námskeið



**Sorgin og lífið**  
– ástvinamissir og áföll



**Heilsudagar**  
í desember



**Líf án streitu**  
– læruðu að njóta lífsins



**Samkennd**  
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