ACC Evidence Based Review: Whole Body Vibration (WBV) Training

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Please note:

This evidence-based review summarises information on the effectiveness and safety Whole Body Vibration across a range of populations for varying purposes. It is not intended to replace clinical judgement or to be used as a clinical protocol. A reasonable attempt has been made to find and review papers relevant to the focus of this report. It does not claim to be exhaustive. This document has been prepared by staff of the ACC Evidence Based Healthcare Advisory Group. The content does not necessarily represent the official view of ACC or represent ACC policy. This report is based upon information supplied up to the end of May 2008.
Acknowledgements

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Conflicts of Interest

None identified.
Executive summary

Background

Athletes and their trainers', geriatricians and patients would all like simple methods to improve musculoskeletal performance and recover more speedily from injury.

Resistance training is a common way to improve muscle performance across many populations; it involves lifting weights such as dumbbells or even bags of flour and also embraces lifting your own body weight as in push-ups and squats. However, for the elderly that type of training is often unachievable or may be unattractive. Scientists have sought ways to enhance muscular performance in other ways and one strategy that has been developed to do this is to administer low frequency mechanical vibrating stimulus to parts or all of the body. Whole body vibration (WBV) involves the person standing or sitting on a platform whilst vertical vibrations are applied to the body. The vibrations are transmitted through the rest of the body through the feet or buttocks. It is claimed that when WBV is used alone, i.e. without resistance training, it improves muscle power and/or strength parameters in the lower limbs, improves balance control and enhances recovery from injury. More recent studies have assessed the efficacy of WBV in diseases or conditions of the nervous and musculoskeletal systems (e.g. cerebral palsy and following knee ligament repair) and with the elderly with a view to improving balance. With the proportion of elderly in the population increasing, morbidity arising from declining musculoskeletal function is an increasingly important public health issue and evidence of efficacy could hold promise for the future.

WBV machines are being installed in gyms, fitness clubs and some models are marketed for use in the home. These developments raise important issues of supervision and safety, as there is much literature published about risks of occupational exposure to vibration.

ACC from time to time are approached by manufacturers of WBV devices to purchase equipment and treatments and, therefore, Research Services has been requested to assess the safety and effectiveness of WBV.

Search strategy

Relevant databases and websites including Medline, Cinahl, Psycinfo, the Cochrane Library and BMJ Clinical Evidence were searched. Meta-analyses, systematic reviews and Randomised Controlled Trials (RCT) that looked at the effectiveness of WBV in prevention/rehabilitation were included in the review if: (i) published in English; and (ii) published during or after 1998. Studies were appraised and graded for methodological quality according to the Scottish Intercollegiate Guidelines Network (SIGN) criteria.
Main results

Fifty-three primary studies were evaluated on the effects of WBV training on musculoskeletal parameters (including: muscle strength, power, balance and bone quality/density) for a range of subjects (athletes to the elderly). Over half of the studies identified involved healthy young male or female adults. Most studies used commercially available machines such as the Nemes® Nemisis; Galileo 2000®, Novotech; and Powerplate. Overall the quality of the studies was moderate. Ten of the 33 RCT’s were rated highly (1+), and one was of very high quality (1++). Most of the studies involved small samples although overall the range was 8-220.

Because WBV training has been administered to a variety of different populations for different purposes, and used different WBV parameters and programme durations, making conclusions about the studies as a single group is not possible. Studies were reviewed in two main sections; WBV training for specific purposes e.g. muscle strength and associated parameters and WBV for specific populations e.g. the healthy elderly. Some studies crossed these sub-groups. The groups are as follows:

1. **WBV training for specific purposes**
   - Effects of vibration training on muscle performance
     - Short-term applications of WBV - <1 week muscle strength, torque and countermovement jump and balance parameters (5 controlled studies and 3 case series)
     - Longer term applications - >1 week for muscle strength, torque and countermovement jump (17 RCT’s and 2 controlled studies)
   - Effects of WBV training on locomotion and balance parameters (7 RCT’s and 3 controlled trials)
   - WBV training for flexibility (3 RCT’s and 1 controlled trial)
   - Effects of WBV training on bone mineral density and bone parameters (7 RCT’s and 1 controlled trial)
   - Effects of WBV training on the cardiovascular, peripheral vascular system and BMI (3 RCT’s, 1 controlled trial and 4 case series).
   - Effects of WBV training on the endocrine system (1 RCT, 2 controlled trials and 1 case series).

2. **WBV for specific populations**
   - WBV training for post-menopausal women (8 RCT’s measuring locomotion, bone and strength parameters)
   - WBV training in the healthy elderly (3 RCT’s and one controlled trial measuring muscle strength, bone, balance and locomotion parameters)
   - WBV training for rehabilitation populations:
     - Diseases and conditions of the nervous system (5 RCT’s, 1 controlled trial and 1 case series)
Anterior cruciate ligament (ACL) reconstruction rehabilitation (1 RCT)

• Other studies (1 RCT).

Conclusions

• The evidence reviewed for this report indicates that WBV is effective in the healthy elderly for balance control and some locomotion parameters. Positive findings were seen with programme durations between six weeks and 12 months with varying frequencies and amplitudes. Most WBV programmes were administered three times weekly. There is no published evidence, however, that this intervention results in a reduction in falls.

• In young untrained healthy adults, the evidence for strength and balance gains with short-term WBV interventions is conflicting, the evidence coming largely from controlled studies. The evidence for longer-term interventions is positive yet unclear due to limited positive outcomes.

• There is moderate evidence for the effectiveness of WBV to improve posterior knee soft-tissue flexibility in trained young healthy females. One RCT only studied the effect of WBV alongside a contract-relax stretching regime in young males as part of a mixed cohort and did not report results separately. Positive findings were seen with a single session of training as well as with several weeks, and with static postures as well as dynamic activities on the platform.

• There is evidence for muscle strength gains in post-menopausal women, however, it is unclear at this point if WBV has the same positive effect on balance and/or bone density parameters, or whether these strength gains are superior to an appropriate resistance training programme.

• A number of studies have been undertaken in patients with neurological diseases or conditions. These studies have been undertaken for Stroke, Multiple Sclerosis, Parkinson's disease and Cerebral Palsy and physically disabled children. These studies have generally involved single sessions of treatment. Whilst some positive outcomes have been reported, there is insufficient literature for conclusions for safety and efficacy to be conclusive.

• Other studies have assessed the impact of WBV on aerobic capacity and body mass index or fat free mass. There is a small amount of limited positive evidence to support WBV for these purposes although it is unclear if these reductions in BMI are significant.
• No serious adverse events have thus far been reported with WBV. There are, however, still valid concerns regarding the safety of WBV reflecting poor reporting. Identified risks of vibration induced neuropathy and falls risks with the elderly or infirm are not allayed by the current body of literature.

Recommendation

Preventing falls in the elderly is of substantial interest to ACC and health providers and purchasers in general. It is recommended that ACC consider purchasing research into the use of WBV for the healthy elderly at high risk of falls as the opportunity arises.
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Glossary

Osteoporosis/Osteopenia

An individual is classified as ‘osteoporotic’ if their BMD values fall well below the average for the 25 year old female (stated statistically as 2.5 standard deviations below the average). This is based on comparing bone mineral density (BMD) in a particular patient with those of a 25 year old caucasian female. If a patient has a BMD value less than the normal 25 year old female, but not 2.5 standard deviations below the average, the bone is said to be “osteopenic” (osteopenic means decreased bone mineral density, but not as severe as osteoporosis).
Whole Body Vibration Training

1. Background
As we age our musculoskeletal function declines and as the proportion of elderly in the population is increasing globally, morbidity arising from such a decline is an increasingly important health issue. Between 30-50% of community-dwelling people 65 years of age and older fall each year in the community. The current and future cost for falls in this age group to ACC alone is 75 million dollars. Five percent of these falls result in a fracture. Morbidity may lead to death; thus in patients with hip fracture the mortality rate is higher than in persons of similar age and gender. Strategies to prevent bone loss due to osteoporosis have focused on load bearing exercises, however, this approach is often not possible due to individual comorbidities and is often unattractive to the elderly. There is a growing body of evidence that suggests low level mechanical stimuli (low frequency vibration) has an osteogenic effect and may be a management strategy for particularly postmenopausal osteoporotic women.

Proponents of WBV also claim benefits across other populations including professional athletes, those recovering from muscle and related injuries and normal healthy adults in terms of strength, balance, locomotion. Research is also being done to investigate its possible utility and viability as a cardiovascular training modality and in rehabilitation populations.

1.1 Whole Body Vibration Training
A number of WBV appliances are commercially available. Appliance specifications vary across the different models. There are three components to vibration, these are; (i) amplitude, which is the extent of oscillatory motion from peak to trough it is measured in mm, (ii) frequency, which is the number cycles per second (measured in Hz) and (iii) the acceleration at which one traverses the amplitude; this is measured in units or fractions of the Earth’s gravitational force (9.8 ms⁻²).

The rationale behind the purported benefits of WBV is that mechanically stimulating the human body at a low amplitude and frequency excites sensory receptors, specifically, muscle spindles which results in reflex activation of motor neurons which then in turn result in muscle contraction. If the WBV machine delivers vibrations at 25Hz then the muscles will contract and relax at approximately the same frequency. Normal exercise recruits muscle fibres variably; this depends on the mode, intensity and duration of the exercise employed. WBV may result in greater recruitment of muscle fibres during exercise due to the need of the lower limb muscles to dampen the vibration. It is thought the mechanical effect of the vibration stimulus has an osteogenic effect on bone. Aspects of the physiological responses of muscles to WBV are reviewed by Cardinale and Wakelin.

Considering the numerous possible combinations of frequency, amplitude and acceleration, it is possible to generate quite varied protocols. In addition, variation in training period frequency (perhaps 2-3 sessions per week) and duration (10 seconds to a several minutes) need to be considered. Different
muscles can also be trained by changing the stance and activity on the machine. It is clear that there are multiple parameters to consider and this may present challenges when comparing studies and claims of therapeutic effect. In addition to these machine variables, subjects’ physical condition and requirements differ; for example athletes who may be at peak fitness have different requirements from WBV than an older person whose need is to prevent injury and maintain quality of life by mitigating age-related decline.

1.2 WBV appliances

Commercially available whole body vibration machines include the Nemes® Nemisis; Galileo 2000®, Novotech; PowerPlate®, Vibrablaster and the Juvent dynamic motion therapy. WBV training may require the subject to maintain an isometric squat in varying positions on the plate or the subject may perform squatting and jumping type exercises with or without additional load. Most vibration platforms are motor-driven systems that generate vibration via eccentric discs or off-centred motors. Vibration platforms are often hydraulically powered enabling the operator to carefully control the vibration characteristics; typically WBV interventions involve relatively low frequencies (25-44Hz) and small amplitudes (2 to 10mm)⁹.

The manufacturers of the Galileo 2000® claim that WBV is a revolutionary training technique that produces an enormous range of health and fitness benefits, from increased strength to improved bone density. It has been “developed in the former Soviet Union to treat Cosmonauts and improve the performance of Olympic athletes, this technology is used widely throughout Europe and North America by elite sports clubs, world class athletes, hospitals, gyms, physiotherapy and therapeutic centres.”¹⁰

The platform of the WBV appliance may vibrate in one of two ways and these are shown in figure 1. The Galileo brand appliance is an example of a ‘teetering’ system that produces the side-to-side vibration movements. The Powerplate® vibration system causes vertical vibrations. The costs of WBV platforms are substantial. A ‘basic’ platform is currently priced at around $8000, with the sport versions at over $18,000¹⁰

Figure 1: Vibration variation in WBV platforms
1.3 Current Practice in New Zealand

Currently in New Zealand various WBV platform models are scattered around the country in different institutes and used for different purposes. Dr. Rick Acland from Burwood Spinal Unit, Christchurch, has a Galileo 900 and Dr. John Cronin from Auckland University of Technology, (Sport and Recreation Department) has a Galileo 2000.

Darryl Cochrane from the Sport Coaching and Management Programme, Department of Management, Massey University, Palmerston North, has a Galileo 2000 and has recently purchased a “Galileo Sport.”

2. Objective

The purpose of this review is to critically examine the literature on the effects of vibration training on muscle strength, power, balance and bone density and quality across a range of populations.

3. Methodology

3.1. Criteria for selecting studies for the review

Studies that administered WBV that focused on rehabilitation, muscle power and strength training, fall prevention and bone density were considered for this review. From an ACC perspective interest may not be high in increasing athletic performance, but such evidence is included here because it relates to the ability of these WBV interventions to affect muscle performance which may be of indirect interest. Studies with subjects with neurological diseases and disorders (e.g. Stroke) were also considered appropriate to include. All ages were considered. Studies reporting impairment and functional outcomes (For example: muscle strength increase, balance improvement) were considered of particular relevance.

3.2. Search strategy

The following Ovid-hosted databases; Medline, Pre-Medline, Embase, Cinahl, Psycinfo, Amed, CDSR (Cochrane Database of Systematic Reviews), CCTR (Cochrane Controlled Trials Register), ACP Journal Club and DARE (Database of Abstracts of Reviews of Effects) were searched using the subject descriptor and free text terms “whole body vibration” combined with database-specific search filters (where available) to distinguish research studies from more general literature. The initial searches were performed in October 2005 and repeated in September 2006 and December 2007. In addition to the Ovid databases, the following evidence based, web-hosted databases were also searched using the free text term “whole vibrating systems”: Bandolier and BMJ Clinical Evidence. The Search strategy
employed for this report is located in Appendix I and also provides the web sites of these databases.

3.3. Method of review

Studies were graded 1++ to 4 according to the Scottish Intercollegiate Guidelines Network (SIGN; Appendix III) evidence grading system. Throughout this report, SIGN grading is noted either within the text or at the completion of the paper’s discussion in brackets; e.g. (1-).

- The type of study was determined by analysing the methodological information described in each report.

- For controlled studies the quality of study design was assessed by analysing the information including the methods of randomisation or blinding, sample size, outcome measurements, period of follow-up, definition of study population and intervention, criteria of inclusion and exclusion and potential bias in the study.

- The levels of evidence were determined by considering both the type of study and the quality of study design for controlled studies according to an international standard.

- Evidence tables summarise the information on study type, clinical conditions, study population, intervention, outcomes and the level of evidence determined.

3.4 Study Design

All study designs were considered suitable for review.

WBV lends itself to an RCT methodology so it was expected some studies would in fact be RCT’s.

4. Results

4.1. Description of studies

Thirty-three of the 53 primary studies identified for literature searching were RCT’s. Most RCT’s compared exercises whilst on a vibration platform with exercises not on a vibrating platform. One RCT assessed compliance with a home-based WBV training regime only as opposed to assessing efficacy.

Seven studies were classified as cross-over trials where the subject acted as their own control and were randomised only to the order in which they
received the control or intervention. Crossover studies have advantages in that sample sizes can be reduced and the reduction of inter-subject variability, order and sequence effects can be overcome, however, suitable washout periods must be defined. To this end, however, a number of studies either failed to report the ‘washout’ period or this was assessed as inadequate meaning the hang-over treatment effects from one intervention to the other may be a factor. The impact of learning using a crossover study design may also confound outcomes.

It is challenging to hide the type of treatment a patient receives with RCT studies if bulky equipment is being tested, or involve intrusive procedures and therefore double blinding in controlled studies is difficult if not impossible. In one study by Bautmans et al (200511), elderly patients were asked to perform a series of exercises on a stationary WBV platform whilst an auditory recording of vibration noise was played; the patients were not informed of their treatment group11. However, it is uncertain whether this strategy was in fact successful and whether volunteers were unable to guess their type of treatment. Three further studies12-14 also used auditory tones to assist participant blinding. The researchers in these studies used low accelerations they reported were barely able to be perceived by the subjects and therefore the combination of auditory signals means that blinding can be assured. This may not be the case for programmes administering larger amplitudes and/or greater accelerations.

One further study manipulated the acceleration between groups using an RCT methodology to ensure blinding. Delecluse et al (200515) randomly assigned subjects to either WBV, (where the acceleration of the vibration platform was between 2.28g and 5.09g), or to a placebo group with only 0.4g. Subjects did not know if they were in the intervention or placebo group.

Subjects in one study were placed into treatment groups “depending on what motivated them”16. In another trial subjects were matched to groups “depending on the ability of the subjects to voluntarily activate their muscles”.17 Such studies are also classified as controlled studies and are scored using the ‘2’ SIGN grading.

Eight case series were reviewed, of which two in particular were preliminary studies assessing the viability and safety of WBV before considering more substantial trials with more subjects and different methodologies. The sample size across all trials varied significantly from 818 to 22019. Overall the trials presented in this review contained small-moderate sample sizes and generally longer trials tended to have larger numbers of participants. All studies used some form of statistical analysis.

The Galileo brand of platform (various models) was used in approximately 40% of the studies, with Powerplate® the next most common used in approximately 20% of the studies reviewed.

The duration of exposure to WBV across all trials ranged from one day to 12 months. WBV platforms were the main intervention in all studies and this was
often compared with normal resistance training (n=2 distinct from WBV exercises on platform, n=7 simulating WBV activities, n=9 combination), although in cases of neurological disorders, comparisons were often with ‘gold standard’ treatments. In 16 of the 33 RCT’s, the application of vibration was the only difference between control and intervention groups (either concurrent comprehensive programme or simulated exercises without vibration). Notably, eight primary studies either involved a ‘no treatment’ arm (n=5) and an alternative resistance or cardiovascular activity programme; in three studies, ‘no treatment’ was the sole alternative to WBV. Comparing WBV interventions with no treatment may raise significant issues of confounding as exercise and vibration were components of all WBV interventions. A description of each study is presented in the evidence tables in Appendix III.

In addition, two systematic reviews were identified that assessed long-term\textsuperscript{20} and short and long-term impacts\textsuperscript{21} of WBV interventions as they relate specifically to muscle power and strength. These informed and guided further study identification but were not considered of sufficiently quality to accept the conclusions made.

WBV parameters were variable across the studies. There was no consistent treatment protocol used across the WBV training studies with respect to amplitude, frequency or acceleration (frequency range 1Hz- 50Hz; acceleration range .1g-10g, amplitude range 2-11mm). It was also evident that the WBV stimulus (type and dose) varied significantly also within sub-groups of studies (studies were grouped based on the purposes or the sub-populations that were enrolled in the studies. This is discussed in further detail below). That said it did appear that for the elderly and/or infirm populations, amplitudes (e.g.2-5 mm) and acceleration parameters (e.g. 0.3g acceleration) were at the lower end of the available ranges. WBV stimulus session length varied from a few seconds to several minutes as did the number of sessions prescribed over a week per week (1-5) for longer programmes. Most studies included rest-periods within individual WBV training sessions (e.g. bouts of 1 minute of WBV followed by 30 seconds rest). The duration of exposure to WBV across all trials ranged from one day to 12 months. A feature of many of the studies was the progressive nature of the longer WBV training programmes; with low doses administered at the start of a programme and higher doses at the end. This is consistent with the overload principle that other exercise modalities use. Most studies identified for this EBH review used commercially available machines such as the Nemes® Nemisis; Galileo 2000®; Novotech; and PowerPlate® brand appliances.

For this report, ‘athletes’ are those subjects as identified from the studies themselves that have engaged in any type of sport or fitness training on a regular basis. The definition of ‘elite’ athletes applies to those that are competitive or nationally ranked athletes as indicated by the studies. A ‘trained’ subject in the context of this report includes either elite athletes, recreationally trained individuals or both.

4.2 Outcome measurements
There were many outcome measurements in the studies. Muscle power was measured by countermovement jump height (CMJ height) (Newtest, Oulu, Finland) in a number of studies. The shuttle run test over a 30m course was used to assess dynamic balance or agility and motor capacity was reported in some studies as being assessed using the validated “timed up-and-go” (TUG\textsuperscript{a}) test. Isometric strength and dynamic strength of knee extensors was typically measured using a motor driven dynamometer. The Tinetti\textsuperscript{b} test, single-leg stance and posturography (postural sway platform) were used for body balance and a few studies reported locomotion parameters e.g. step length.

Other outcome measures included bone turnover using biochemical serum tests or computed tomography and DEXA scanning for bone mineral density (BMD). Arterial blood flow was assessed in one trial using a Doppler sonograph. Other typical measurements included heart rate, blood pressure and oxygen ($O_2$) uptake as a measure of aerobic capacity.

Studies were reviewed and two main sections; WBV training for specific purposes e.g. muscle strength and associated parameters and WBV training for specific populations e.g. the healthy elderly. There was some overlap between these groups. The groups are as follows:

1. **WBV training for specific purposes**
   - Effects of vibration training on muscle performance
     - Short-term applications of WBV - < 1 week muscle strength, torque and countermovement jump and balance parameters (5 controlled studies and 3 case series)
     - Longer term applications - > 1 week for muscle strength, torque and countermovement jump (17 RCT’s and 2 controlled studies)
   - Effects of WBV on locomotion and balance parameters (7 RCT’s and 3 controlled trials)
   - WBV for flexibility (3 RCT’s and 1 controlled trial)
   - Effects of WBV training on bone density and bone parameters (7 RCT’s and 1 controlled trial)
   - Effects of WBV training on the endocrine system (1 RCT, 2 controlled trials and 1 case series)
   - Effects of WBV training on the cardiovascular, peripheral vascular system and BMI (3 RCT’s, 1 controlled trial and 4 case series).

2. **WBV training for specific populations**

\textsuperscript{a} The timed up and go test is a valid measure of the time an individual takes to rise from a standard chair, walk 3 metres, turn, walk back to the chair and sit back down.

\textsuperscript{b} The Tinetti Balance Test is a subjective ordinal measure of balance in the elderly and neurological subjects. Subjects are ranked 0-2 by the assessor on their ability to sit, stand from a chair, turn, balance with perturbation and eyes shut. There is also a 12 point Tinetti gait measure.
Whole Body Vibration Training

- WBV training for post-menopausal women (8 RCT’s measuring locomotion, bone and strength parameters)
- WBV training in the healthy elderly (3 RCT’s and 1 controlled trial measuring muscle strength, bone, balance and locomotion parameters)
- WBV training for rehabilitation populations:
  - Diseases and conditions of the nervous system (5 RCT’s, 1 controlled trial and 1 case series)
  - Anterior cruciate ligament (ACL) reconstruction rehabilitation (1 RCT)
- Other studies (1 RCT).

4.3 WBV training for specific purposes

4.3.1 Effects of WBV training on muscle performance

This section includes studies that investigated the effect of WBV of lower limb muscle power and jumping ability. The effects of WBV on more complex locomotor activities, for example rising from a chair are discussed in a later section. The duration of WBV training is probably important from the perspective of changes in muscle performance. Intuitively, it seems sensible to propose that a single training session will have different consequences on muscle physiology than comparable sessions repeated over an extended period. WBV over a single session is thought to affect neuronal impulses and blood flow with little remodelling of muscle whereas in longer trials remodelling of muscle and skeleton may occur. Therefore, this section is divided into two subsections to emphasise that distinction, although clearly there is a continuum of exposure available. For this report, short-term exposure to WBV is considered up to one week (irrespective of sessions during that time).

4.3.11 Short-term applications of WBV - < 1 week muscle strength, torque and countermovement jump

Eight studies investigated the effects of short-term WBV, five were controlled studies (subjects serving as own controls) and three case series. No primary studies used a randomised controlled trial methodology. Two systematic reviews\(^2^0\)\(^2^1\) were identified and considered for this section. Rehn et al (2007\(^2^1\)) reviewed papers reporting both long and short-term WBV, however, assessed methodological quality using a new un-tested instrument. Nordlund et al (2007\(^2^0\)) reviewed papers reporting on muscle strength and jump performance outcomes following longer-term regimes, however, failed to describe its review process in sufficient detail. These concerns meant a review of all the primary literature was in fact required. Table 1 provides a summary table of the primary literature for short-term WBV interventions.

Subject numbers across studies ranged from 9-37 and comprised mainly young healthy males between the ages of 21-35 years. One study involved elite female field hockey players\(^2^2\) and all apart from one paper’s outcomes of
interest related to lower body strength, power and/or CMJ. WBV frequency (15-40 Hz) and amplitude (2.5-10mm) varied across the studies. Generally speaking, the subjects were required to perform a series of static exercises on the platform, with rests provided in between exercises and sets. Sessions varied from 30 seconds to 10 minutes. A single case series involved the subjects performing activities on the platform to exhaustion.

Two studies indicated positive, statistically significant improvements in maximum voluntary contraction (MVC) of the knee extensors (both 2+ grade) and one with improved leg press power (grade 3) with a single bout of WBV training. Conversely, one methodologically identical study by the same authors measured no change in either isometric knee extension force or a host of other outcomes, including stability, vertical jump and a shuttle run.

Statistically significant improvements in CMJ height were reported in four papers following WBV. Improvement in CMJ height across the studies ranged from 2.524%-8.122. However, results from an almost identical study reported no improvement in CMJ or other performance measures. The authors offered no explanation for these conflicting results. These studies were all of reasonable methodological quality and all controlled studies. Not all authors, however, reported positive effects. For example, De Ruiter (2003a) evaluated the acute effects of one session of WBV training. Ninety seconds following the vibration treatment, there was a 7% decline in force production during the maximal voluntary contraction of the knee extensors. The study period was extended to six sessions over two weeks, however, no improvement in muscle performance was seen despite this longer intervention period.

The methodological quality of the papers considered for short-term WBV reporting on strength and power outcomes was considered adequate; most papers, however, lacked information regarding assessor blinding and studied small samples. No randomised controlled trials were reviewed.

Most studies reported short-term improvement in strength and/or power parameters following usually single sessions of WBV, however, reasonable quality evidence to the contrary was reviewed. The variability of WBV parameters used in the studies makes generalisability to specific groups of WBV regimes difficult. How these strength and/or power improvements may then relate to function and/or sports performance or in fact how enduring they may be is unknown.

Regarding safety and adverse events, one paper reported subjects having said the sensation was “stimulating”, whilst another noted an itching erythema was evident following treatment in over half the participants. Most studies reported adverse events and safety issues poorly, an example of which is: “subjects were to wear gym shoes to prevent bruising”. Notably, though, most papers described a suitable warm-up prior to WBV and/or assessment, with variable use of stretching manoeuvres.
Key message

There is conflicting evidence from a small number of moderate quality papers to support the efficacy of short-term WBV for muscle power and/or strength and/or CMJ improvement. This literature by and large involves healthy male subjects. These studies were controlled studies some with randomisation to the order of intervention only. Although well designed studies of this nature may have substantial study power, considering the overall poor quality of these papers and the conflicting evidence, a reasonable conclusion is that the efficacy of short-term WBV for muscle power and/or strength and/or CMJ improvement is thus far unclear.

Despite the fact that WBV interventions are brief, and thus far, no serious adverse events have been reported, safety issues have to date been poorly considered.

4.3.12 Longer term applications > 1 week for muscle strength, torque and countermovement jump

Eighteen primary papers were identified reporting on the impact of long-term WBV interventions on muscle strength, torque, countermovement jump and other similar outcomes across a variety of populations. There were sixteen RCT’S and two controlled trials. Table 2 provides a summary table of the primary literature reviewed.

Eight papers studied healthy adults of varying ages, including older adults. One study assessed the effect of WBV strength/power parameters in competitive child skiers. Six papers studied the impact on trained subjects, this included elite and non-elite athletes. Four papers specifically targeted older adults; three targeted post-menopausal women and one, male and female rest-home-dwelling elderly subjects. The evidence for these latter populations is reviewed in a later section.

Overall, WBV regimes ranged from 9 days to 8 months. Study durations were clustered around the 4-8 week mark, with subjects participating in on average three sessions per week (ranging from unspecified session duration to 30 minutes) with at least one day in between sessions. Outcomes considered were torque, average strength of the lower limbs, and a range of short-duration functional tasks that included: CMJ, box jump and squat jump. Those studies that studied older age groups included a range of other outcome measures including tests of balance, bone density and flexibility (discussed in subsequent sections).

WBV parameters varied considerably across this group of studies, although in general, administered higher frequencies and amplitudes (12-45 Hz), higher acceleration (2-8g) and higher amplitudes (2.5-11mm) to younger participants. It may be reasonable to presume that tolerance and benefit may be successfully achieved with the lower dose applications and adverse events less
likely. Sample sizes across this group of papers varied from 14-89 with by and large, larger samples involving the elderly.

RCT’s compared WBV interventions with either the same exercise regime without vibration (n=12) or no treatment – either as one arm or the only alternative (n=2 and n=3 respectively).

One RCT specifically assessed the effect of administering different WBV frequencies to subjects on knee strength. Savelberg et al 2007 measured a significant increase in peak torque in the knee extensors across all treatment groups/frequencies (20, 27 and 34 Hz); no between-group differences in peak torque were found. Subjects performed three sessions per week for four weeks, increasing amplitude and duration of WBV as time went by. A concomitant reduction in Type I muscle fibres was seen in the control group’s soleus muscles. This was also not evident in the vibration group. This study involved only 23 subjects (1-).

Four further papers studied the impact of WBV on young healthy untrained adults. Torvinen et al (2002c, 1- and 2003, 1+) report on the same randomised cohort (n=56) after four and eight months of WBV training (males/females). Increases from baseline in CMJ height were reported at four months (8.5%) following a four-minute-a-day WBV bout with exercise, performed 3-5 x per week; CMJ heights reduced slightly at the 8-month point (7.8%). The control group was told not to change their activity levels. A 3.7% increase was seen in lower limb extensor strength at two months, however, this diminished at four months. The authors reported this was due to a learning effect in the control group (control subjects were told not to change their activity level). Furthermore, no change was seen in shuttle run or balance outcomes measured concurrently at any time period.

The two remaining studies compared WBV with ‘no treatment’ and resistance and cardiovascular training arms. Roelants (2004a) assessed the impact of a 24-week WBV programme on body composition and knee extensor strength (controlled study). Isometric strength improved 24.4% from baseline, and isokinetic improvements range from 5.9-8.3%. These improvements were similar to those seen in both alternate treatment arms (cardiovascular and resistance groups). A 2.2% increase in fat free mass in the WBV group was the only significant difference between WBV and the alternate intervention. The reduction in fat free mass will be discussed further in a later section.

Delecluse et al (2003) studied 67 untrained female adults and similarly identified that both the resistance and WBV groups showed significant strength improvements in isometric knee strength. Control and placebo groups showed no significant improvements (p>0.05). The only difference between WBV and resistance groups was a statistically significant difference in CMJ height after four months of training (7.6%; p<0.001). No adverse events occurred during the study.

No safety issues were identified from these four papers.
Whole Body Vibration Training

Key message
Evidence to date appears to indicate that although WBV training may result in some muscle strength gains with a longer term programme, the evidence seems to indicate that WBV may not provide additional benefit over and above comprehensive resistance training and/or a "gymnastics" programmes. A single moderate quality study indicated CMJ parameters may be further enhanced over and above that provided by a resistance training programme. The positive results, however, from many studies regarding other functional outcomes must be acknowledged. These are discussed in subsequent sections. No safety issues have been identified to date.

Six further papers studied trained or elite athlete subjects. Sample sizes were small, ranging from 14-28. Programme duration ranged from 9 days to 8 weeks. Two RCT’s and one controlled trial showed no WBV effect after 5, 9 and 11 weeks respectively. WBV parameters for this group varied; amplitude 2.5-11mm, frequency 25-40 Hz. Acceleration was reported in one study only and varied through the programme (2.5-6.4g).

Cochrane et al (2004) enrolled non-elite athletic adults athlete into a 9 day WBV programme (5 days daily WBV, 2 days break, 4 further days daily WBV). Control subjects performed the same exercise next to the WBV platform. At the completion of the study period, no significant improvements were seen from baseline to follow-up in either control or WBV groups with respect to CMJ, squat jump, sprint or agility parameters. The authors measured perceived discomfort following each daily WBV session (9 days total), reporting a significant reduction in discomfort (although location and severity not specified) following each treatment. Discomfort reduced with controls also in a similar way and extent.

Delecluse et al (2005) showed no improvements over time or differences between groups after a five week WBV programme in terms of knee extensor and flexor strength (p>0.05) or velocity (p>0.05), CMJ performance (p>0.05) and sprint velocity (significance not reported).

Finally, de Ruiter et al (2003) reported no significant improvements following an 11 week programme of static-posture WBV as compared with static postures with no vibration. Subjects in this study were randomised according to their ability to contract their muscles; this may confound outcomes.

Kvorning et al (2006) allocated 'moderately trained' subjects into a 'squat' training programme, 'squat and WBV' group and a 'WBV alone' group. No between group differences were seen for Maximal voluntary contraction of the knee extensors (MVC), with only 'squat' and 'squat and vibration' groups showing improvements from baseline. Mean power showed a greater increase in the 'squat' group (25.9-27.4 W kg⁻¹) as compared to the 'vibration' group (25.3-24.7 W kg⁻¹) and 'squats and WBV' (26.3-26.6 W kg⁻¹). WBV and resistance training did not increase MVC and CMJ height compared to squat alone. The authors could not explain these findings.
Two RCT’s showed positive effects (both graded 1-) with programmes over 10 days and 8 weeks. Control groups varied across the studies; one used two further arms; a squat regime without vibration and squat alone\textsuperscript{33}, and one failed to describe the control group intervention\textsuperscript{32}.

Findings from the Ronnestad et al (2004\textsuperscript{33}) study points to the superiority of squats performed on a vibration platform compared with squats without WBV as long as the external load is similar. Statistical significance was reached only with respect to CMJ (p<0.01) after five weeks. Both groups showed significant increases in ‘one repetition max’ performance squats (p<0.01). The sample size for this study was small (n=16).

Fagnani et al (2006\textsuperscript{32}) indicated significant improvements from baseline to follow-up with an 8 week programme with respect to leg press peak force (p=0.038) and total work (p=0.004), CMJ (0.00002) and sit-and-reach flexibility (p=0.00004). Whilst these results show a significant difference between the groups, the control was poorly described and it is possible that the improvements may be attributed to the exercises on the platform itself. The sample is also small (n=26).

A final RCT compared the effect of a regime of daily\textsuperscript{40} (2 x 6 minutes daily) supine WBV (Galileo space device) on bed-rested subjects compared with static exercises. The reduction in calf muscle size and function evident in the control group after 55 days of bed rest was not seen in the WBV group, suggesting the effects of bed-rest may be mitigated largely by the application of WBV. This study has not been considered when making conclusions for this group as it administers a different type of vibration training.

Key message

| In summary, there is conflicting evidence of effectiveness in trained subjects. CMJ height or centre of gravity only measures appeared to consistently be better than controls across the positive effect studies, there is variability, however across some other parameters e.g. flexibility, peak force. No particular safety issues were identified. |

4.3.13 Different populations

One RCT of moderate quality investigated the impact of WBV in children, in this instance, competitive child skiers (n=17; 11 males; age range 9-15 years). Subjects underwent a six week programme of three sessions per week, 30 minutes per session and performed ski-type activities on the WBV platform. Both groups indicated a significant increase in box jump repetitions at six weeks, however, the WBV group out-performed the control group (67.06 mean reps vs 55.19 reps, p=0.013). A statistically significant increase in plantarflexor strength in the WBV group was the only other parameter of note (90.09 WBV vs 68.18 control). Side effects were not mentioned.
### Section conclusion

In summary, there is a substantial amount of literature that reports on strength/power outcomes following longer term WBV. The heterogeneity in terms of populations, ages and treatment parameters across the studies makes comparison difficult. Four of the 16 RCT’s in the longer-term training group of studies were considered to be of high methodological quality and used reasonable sample sizes. Most papers had a variety of methodological issues, poor or absent reporting, and/or failed to consider the intention to treat strategy, affecting their overall quality. A small number of papers did not randomise appropriately.

All papers comparing WBV with ‘no treatment’ groups WBV improved muscle strength parameters. A ‘no treatment’ control may however, be considered as an unsuitable control. A number of studies reported improvements following WBV as compared with alternative treatments; these studies involved a variety of WBV regimes. Those papers that compared WBV with a comprehensive resistance and/or cardiovascular programme however, did not produce consistent findings to support added benefit.

Four studies failed to report adverse events in any form. Reported adverse events ranged from leg itching, erythema and oedema, resolving promptly following treatment, to knee pain (one study). Authors appear well aware of the documented negative effects of vibration and most reported no side effects in their study groups. Papers to date neither report outcomes that indicate the sustainability of such gains, nor whether muscle changes with WBV impacts on sports performance and/or function.
## Table 1: Studies summary – Short-term training measuring musculoskeletal impairment and/or strength parameters only

<table>
<thead>
<tr>
<th>AUTHOR</th>
<th>YEAR</th>
<th>STUDY TYPE</th>
<th>PARTICIPANTS</th>
<th>WBV PARAMETERS</th>
<th>SIGN GRADING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roelants et al</td>
<td>2006</td>
<td>Controlled study; Subjects acted as own control</td>
<td>15; young healthy male</td>
<td>Duration: 1 session, 4 sets, 3 isometric exercises; Frequency: 35 Hz; Amplitude: 2.5mm</td>
<td>2+</td>
</tr>
<tr>
<td>Cormie et al</td>
<td>2006</td>
<td>Controlled study; Subjects acted as own control</td>
<td>9; all young healthy males</td>
<td>Duration: 1 session, 30s WBV duration; Frequency: 30Hz; Amplitude: 2.5mm</td>
<td>2+</td>
</tr>
<tr>
<td>Cochrane and Stannard</td>
<td>2005</td>
<td>Controlled study; To assess the effects of WBV on countermovement jump, grip strength and lower limb flexibility</td>
<td>18; elite female hockey players</td>
<td>Duration: 1 session of exercises; Frequency: 26 Hz; Amplitude: 2.5mm</td>
<td>2+</td>
</tr>
<tr>
<td>De Ruiter et al</td>
<td>2003a</td>
<td>Case series; The effect of a single WBV session on knee strength parameters</td>
<td>12 healthy untrained students; 7 male</td>
<td>Duration: 1 bout; 5 x 1 minute; 2 minute rests in between; Frequency: 30Hz; Amplitude: 8mm</td>
<td>3</td>
</tr>
<tr>
<td>Torvinen et al</td>
<td>2002a</td>
<td>Controlled study; Subjects acted as own controls</td>
<td>16; 8 men; healthy subjects</td>
<td>Duration: 1 session, 4 minute WBV, twice; washout period; Frequency: 15Hz-30z; Amplitude: 10mm</td>
<td>2+</td>
</tr>
<tr>
<td>Torvinen et al</td>
<td>2002b</td>
<td>Controlled study; Subjects acted as own controls</td>
<td>16; 8 men; healthy subjects</td>
<td>Duration: 1 session, 4 minute WBV, twice; washout period; Frequency: 15-40Hz; Amplitude: 10mm</td>
<td>2+</td>
</tr>
<tr>
<td>Rittweger et al</td>
<td>2000</td>
<td>Case series; Loaded squat regime with vibration</td>
<td>37; 21 males; young healthy subjects</td>
<td>Duration: 2 sessions; exercised till exhaustion in both; Frequency: 26Hz; Amplitude: 10.5mm</td>
<td>3</td>
</tr>
<tr>
<td>Bosco et al</td>
<td>2000</td>
<td>Case series; Effect of WBV on jump performance</td>
<td>14; all healthy active males</td>
<td>Duration: 1 session, 10 x 60s bouts; Frequency: 26Hz; Amplitude: 4mm</td>
<td>3</td>
</tr>
</tbody>
</table>
### Table 2: Studies Summary– Long-term training measuring musculoskeletal impairment and/or strength parameters only

<table>
<thead>
<tr>
<th>AUTHOR</th>
<th>YEAR</th>
<th>STUDY TYPE</th>
<th>PARTICIPANTS</th>
<th>WBV PARAMETERS</th>
<th>SIGN GRADING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Savelberg et al</td>
<td>2007</td>
<td>RCT</td>
<td>Investigated effect of various frequencies of WBV on muscle torque of knee extensors</td>
<td>Duration: 4 weeks, 3 sessions/week, in one treatment position; 1 minute between each series of vibration bouts; Frequency: 20Hz, 27 Hz, 34Hz; (20Hz different position); Amplitude: 5-9mm</td>
<td>1-</td>
</tr>
<tr>
<td>Fagnani et al</td>
<td>2006</td>
<td>RCT</td>
<td>The effect of 8 weeks of WBV on dynamic muscle strength and flexibility</td>
<td>Duration: WBV for two exercises, 3 sessions/week, 8 weeks; Frequency: 35Hz; Amplitude: 4mm</td>
<td>1-</td>
</tr>
<tr>
<td>Blottner et al</td>
<td>2006</td>
<td>RCT</td>
<td>To investigate if WBV with a resistance programme has an enhanced effect on strength than resistance alone</td>
<td>Duration: 6 minutes, 2 x daily, 55 days of bed rest; Frequency: 20-30Hz; Amplitude: 5mm-10mm</td>
<td>1-</td>
</tr>
<tr>
<td>Mahieu et al</td>
<td>2006</td>
<td>RCT</td>
<td>The effect of supine WBV in bed-rest subjects compared with static exercises</td>
<td>Duration: 30 minutes/session, 3 x weekly; Frequency: 24-28Hz; Amplitude: 2-4mm</td>
<td>1-</td>
</tr>
<tr>
<td>Kvorning et al</td>
<td>2006</td>
<td>RCT</td>
<td>To investigate the effect of WBV and resistance training on neuromuscular and hormonal measures (maximal isometric voluntary contraction)</td>
<td>Duration: 6 sets of 8 repetitions of weight-loaded squat; 2 minute rests in-between sets for 9 weeks- mean sessions 20.5; Frequency: 20Hz for the first 5 weeks, then 25 Hz; Amplitude: 4mm</td>
<td>1-</td>
</tr>
<tr>
<td>Delecluse et al</td>
<td>2005</td>
<td>RCT</td>
<td>5 week WBV programme in elite sprint trained athletes</td>
<td>Duration: 5 weeks 6 exercises, 3 sets Frequency: 35-40Hz increased over 5 weeks: Amplitude: 1.7-2.5 mm increased over 5 weeks</td>
<td>1-</td>
</tr>
<tr>
<td>Baumans et al</td>
<td>2005</td>
<td>RCT</td>
<td>To examine the effect of 6 weeks of WBV in as compared with sham treatment on function, strength and flexibility</td>
<td>Duration: 6 week programme consisting of 6 static exercises; Frequency: 30-40Hz; Amplitude: 2-5mm</td>
<td>1+</td>
</tr>
<tr>
<td>Roelants et al</td>
<td>2004a</td>
<td>Controlled study</td>
<td>Effects of 24 weeks WBV on body composition and muscle strength</td>
<td>Duration: Exercise series; Frequency: 35-40Hz; Amplitude: 2.5-5mm</td>
<td>2+</td>
</tr>
<tr>
<td>Roelants et al</td>
<td>2004b</td>
<td>RCT</td>
<td>Effects of WBV on knee strength and speed of movement</td>
<td>Duration: 30 minutes/session, 3 x week 24 weeks; Frequency: 35-40Hz; Amplitude: 2.5-5mm</td>
<td>1+</td>
</tr>
<tr>
<td>Cochrane et al</td>
<td>2004</td>
<td>RCT</td>
<td>The short term effect of whole body vibration training on vertical jump, sprint and agility performance</td>
<td>Duration: 9 days; 5 consecutive days; 2 days rest; 4 further days; two-minute exposures separated by 40 seconds for 5 exercise positions; Frequency: 26Hz; Amplitude: 11mm</td>
<td>1-</td>
</tr>
</tbody>
</table>
### Whole Body Vibration Training

<table>
<thead>
<tr>
<th><strong>AUTHOR</strong></th>
<th><strong>YEAR</strong></th>
<th><strong>STUDY TYPE</strong></th>
<th><strong>PARTICIPANTS</strong></th>
<th><strong>WBV PARAMETERS</strong></th>
<th><strong>SIGN GRADING</strong></th>
</tr>
</thead>
</table>
| Verschueren et al | 2004    | RCT            | 70 post-menopausal healthy women | Duration: Exercise series, 3x week, 24 weeks  
Frequency: 35-40Hz  
Amplitude: not stated                                       | 1+               |
| Ronnestad et al  | 2004    | RCT            | 16 males         | Duration: Squats on WBV appliance; 3 x/week for 5 weeks  
Frequency: 40Hz  
Amplitude: not stated                                       | 1-               |
| Russo et al      | 2003    | RCT            | 29 post-menopausal community dwelling women | Duration: 6 months, 2 x weekly, 2 x 3 minute bouts  
Frequency: 12-28Hz first month; 28Hz remaining 5 months  
Amplitude: laterally oscillating platform                     | 1-               |
| Salvarani        | 2003    | RCT            | 20 ACL reconstruction patients; 17 males | Duration: 5 x 1 minute bouts daily for 2 weeks  
Frequency: 30Hz  
Amplitude: not stated                                       | 1-               |
| De Ruiter        | 2003b   | Non-randomised controlled study  
Eleven week WBV on jump height, contractile properties and activation of human knee extensors | 20 physically active adult students | Duration: 3 weekly sessions, 11 weeks  
Frequency: 30Hz  
Amplitude: 8mm                                                | 2-               |
| Torvinen         | 2002c   | RCT            | 56 healthy adult volunteers; 21 males | Duration: 4 months, 3-5 x week; light exercise programme (4 minute total WBV daily;  
Frequency: increased over 4 months; 25-40Hz  
Amplitude: stable at 2mm  
Acceleration: varied according to frequency; 2.5g-6.4g (40Hz) | 1-               |
| Delecluse et al  | 2003    | RCT            | 67 untrained healthy female adults | Duration: 12 weeks, 3 x week, series of exercises  
Frequency: 35-40Hz  
Amplitude: 2.5-5mm                                          | 1-               |
| Torvinen         | 2003    | RCT            | 56 healthy adult volunteers; 21 males | Duration: 8 months, 3-5x week; as above; 4 minutes daily  
Frequency: increased over 4 months; 25-45Hz (oscillating)  
Amplitude: 2-6g  
Acceleration: 2-6g                                           | 1+               |
| Bosco et al      | 1998    | RCT            | 14 healthy sports-engaged adults (gender not stated) | Duration: 5 x 90 seconds WBV for 10 days  
Frequency: 26Hz  
Amplitude: 10mm                                              | 1-               |
4.3.2 Effects of WBV on locomotion and balance parameters

Whilst several investigators studied muscular performances such as vertical jumping and leg extension, it is important to assess the relevance of these findings to wider parameters of performance, such as speed across the ground and mobility. These may be particularly relevant in terms of being risk factors for falls in the elderly.

Ten studies (seven RCT’s and three controlled studies) measured balance (static and/or dynamic) parameters following WBV programmes.

Two studies discussed the effect of short-term WBV interventions with eight papers administering a longer programme ranging from 9 days to 12 months. Half the studies involved older adults (>55 years of age); the remaining half involved subjects with ages between decades two to four. Papers reporting on outcomes in older adults and post-menopausal women are discussed in their respective sections. This evidence reviewed in this section involves younger adults only.

Two studies that delivered a single, four-minute WBV session were by the same authors; both cross-over studies using the subjects as their own controls. These studies were identical in terms of methodology with a one-two week washout period between control and interventions; they differed only in the WBV parameters (frequency and amplitude) and in the fact they recruited different subjects; that said, the cohort age and gender mix was very similar. Concurrent with the WBV intervention (4 x 60 seconds was session) was a 60 second “light exercise programme”. A 15.7% (p=0.049) improvement was seen in body balance as measured by an automated postural sway platform following WBV training with an amplitude of 10mm and variable frequency (15-30 Hz, increasing 5Hz per minute) measured two minutes after the intervention. Concurrent with improvement in postural sway was strength and CMJ height. These effects were not lasting when measured at 60 minutes post-intervention. The alternate study frequency was 25-50Hz at 2mm amplitude. Surprisingly no WBV training effect was measured between the groups in the alternate study by the same authors. The point of difference between the studies appeared only to be the different amplitude administered. This may indicate WBV parameters (in this case amplitude) are of importance when prescribing treatment. No side effects occurred. Both papers were graded 2+.

Regarding longer-term programmes in healthy young adults, two further RCT’s by the same authors assessed the impact of exercises on a WBV following a four-month and an 8-month WBV regime (same cohort; n=56, 4 x 60 seconds per session, thrice weekly). WBV frequency was increased throughout the programme in a standardised fashion (25-45Hz) yet the amplitude was kept stable throughout at 2mm. No changes in either static or dynamic balance (assessed by 30m shuttle run) were identified at either four or eight months. The study reporting eight-month outcomes was high quality (1+), however, the earlier paper was deficient in describing the control group interventions and failed to report the randomisation process; this reflects its grading of 1-.

Finally, Cochrane et al (2004) administered daily WBV (five static postures) for 9 days (5 days successive WBV, 2 day break, 4 further days WBV) in a
group of athletic students. Agility as measured by the “up and back test” (2 x 15 metre sprint with turns) was unchanged, as were other parameters of CMJ, squat jump and sprint from baseline to follow-up. The authors also measured perceived discomfort from the interventions and reported that although this was notable in both control and WBV participants at the commencement of the study, both groups improved almost daily. The issue of discomfort was not discussed in detail and no further adverse events occurred. This study was graded 1- due to the randomisation process being poorly described and due to the small sample (n=24).

Key message

Five studies primarily enrolling healthy untrained adults have reported the impact of WBV training on static or dynamic balance. Two involved a single session and three longer programmes. Evidence is conflicting for shorter programmes but consistently the longer programmes have shown no effect. All studies were of moderate quality. The only side effect from these groups of studies was a diminishing level of discomfort experienced by participants from the WBV training programme over 9 days.

4.3.3 WBV training for flexibility

Researchers are also interested in seeing if WBV may influence muscle flexibility. The same physiological mechanisms involved when undertaking usual muscle stretching interventions may be harnessed or augmented with WBV. Identifying a further modality to influence flexibility would offer much as reduced soft-tissue flexibility and/or shortening is linked to restricted joint movement and possibly to a higher risk of muscle tears and other injuries.

Four studies (three RCT's and one controlled trial) measured soft-tissue flexibility outcomes following WBV regimes. Two of the four studied trained females. All four used a commonly used outcome of posterior knee soft-tissue and hamstring muscle group extensibility (the sit-and-reach test), with one study measuring upper limbs flexibility using the ‘hand-behind-head’ functional measure. This measures a combination of mostly glenohumeral (shoulder joint) movements.

Programme durations varied from a single bout to longer programmes of up to 8 weeks. Frequencies were similar across the studies involving younger subjects with frequencies varying from 26-35Hz and amplitudes from 4-10mm. The elderly cohort was prescribed a lower amplitude (2-5mm). Outcomes in the healthy elderly cohort will be discussed in the ‘WBV training in the healthy elderly’ section.

Van den Tillaar et al (2006) hypothesised that a four-week WBV programme would increase ‘hamstring’ flexibility. A mixed-gender cohort of nineteen healthy young adults was randomised into WBV or control groups. The WBV intervention was a five minute treadmill walk followed by 30 second bout of
WBV, thrice weekly. Each session finished with three hamstring stretches using a 'contract-relax' method, a stretching method purported to utilise the stretch-reflex pathway and produce flexibility gains greater than with static stretching. The control group underwent warm-up and stretching only. Subjects adopted a semi-squat position with knees at 90° flexion on the platform. Both groups showed a significant increase in hamstring length at the end of training (p=0.024). Final hamstring range of motion, however, was better in the WBV group (26.8° vs 12.4° (p=0.002)). The authors suggested three possible mechanisms for the improvement seen; 1. A vibration-increase in local blood flow which increased muscle and connective tissue flexibility; 2. An enhanced quadriceps stretch-reflex loop and; 3. Vibration-induced pain inhibition, which meant subjects could stretch beyond earlier limits. This paper was of high quality (1+).

Two subsequent papers assessed hamstring flexibility in female athletes (Cochrane and Stannard, 2005 and Fagnani et al, 2006); the former paper involving a single session, the latter a thrice weekly regime over 8 weeks. Flexibility was not the sole focus in either programme, but rather one outcome of a battery of outcomes. Both programmes indicated statistically significant superior hamstring flexibility gains over control participants. Results following a single session indicated hamstring flexibility measured by the sit-and-reach test improved by 8.2% (both control groups 5.3%). The results from the 8-week in control participants were a sit and reach distance of 19.59cm as opposed to 22.6cm mean average in the WBV group(p=0.00004). Controls were in the first study, static posture on the WBV platform standing without vibration and seated cycling; the second study involved a largely unknown control ("specific programme training"); neither of these two studies involved other stretching techniques, and whilst this may have added an additional confounder to the mix, suggesting flexibility improves as a result of some of the treatment interventions alone may be ambitious. Furthermore, in both studies, samples were small (n=18 and 26), and only involved female athletes; this implies findings from these latter two papers may not be generalisable to untrained groups or males. There were additional concerns with the quality of both studies that reflect the gradings of 2+ and 1- respectively.

Regarding safety, one study only failed to report adverse events. Overall four subjects withdrew across the four studies, all but one reportedly for reasons unrelated to treatment.
Whole Body Vibration Training

Key message
Evidence from one quality RCT with a healthy mixed gender cohort indicates WBV in conjunction with a contract-relax programme is effective in producing a clinically important improvement in posterior knee soft-tissue extensibility after four weeks. This study did not analyse outcomes with respect to gender. Two further studies of lesser quality involving trained female athletes indicate positive outcomes after both short and longer term interventions. No safety issues were identified, although one lower quality paper failed to report these.

4.3.4 Effects of WBV training on bone mineral density and other bone parameters

Studies in rats and sheep suggest that WBV has beneficial effects on BMD and therefore could have comparable effects in humans\cite{43,44}. The premise is that the mechanical stimulus provided by the vibration is osteogenic\cite{5}.

Seven primary studies were identified that measured bone mineral density (BMD) and other bone parameters, five of which specifically investigated this in post-menopausal women\cite{13,45-48}. Those concerning post-menopausal women are discussed in a separate section. Two studies specifically assessed the effect of WBV training on females with diagnosed bone density reduction (previous fracture\cite{49} or with a diagnosis of osteoporosis\cite{46}); one examined bone density parameters in a young healthy, mixed gender group\cite{36}. This group of studies comprised six RCT's and one controlled trial.

Osteoporosis is currently defined as a BMD score of 2.5 standard deviations below the average, as compared with a 25 year old caucasian female\cite{1}.

Two papers studied bone outcomes in younger adults\cite{36,49}. Gilsanz et al (2006\cite{49}) instigated a 12-month WBV programme recruiting 50 “healthy white females” between the ages of 15 and 20. These subjects were randomised into a control group (calcium supplement) or calcium and WBV on the basis of how geographically close they were to the assessment centre. Subjects had suffered a previous fracture and had the lowest BMD readings as compared with 150 similar adult females. Improvements were made in both groups across most BMD parameters over the study period. All bone and muscular parameters increased significantly from baseline in the WBV group – for axial and appendicular measures in terms of cortical bone, cross-sectional area and muscle area ($p<0.001-0.003$). The control group improvements reached significance for femur cross-sectional area ($p=0.05$) (between-group difference statistically in favour of WBV ($p=0.04$)) and one muscular parameter only (between groups not significant ($p=0.16$)). One subject in the WBV and four control subjects withdrew from the study due to lack of interest. This score was graded 2- with the primary concern around the allocation of subjects to treatment groups.

Torvinen et al (2003\cite{36}) administered a four minute session, 3-5 x weekly over 8 months to healthy adult males and females and compared outcomes with a 'no treatment' group. Findings indicated WBV had no impact on mass, structure or bone strength in lumbar spine, femoral neck, trochanter, heel and distal forearm locations. No adverse events were observed in this group. This study was
graded highly 1+, although it did use a ‘no treatment arm’, which may be inappropriate.

**Key message**

Two studies to date have investigated the impact of WBV training on bone mineral density or other bone volume and or quality parameters. One quality RCT in young females with low bone mineral density indicated some positive outcomes after 12 months of training. Conflicting evidence, however, comes from one mixed cohort showing no effect after an 8 month WBV training programme.

No safety issues have been identified to date.

### 4.3.5 Effects of WBV training on the cardiovascular, peripheral vascular system and BMI

For some, standard training modalities to stress the cardiovascular system for the purposes of enhancing aerobic capacity are unattractive or impossible. Using WBV may be a viable low impact alternative for such individuals.

One controlled study and two case series investigated the impact of WBV on cardiovascular exertion/aerobic capacity; two (one RCT and one case series) investigated the effects on peripheral vasculature. Two RCT’s and one case series in particular investigated the effect of WBV the potential of WBV to effect weight loss by measuring fat loss and/or Body-mass index (BMI) outcomes following WBV.

Rittweger et al (2000) exercised a group of 37 healthy young adults to exhaustion on a platform, performing squats with load. Heart rate increased to an average 128 beats/minute, with blood pressure increasing to 132/52 on average. Oxygen uptake ($V_O^2$) was 48.8% of that compared with $V_O^2$ maximum results from cycle ergometry. The authors concluded WBV could elicit a mild cardiovascular stress when exercised to exhaustion. An itching erythema was noted in almost half of the participants. No drop-outs due to this were reported (3).

The same authors using a cross-over trial methodology compared oxygen uptake and perceived exertion in a group of 12 healthy adults following WBV. Subjects performed exercises (3 x 3 minute squat combinations) with and without WBV with a 10-15 minute washout period. Perceived exertion was greater following the WBV intervention (e.g. average of 14.4 without vibration to 16.8 with a loaded squat exercise). Maximal oxygen uptake was significantly better in the WBV with exercise group than without WBV (e.g. loaded squat=12.1 without vibration vs 17.1 after WBV). The training effect the authors believed may be considered equivalent to “moderate walking”. It is unknown if subjects were randomised to the order in which they received the intervention. Side effects were not mentioned (2-).

One small case series investigated the effect of WBV on patients with diagnosed Chronic Fatigue Syndrome with the aim of increasing subjects’
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aerobic capacity and improving quality of life. Ten subjects underwent a six-month WBV programme (unknown number of sessions/week) with the following parameters: 18-22Hz, 10mm amplitude. The programme increased gradually from two minutes of static WBV postures to four within three sessions (18-22Hz, 10mm) and subjects performed two stretches at the end of the WBV training. All patients reported worsening of fatigue in week one which reportedly resolved from week two on. Although this study presents interesting results, case series present relatively low-level evidence and the sample size was very small. Side-effects could have been discussed in further detail (3).

Two further studies examined the peripheral effects of WBV.

Kerschan-Schindl et al (200152) presented case series information that blood flow measured by Doppler sonography in quadriceps and gastrocnemius musculature increased following a single session (9 minutes) of WBV. Blood flow changes in both muscles was sufficiently great for the authors to assert the effects of WBV are due to muscle contractions during the WBV rather than passive vibration (3).

Using an RCT methodology, Lohmann et al (200753) investigated the impact on skin blood flow in three groups, vibration only (subject supine with calves resting on the vibration plate), vibration and exercise (routine) and exercise only. Indications are that skin blood flow (SBF) in the right distal calf in the WBV alone group increased to 250% following the intervention and remained significantly elevated for a further 10 minutes. The other two groups showed, if anything, a slight reduction in SBF following the intervention at all time points. The SBF reduction in the alternate groups may be explained by the calf musculature's requirement for oxygenated blood, thereby reducing cutaneous blood flow. This may have implications for peripheral vascular conditions. WBV appeared to have countered this effect. The authors failed to describe how subjects were randomised, or whether baseline vascular parameters and body parameters were similar. (1-).

The authors in these latter papers failed to report adverse events or safety issues.

Three papers investigated the effect of WBV on BMI.

Gusi et al (200645) used an 8-month programme targeting post-menopausal women and reported significant difference in BMI in favour of the WBV group at the end of the study (.9 WBV vs .1 control, p=0.049) (1-). This programme administered a thrice weekly WBV training programme (12.6 Hz, 3mm amplitude, static squat posture on the platform).

A further small case series51 , described in detail earlier in this section, administered WBV training to in a group of individuals with Chronic Fatigue Syndrome. A reduction in BMI (p<0.05) after six months of training was reported. Notably, subjects reported feeling more fatigued after week one. The authors report this improved from week two onwards (3).
To the contrary, results from Roelants et al. (2004) indicated only fat free mass showed a significant difference in favour of the WBV group (young females) after six months of training (2.2%). Subjects performed unloaded static and dynamic exercises on the platform at 35-40Hz, 2.5-5.0 mm amplitude. A change of 2.2% appears too small to be of clinical significance. Results were compared with two groups; one ‘no treatment’ group and one that underwent a standard cardiovascular and resistance training programme. No other changes were seen in any group for weight, percentage body fat or skin fold thickness (2+).

Regarding adverse events, the only point of concern may be the increase in fatigue noted in the Chronic Fatigue group. This indicates care should be taken to minimise the potential for symptom augmentation in such groups.

**Key message**

<table>
<thead>
<tr>
<th>There is currently insufficient literature to support WBV improves aerobic capacity. Evidence comes from one poor controlled study and two case series. One study has compared the effect of WBV to that of a ‘moderate walk’.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two studies investigated the impact of WBV on peripheral blood flow with the intention of this in future perhaps being useful for peripheral vascular conditions. There is insufficient evidence to support the safety of WBV for these specific purposes. No substantial safety issues have been identified thus far from the limited number and quality of papers, although few papers reported safety issues.</td>
</tr>
<tr>
<td>Evidence from two RCT’s indicated reduction in BMI or fat free mass following WBV training regimes. It appears unlikely, however, that the 2.2% reduction reported in one study in fat free mass is important. The minimal increase in metabolic rate reported from other literature and noted from peer review of this document would indicate this modality is unlikely to be an effective modality to effect in significant fat loss and or/bmi reduction.</td>
</tr>
</tbody>
</table>

**4.3.6 Effects of WBV on the endocrine system**

Examining hormone levels following WBV is an area of interest for researchers as it may provide information as to the mechanisms by which WBV may induce strength related changes and possibly weight loss. To this end, four studies (one RCT, two controlled trials and one case series) were identified and reviewed.

Bosco (2000) using a case series design reported an increase in testosterone but a drop in cortisol and growth hormone following a 10 x 60 second single session of WBV in a group of healthy males. The authors postulated the WBV stimulus was insufficient to stimulate a general stress response, however, the simultaneous increase in testosterone and neuromuscular responses (as outlined in the short-term strength section of this report) are simultaneous and may have a common mechanism.
Di Loreto et al (2004) studied the effects of two WBV training sessions on blood glucose and hormonal concentrations (insulin, glucagon, cortisol, epinephrine, norepinephrine, GH, IGF-1, free and total testosterone) in 10 healthy men. Volunteers were subjected to a single bout of 25 min WBV either in the absence or presence of vibration. Results showed reduced plasma glucose concentration and increased norepinephrine plasma levels. The authors concluded that the intervention may have increased glucose utilisation due to induced muscle contractions, however, did not expect this to be sufficient to reduce fat mass in obese individuals.

Goto and Takamatsu (2005) administered a single session of WBV (10 x 60 second bouts) using an RCT methodology in a group of 8 healthy untrained males. Serum free fatty acids significantly decreased in both groups following sham and WBV interventions but no statistically significant difference was found at any time point between the groups. The authors concluded that although growth hormone increase has in previous studies been linked with a lipolytic effect this was not seen in this study. This may be due, the authors suggested, to the fact that this sample comprised non trained participants.

A further study (Kvorning et al 2006) explored the hormonal responses to WBV that are thought to be responsible for muscle hypertrophy and therefore strength gains following WBV. Subjects were randomised to a squat-trained group (loaded squat), squat and WBV (loaded squat on platform) or a WBV only group (squat with broomstick) over 9 weeks. WBV did not change the acute hormonal response to a training session after a training period. The authors concluded that hormonal changes thought to mediate strength gains were not seen in this study and decided that the WBV intensity may need to be increased to see this effect.

No papers reviewed thus far concerning hormonal responses to WBV reported on safety or adverse events.

**Key message**

There is a limited body of literature investigating the effects of WBV on the endocrine system. The premise of affecting hormones that mediate both strength and weight loss is unclear.

Adverse events are poorly reported across these studies. Safety issues may well be unlikely to be of great concern in the single session interventions, however, for longer programmes may be important.

### 4.4 WBV training for specific populations

#### 4.4.1 WBV training for post-menopausal women

Eight RCT’s in total were identified that assessed the impact of WBV training in post-menopausal women. Five papers were identified that assessed bone mineral density parameters in older women three reported outcomes relating to lower limb muscle strength and/or countermovement jump WBV Parameters.
varied across studies from 12-40Hz, Hz, with acceleration of 0.2-10g. Interestingly higher acceleration and frequencies were used in the studies that investigated WBV training impact on bone parameters. One RCT in this group investigated balance parameters.

Verschueren et al (2004) assessed the impact of WBV training on muscle strength and bone quality in a cohort of 70 post-menopausal women aged between 58-74 years. This study excluded individuals with diagnosed osteoporosis. Subjects were randomly assigned to a WBV group (n=25), a resistance training group (n=22; non-weight bearing exercise) or a no-treatment control group (n=23). The intervention groups trained thrice weekly for six months. Increased BMD of the hip (p<0.05) was reported in the WBV training group with no change either in the control or resistance groups. This study was graded 1+, despite the fact that blinding methods were not specified. Importantly, resistance training in this instance was non-load-bearing and this may have a confounding effect on the impact of WBV (combining WBV and weightbearing activities).

Iwamoto et al (2004) reported BMD and back pain outcomes in the lumbar vertebrae in post-menopausal women to determine if WBV enhanced the effect of the medication alendronate (used to treat osteoporotic fractures). Fifty women were randomly assigned to an alendronate or alendronate and WBV training exercise group. WBV training consisted of a four-minute duration static posture regime carried out once per week, for 12 months. Results showed that only a reduction in chronic back pain was greater in the WBV, leading the authors to conclude this was due to the relaxing effect of the WBV on the back musculature. BMD increased in both groups to the same extent and thus in this experimental design WBV gave no additional benefit. However since both groups received alendronate it is not possible to exclude that WBV alone could affect bone mineral density. Furthermore, WBV once per week may not in fact be therapeutic.

Russo et al (2003) administered a six-minute, twice weekly WBV regime for six months to 29 post-menopausal women. Subjects were excluded if they had evidence of metabolic bone disorders but were eligible if they were undergoing hormone replacement therapy. Findings were compared with a similar cohort that underwent no training. No bone characteristic changes were noted at study completion between the two groups. Knee pain preventing study completion occurred in one WBV subject. This was a study of average quality with significant reporting issues.

Rubin et al (2003) studied the impact of home based WBV appliances in women 3-8 years following the onset of menopause. Subjects spent 10 minutes twice daily, seven days per week for 12 months standing on a WBV platform in their home. The control group stood on an inactive machine. The placebo and active WBV both emitted similar auditory signals when in operation and compliance with treatment was able to be electronically monitored. Groups differed at baseline with the placebo group weighing more (p=0.03; 69.0kg vs 63.8kg in WBV group) and having a higher body mass index (BMI) (26.4 vs 24.4, p=0.04). Forty-six subjects had complete final records. One headache
was reported in the placebo group, and there were 6 withdrawals (one active and five placebo). These were not explained and if subjects dropped-out within three months, they were replaced.

Intention to treat analysis of all 70 recruited subjects indicated non-significant changes in BMD in or between groups. The active group lost 0.69% femoral neck BMD versus a 0.27% loss in the placebo group. For the trochanter, the active group lost 0.07% BMD versus 0.19% in the placebo (no p-values reported).

Of the 64 remaining participants, 56 had a 12 month DEXA scan results. Compliance with all treatments across this group ranged from 1-95%. Thirty-seven percent of the subjects completing the study were at least 80% compliant. As there was a strong positive association between compliance and efficacy, regression analyses were undertaken which showed that with 100% compliance, trochanteric BMD would be projected to increase 5.1% (p=0.085); for the femoral neck, 1.8% (p=0.4) and BMD of the spine would be predicted to show the greatest increase of 7.1% over a year (p=0.0039). Post-hoc analyses indicated bone density loss was prevented in women with lower body mass.

The authors iterated that future studies would need to attend to compliance issues. An earlier paper by Hannan et al (2004) investigated the feasibility of WBV regime in elderly post-menopausal women. This study had shown better compliance (93% for a once daily 10 minute treatment over six months). This paper was well conceived and well reported (1++).

A further paper by Gusi et al (2006), compared thrice-weekly WBV sessions with a walking programme over 8 months. Only femoral neck BMD (measured femoral neck, greater trochanter and lumbar spine) was significantly greater in the WBV group at study completion (p=0.011). Two subjects in the WBV group and four in the control group dropped out due to lack of interest. This study was graded 1-. Overall adverse events across the papers were reported adequately. These were relatively minor ranging from one case of knee pain to disinterest.

Three quality RCT’s (Roelants et al 2004b, Verschueren et al 2004 and Russo et al 2003) indicate positive gains in muscle strength parameters following a WBV regime in post-menopausal women. Two of these studies have been already discussed with respect to bone density and other bone parameters in this section.

Roelants et al randomised 89 subjects into a WBV training group, a resistance training group or a ‘no-treatment’ control group. Training was thrice weekly for 24 weeks, commencing at 35Hz and 2.5mm and increasing to 40Hz and 5mm by the programme end. Equally positive gains were seen in both WBV and resistance training groups at programme completion with respect to isometric and dynamic knee extensor strength (15 and 16% respectively), speed of knee extension movement (7.4% and 6.3% at 1% and 20% of maximum) and CMJ height (19.4% increase); no change was seen in control participants (1+).
Verschueren et al, a 15% and 16% improvement in isometric and dynamic muscle strength respectively in participants’ knee extensors as compared with a resistance training group (p<0.01). The dose was 6 minutes WBV per session; three sessions per week for six months; the starting frequency was set at 35Hz and increased to 40Hz, with the acceleration between 2.28-5.09g (1+).

Russo et al reported a 5% improvement in muscle power (as measured by CMJ) following a six-minute, twice-weekly WBV regime for six months. Frequencies were progressed from 12-28Hz, acceleration .1-10g using a lateral oscillating platform over the length of the programme.

No substantial safety issues were identified in these latter three papers. Adverse events were clearly described across all three papers with one study reporting one case of knee pain in the WBV group, whilst oedema, leg itching and erythema was reported in over half the participants in one other study.
Key message

Bone density:
There is conflicting evidence for the efficacy of WBV interventions for the purposes of improving or preventing reduction in bone mineral density or other bone quality/volume parameters in post-menopausal women. Evidence comes from five randomised controlled trials, three of which indicate either enhanced BMD or WBV being effective to prevent bone loss. One study that showed no effect on BMD that administered WBV may be queried on the basis of overall WBV dose (once weekly application). This study also was the only study to target osteoporotic women. Further research would be needed to clearly determine the impact of WBV in healthy and osteoporotic populations.

No literature has been published to date indicating WBV is effective in reducing the incidence of fractures, largely the purpose of WBV in this population. It is also not clear from studies to date whether the potential for WBV to effect bone parameter changes may be different for women with diagnosed osteoporosis as compared with perhaps osteopenic post-menopausal women. Compliance with long term programmes WBV regimes appears to be an important issue.

There appears moderate evidence to suggest this is a safe intervention. Adverse events were well reported and included knee pain to disinterest. No serious adverse events have to date been reported.

Strength:
There appears moderate evidence for isometric and/or dynamic strength gains in knee extensor musculature and CMJ height in post-menopausal women based on the evidence from three quality RCT’s. It is unclear, however, if WBV training produces superior outcomes to those from conventional resistance training programmes based on conflicting evidence from two RCT’s.

There is moderate evidence that WBV training is safe for this population.

Balance:
One RCT administering a 12-week WBV training programme reported statistically significant improvements in single-leg balance. The control group, however, undertook a walking programme and this may be considered an unsuitable intervention for the improvement of balance. Choice of control group in future studies will be important to determine whether WBV may be superior to standard programmes as has been questioned with the other outcomes for this population.

There is no information to date whether such gains are enduring and/or they result in a reduction in falls or an improvement in function.
4.4.2 WBV training in the healthy elderly

Three quality RCT’s and one controlled study studied groups of healthy elderly subjects for the purposes of improving strength, balance, gait and flexibility. Subject numbers ranged from 24 nursing home residents to 220 community dwelling adults. Programme length varied from 6 weeks (n=2) to 12 months. WBV parameters varied from 10-30Hz and 3-7mm amplitude. Amplitudes appeared to vary in conjunction with rest periods (15-90s), and numbers and type of exercises (static posture vs active exercises on the platform). Note that studies that are included in this section may well involve post-menopausal women to some degree. The four studies included here study do not consider bone mineral density as an outcome of interest as was the case with the post-menopausal population.

Three papers compared WBV and exercise with exercise alone\textsuperscript{11,55,56} and two papers compared WBV with a comprehensive fitness or walking programme\textsuperscript{19,45}.

Table 3 provides a summary of WBV and programme parameters across the healthy elderly cohort papers.

Outcomes measured included; single leg balance (time); the TUG – a measure of speed to rise from a chair, walk a short distance and return to the chair, and balance using automated postural sway measures. Gait parameters were measured infrequently (step number and length).

Bautmans et al (2005\textsuperscript{11}) and Bruyere et al (2005\textsuperscript{55}) both administered six-week WBV training interventions. The former study administered WBV training to a group of 24 rest home residents, the subjects performing a series of six exercises whilst standing on the WBV platform; there were three sessions of WBV per week, whilst both groups concurrently received additional chair-based group exercise sessions (twice weekly). The control group stood on the non-operational platform listening to the sound of a vibrating platform. Improvement in body balance scores was significantly better in the WBV training group at six weeks (Tinetti test overall score=13.9 vs 11.8, p=0.001). WBV participants reduced their time significantly in the ‘TUG’ test (15.3 vs 14.8, p=0.029). Hamstring flexibility as assessed by the sit-and-reach test and shoulder flexibility as assessed by the ‘hand-behind-head’ test after six weeks indicated no change from baseline to the six-week follow-up. It is unlikely the upper limb flexibility test was a valid outcome considering the lower limb WBV intervention. Interestingly no significant difference was reported between WBV training and control groups for knee extensor strength despite the positive changes seen in the other outcomes. Notably, also this study did not directly compare WBV training with a stretching routine, and therefore excluding confounding factors may be difficult.

No substantial safety issues were identified, although one participant dropped out of the WBV group due to fear and one other due to groin pain. This study was high quality (1+).

Bruyere et al (2005\textsuperscript{55}) assessed the effect of static posture WBV training sessions on muscular performance and body balance in 42 nursing home
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residents. The WBV training group improved by 3.5±2.1 points on the body balance score compared with the control group, which consisted of a comprehensive balance and exercise programme (p<0.001) at the end of the study. Tinetti scores at study completion indicated that the WBV training group, having been within the range for being ‘at risk’ of falls at baseline (14.9/28; threshold=19/28), was now outside these parameters (20.5/28). These results present the first data that suggest that WBV training may in fact improve elements of fall risk. Quality of life scores as measured by the Short Form-36 (SF-36) also improved on 8 of 9 items compared with the control group. These changes were statistically significant and included aspects of pain, social and physical function and general health. Minor tingling in the lower limbs in some subjects was the only adverse event reported. This was a high quality study (1+), the only negative being the small sample size (n=44).

Bogaerts et al (200619) undertook the longest programme thus far published, administering a 12 month programme to healthy community dwelling adults between 60 and 80 years of age (n=220). Ninety-four subjects were assigned to the WBV group, 60 to a fitness programme (including cardiovascular endurance, resistance, balance and flexibility training, (FIT)) and 66 to the control group (no treatment). Thrice-weekly sessions lasting a total 40 minutes involved an exercise routine that included squats, toe-raising and one legged squats on the WBV platform. Seven withdrawals due to knee pain were reported but not explained. Dynamic posturography, which tests gaze and postural stability57 was the primary outcome measure. This “provides clinical information specific to the patient’s use of individual sensory inputs and motor reactions under a variety of daily life conditions” and reportedly “relates well with the patient’s symptoms and functional complaints.” Results were reported only for those that complied with >80% of the sessions over the 12 month period, and in this case excluded 23 subjects. Results reported for sway-referenced conditions indicated that all three groups made statistically significant improvements from baseline to 6 months and baseline to study completion. Two results only were, however, significant; firstly, for one condition studied with posturography (sway referenced vision and support surface57) the number of falls whilst testing reduced in both WBV and fitness groups, but not in controls. The FIT group showed the greater reduction (79% WBV vs 87% fitness; p<0.05, no statistically significant difference between FIT and WBV). One further parameter improved solely for the WBV group - the sway energy score for ‘toes down rotations’ (between groups p=0.040); pre-mid and pre-post improvements were highly significant for WBV but not for FIT or controls (both p<0.001). The authors concluded WBV could contribute to some aspects of postural control in a healthy elderly population. This study was large and well conceived, but the management of missing data was not reported. Between-group sample size differences were also not explained. There were seven cases of knee pain (WBV=5, FIT=2). It is unknown if these were attributed to the interventions although it is likely, and whether this resulted in patients dropping out is unknown. To determine the impact on true falls prevention, the

1 Buatois et al (2006) reported in one study that loss of balance in the last trial of the SOT test was the best predictor of recurrent falls risk (OR=3.6,95% CI=1.3-10.11. Interestingly other clinical tests of balance - timed up and go and one leg balance tests revealed no significant differences between fall numbers.
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cohort would need to be followed longitudinally with long-term WBV interventions (1-).

Finally, a non-randomised controlled study of lower quality by Kawanabe et al (2007) administered a four-minute session once weekly to a mixed gender elderly group (four males only). Both WBV and control groups concurrently received an exercise intervention including balance and strength and 30 minutes walking twice weekly. The addition of one WBV session weekly resulted in the WBV subjects reducing their 10-metre walking time, improving their single leg stance and increasing their step length (all p<0.05). These results seem convincing, however, considering the participants were allocated to the WBV or exercise group based on their willingness to participate and cohort sizes were substantially different (27 WBV training vs 40 Fitness), questions remain regarding the confidence that can be placed in these results (2+).

Regarding safety, a variety of adverse events are reported across the papers; these ranged from minor tingling in the lower limbs to musculoskeletal complaints. Bogaerts et al reported 5/94 withdrawals in the WBV group due to knee pain (unspecified and poor detail). Only one study of low quality failed to discuss adverse events.

Somatosensory function declines with age and such changes have been associated with diminished motor performance. The human balance control system relies in part, on somatosensory feedback which is diminished in the elderly and is associated with an increased likelihood of falling. In an ingenious study (not formally reviewed as outside the project brief) it was shown that randomly vibrating shoe insoles (rather than a WBV platform) ameliorated age related impairments in balance control. The sample of 27 volunteers included 15 young people and 12 elderly participants. They measured the effect of vibration on postural sway and whilst there was improvement in both groups, it was more marked in the elderly group. Improvement was seen in two parameters; mediolateral range (p=0.008) and critical mean square displacement (p=0.012)). This preliminary case study (graded 3) raised the issue that studies may be best directed towards those that need therapy, rather than using healthy young volunteers.

Key message

There is moderate to strong evidence that administering a WBV regime both as a stand-alone programme and in addition to an appropriate exercise regime reaps balance benefits in older adults, with as short a programme as 8 weeks. One study that reported improvement in balance and locomotion parameters interestingly reported no improvement in subjects’ knee extensor strength. Gains identified from three quality trials appear to be realised both with WBV regimes requiring the subjects to exercise or hold one or more static postures with as few as one session per week. Not all studies, however, reported substantial clinical improvements and it is unclear as to the superiority of WBV training programmes over conventional cardiovascular, resistance and/or balance programmes. It is also unknown whether the changes measured may be enduring or if real-life falls reduction is realised.
One RCT only has investigated the effect of WBV training on flexibility in the healthy elderly. No improvements were seen using two common measures of upper and lower limb flexibility after 6 weeks of WBV training.

The number and severity of adverse events overall appear relatively minor and at this point seem unlikely to impact on the viability of the intervention.
Table 3: Dosage for longer-term WBV interventions in the elderly for those studies assessing balance and locomotion parameters

<table>
<thead>
<tr>
<th>Paper</th>
<th>Duration of overall programme</th>
<th>Population</th>
<th>WBV duration</th>
<th>Rest♦</th>
<th>Exercise/static posture</th>
<th>Frequency♣</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bautmans et al</td>
<td>3 x week for six weeks</td>
<td>24 Nursing home residents, Mean age 77.5 yrs</td>
<td>Duration of the six static exercises each session varied from 30-60 s with varied reps of 1-3</td>
<td>30-60 s; variable over programme</td>
<td>6 static exercises</td>
<td>30-45 Hz, 30Hz commencement progressed over programme</td>
</tr>
<tr>
<td>Kawanabe et al</td>
<td>Once per week for 2 months</td>
<td>4 men and 63 women ‘clinic visitors’ mean age 71-2 yrs</td>
<td>4 minutes ♦</td>
<td>unknown</td>
<td>Stood on platform; ‘bent hips and knees’</td>
<td>12-20 Hz, unspecified progression</td>
</tr>
<tr>
<td>Bruyere et al</td>
<td>3 x per week for 6 weeks</td>
<td>42 Nursing home residents 63-98 yrs</td>
<td>4 x 1 minute</td>
<td>90 s rest</td>
<td>Stood on platform; unspecified position</td>
<td>10 Hz for minutes 1 and 3; 26Hz for minute 4</td>
</tr>
<tr>
<td>Bogaerts et al</td>
<td>3 x week for 12 months</td>
<td>220 Community dwelling adults 60-80 yrs</td>
<td>30-60 second bouts ♣</td>
<td>15-60 s rest; variable over programme</td>
<td>Combinations of static and dynamic exercises across programme</td>
<td>30-40Hz -- varied over the programme</td>
</tr>
</tbody>
</table>

♦ it is unknown if this 4 minute WBV intervention was split by rest periods
∧ it is assumed study subjects are community dwelling adults, but the paper does not specify
♦ rest between bouts of WBV
♣: authors stated maximum 40 minutes total session including exercises and warm-up/cool down; programme progressed from 4-12 series of progressive exercises
4.4.3 WBV training in rehabilitation populations

4.4.3.1 WBV and diseases/conditions of the nervous system

Seven papers in total were identified that administered WBV training to subjects with neurological conditions or diseases. WBV training has been trialled on the basis of producing balance and functional improvements by and large, however, one paper investigated the impact of WBV on bone mineral density in physically disabled children. WBV frequencies ranged from 1 to 90Hz. Amplitudes were by and large 3mm across all studies.

Two papers reported on WBV with stroke populations. Van Nes et al (2004) gave 23 unilateral chronic stroke patients a short course of WBV and reported improved proprioceptive control of posture. This study was a case series and served as a pilot project for a well-conceived RCT. The subsequent RCT indicated that WBV administered regularly in a larger group of stroke sufferers, however, had no beneficial effects on balance or other outcomes. Fifty-three patients with moderate to severe functional disabilities six weeks post-stroke and within three days of admission to a rehabilitation centre were randomised to either WBV or exercise therapy on music (stand on platform and have music akin to vibration sounds played). Both groups also concurrently received a comprehensive inpatient rehabilitation program which included physical therapy, occupational and speech therapy. The WBV group received 4 x 45-second stimulations for five days per week over six weeks. Although improvements were seen in all outcomes at the end of the study, and seemed to continue improving up to 12 weeks, no between-group differences were found at any time-points. The failure to, however, stratify subjects based on stroke type (ischaemic vs haemorrhagic) may have confounded the outcomes. Two patients in the control group suffered a further CVA, whilst one in the WBV group withdrew for non-health reasons. This study otherwise was of high quality.

Four further studies (two involving Parkinson’s subjects and one each involving cerebral palsy and multiple sclerosis sufferers) were reviewed. Three were RCT’s and one a controlled trial.

Haas et al (2006) administered a single session of WBV to a group of long-term Parkinson’s sufferers using a controlled trial design (randomised to WBV followed by a rest period, or rest followed by the WBV intervention. Five 60-second WBV bouts (static posture held) were administered in a single session.

The ‘rest’ period was unspecified and was the control intervention. No significant changes in Unified Parkinson’s Disease Rating Scale (UPDRS) scores were identified after the rest period, however, all subjects showed improvement in their scores after WBV, with a 16.6% reduction in scores in group A (WBV followed by rest intervention) and a 14.7% reduction in Group B (rest followed by WBV). Most improvement was seen in tremor and rigidity (24 and 25% respectively) although all changes excepting cranial scores were significant at the p<0.01 level. No adverse events occurred. This study, however, failed to adequately describe the ‘rest period’ and there were other methodological concerns.
Turbanski et al (2005) also administered a single session (5 x 60 seconds static posture) on the WBV training platform, randomising Parkinson's sufferers depending on their UPDRS scores. In this instance, WBV was compared with a group who undertook a “moderate” walk around the hospital grounds. Narrow and tandem standing scores improved significant for both groups from baseline to follow-up (7.1%; p=0.04 control and 14.9%; p=0.00 WBV). Tandem standing improvements only were significantly better in favour of the WBV group (24% vs 11.3% improvement in control; p=0.04). Although these results appear promising after a single session, safety issues or adverse events were not reported (1-).

The effect of a single session of WBV was piloted with 12 patients (six test and six control) with multiple sclerosis. Inclusion criteria were disturbance to balance and presence of gait disorders (impairment ≤ 5 on Kurtzke’s score§). Of the three outcome measures; posture, functional reach and TUG, only TUG scores improved. The improvement was significant (p=0.04) at one week after WBV and not significant (0.093) two weeks after the test. This was an RCT but used a very small sample. One WBV subject complained of fatigue during the study, but no drop-outs were reported (1-).

The effects of three sessions/week of WBV over 8 weeks in 14 adults with cerebral palsy has also been investigated. Patients were randomised to either WBV or resistance training. This study had the following five outcome measures: spasticity, isokinetic muscle strength, walking, TUG and a combined functional measure (Gross Motor Function Measure**), yet to be validated in adult patients. Despite the fact some components of the GMFM increased in the WBV group from baseline to follow-up, no between-group differences were found at 8 weeks; furthermore, although an improvement in extensor spasticity (p=0.04) occurred there was no carry-over into function. No spasticity changes were significant for other muscle groups. Stiffness following treatment occurred in one subject in the WBV group and three in the control group. The use of the GMFM with this group and the small sample reflects its grading of 1-.

Finally one paper has published results following a WBV intervention in physically disabled children. Twenty children capable of standing independently but with limited mobility were recruited to undertake a 10 minutes daily, 5 days/week WBV standing programme over six months. The purpose of the study was to investigate whether the WBV intervention had any effect on BMD in a group well known for impaired bone density and a high falls risk due to reduced and impaired mobility. Ten children each were randomised to a standing WBV appliance or a placebo appliance. Again, both appliances emitted auditory tones whilst ‘in operation’ in order to ensure subject blinding.

---

§ Kurtzke’s scale was a scale developed some 50 years ago to describe disability from multiple sclerosis. It has since been revised and is now widely accepted measure of clinical evaluation of MS based on clinically observed, not patient described, problems associated with multiple sclerosis. It currently has an ordinal scale of 0-10 with 0 being a normal neurological exam, and 10 being death from multiple sclerosis. It is now known as the Expanded Disability Status Scale (EDSS). It appears at a glance to be well validated.

** The GMFM is a motor skill assessment used for children with cerebral palsy validated for children between 5 months and 16 years.
There were three drop-outs over the course of the study, only one of which was related to the treatment (withdrawal due to disinterest). No other adverse events occurred.

Randomisation was paired based on BMD baseline readings according to North American norms.

Analysis of the baseline data indicated that there was substantial, statistically significant differences between the groups with respect to age and weight (WBV group mean age=6.9 years vs 11.2, no p value provided; WBV group mean weight=25.8kg vs 40.8, no p value provided).

Proximal tibial BMD results indicated a 6.3% increase from baseline in the WBV group as compared with an 11.9% reduction in the control group. This difference was highly statistically significant (p=0.0033). Lumbar spine BMD results indicated a 5.5% increase in the WBV group and a 0.3% increase in the control group (p=0.31). The authors believed the lack of change in the lumbar spine reflected the ability of the body to dampen down the effects of vibration to the axial skeleton. No changes were seen between groups or from baseline to follow-up in diaphyseal bone area, cortical thickness and density and muscle area. This was also a well designed and reported study with some indication of potential benefit of this intervention with appropriate supervision (1+). Notably compliance was a low 44%. No relationship was found between compliance and effect.

**Key message**

WBV has been trialled with a variety of neurological conditions or disorders. By and large most trials have been undertaken with the purpose of impacting on balance and function. WBV regimes appear cautious, as judged by the duration and frequencies used (generally 3mm amplitude) and all but one, administered single sessions with small samples. Some parameters have shown improvement, albeit with small samples. The single high quality RCT with stroke patients indicated WBV was not effective in improving balance or locomotion parameters over and above a comprehensive in-patient rehabilitation programme. One quality RCT has piloted home-based WBV with physically disabled children to investigate the impact on bone mineral density. Adverse events across a mixed group of papers are to date small in number and minor. Not all papers reported safety issues.

**4.4.32 Anterior cruciate ligament reconstruction rehabilitation**

In contrast to training for fitness, WBV has been used to aid recovery from injuries. One study was identified as such that assessed the effect of WBV training on strength and other rehabilitation parameters in a group of patients that had undergone knee anterior cruciate ligament reconstruction. In this study 20 subjects were randomised evenly to one of two groups. Subjects in the WBV training group received five daily administrations of WBV (30Hz frequency for 1 minute) over a two-week period. There were significant increases in the WBV training group with respect to muscle strength (p<0.001).
and force peaks (p<0.005) as compared with controls. Although the authors concluded that WBV incorporated with rehabilitation protocol aided recovery of muscle strength, this conclusion should be regarded with caution. Firstly, the number of participants was small; secondly, the time frame was only two weeks; and lastly, the subjects in each group did not follow exactly the same rehabilitation programme. This may have confounded results. Side effects or adverse events were not mentioned; this is of particular concern as this is a post-surgery WBV application. This study was graded 1-.

4.4.4 Other studies

Further to the findings of an earlier WBV study that identified a reduction in back pain following WBV, Fontana et al (200566) undertook a pilot study to assess a subject’s ability to detect lumbosacral position-sense following WBV. Individuals that have an awareness of the position of their pelvis and spine at rest or during activity have been shown to recover from back pain episodes more promptly than others. Modalities that could improve a subject’s ability to detect their spine and pelvis position may, therefore, be beneficial in managing patients with back problems. This was a small RCT involving healthy young adults administering a single 5-minute session of WBV training. Control participants stood on the WBV platform in the same position without vibration. A significant improvement in lumbosacral position sense was seen in the WBV training group only (39%, p=0.008). This was a pilot study and although failed to report safety issues was otherwise well carried out (1-).

5. Discussion

There is a substantial volume of literature, largely published in the last five years investigating the effects of WBV. WBV has been administered across a range of ages and populations for vastly different purposes – from the young athlete to the elderly, osteoporotic female, for balance improvement to body mass reduction. Because of this heterogeneity, the evidence is not clear regarding WBV safety and effectiveness in general. There is more clarity when WBV is considered separately for these sub-populations and purposes. The key messages for varied purposes with different populations have been stated in the body of this report.

WBV programme parameters varied substantially across study interventions; machine-related parameters include amplitude, frequency, acceleration and oscillation type; programme parameters concern overall dose and whether the individual holds a static posture as opposed to performing one or more exercises on the platform. The impact of these varying WBV parameters within any sub-population is unclear. Empirical evidence and information regarding the harmful effects of vibration frequencies and exposures currently appear to guide WBV treatment protocols.

The impact of WBV with trained versus untrained individuals is unclear and it has been suggested by some authors that physiologically there is little ‘room for improvement’ in trained individuals. This may suggest WBV may be of greatest
benefit in the deconditioned and infirm. For some sub-populations and/or purposes, it is unclear if WBV training is superior to standard exercise and it appears from the literature to date that WBV training appears to produce similar but not better gains. Whilst this is not a negative, per se, there are pros and cons that would need consideration if considering WBV training; on the one hand, a conventional programme may be cheaper and simpler to administer, although potentially unattractive to some; WBV, however, may be a viable alternative to individuals that cannot access or participate in a standard programmes whether due to disinterest or because of individual co-morbidities.

Studies that compare WBV training with 'no treatment' may be of limited use as WBV training in itself combines vibration and some degree of resistance training (posture or exercise). This may confound outcomes.

5.1 Safety and adverse effects of WBV interventions

Approximately half the primary studies failed to adequately report adverse events and/or safety issues with three-quarters of the studies applying short-term WBV interventions failed to adequately report adverse events. Those studies that did inform the discussion regarding safety reported no serious adverse events such as falls, fall-related fractures or cardiovascular events.

In view of the fact that in elderly and stroke populations a primary aim is the improvement of balance and locomotion parameters, it would be unfortunate and ironic for the intervention to cause such adverse events. WBV also may be unattractive to some due to disinterest or fear. The literature is silent whether elderly subjects in particular were fearful or had difficulty accepting this modality although compliance issues were identified in two in-home programmes and disinterest were reported in a number of studies.

“Minor” adverse events included erythema/itching and tingling of the lower limbs, fatigue and boredom (which saw subjects withdraw). Bruyere et al (2005) reported two patients dropped out of the study because of transient minor tingling of the lower limbs. De Ruiter et al (2003b) reported that one subject from a study group of 10 experienced shin pains during WBV and dropped out of the trial.

Two further studies reported musculoskeletal complaints such as knee, groin and shoulder pain and finally Bogaerts et al (2006) reported seven of 220 elderly participants complained of knee pain. The authors provided no further insight into these complaints, or whether they resulted in subjects dropping-out (5 WBV, 2 Control).

It is not known if all of these musculoskeletal complaints were directly attributable to the WBV treatment, or in most studies whether the adverse events resulted in subjects ‘dropping-out’. Certainly it is plausible that sustaining static postures on the platform in significant knee flexion could be harmful.

To the contrary, two studies specifically reported subjects enjoyed the vibration loading which they considered not to be a difficult workout; one study
reported also that patients felt refreshed in the leg and back muscles immediately after WBV exercise\textsuperscript{46}.

There is substantial evidence that some forms of vibration harm the human body\textsuperscript{9}. For example hand arm vibration syndrome (HAVS) is associated with excessive exposure to vibration and is reported in workers operating drills. It is encouraging that neuropathic symptoms have not thus far been reported with WBV training. It is, however, disturbing that approximately half the studies either failed to report adverse events in any way or did so poorly.

WBV sessions are generally of short duration which may mitigate the appearance of such symptoms. Over-exuberance, however, could easily extend the duration and frequency of these episodes to levels where the consequences for both efficacy and particularly harm are unknown. Although it easy to make recommendations that WBV therapy is appropriately monitored, these machines are being installed in gyms and sold for domestic use where supervision is more than likely to be minimal. Compliance has been shown to be of concern in a few longer term home-based WBV training studies. Researchers will need to carefully compliance issues when designing future studies.

5.2. Limitations of the review

This report was restricted to studies published in English. The authors acknowledge that this may exclude some valuable information relating to the effectiveness and safety of WBV platforms. The omission of these studies was unavoidable, as the resources to translate the journal articles into English were not available to the authors of this report.

It must also be acknowledged that publication bias may exist, in that studies may not have been published which found a neutral outcome or an outcome that did not serve the purpose of the funding body. Furthermore, other studies may have been conducted that found a contradictory result which have not yet been published.

This report did not systematically review literature regarding harmful effects of vibration from occupational exposure nor did it consider local or upper body vibration interventions (e.g. Bosco 1999\textsuperscript{67}).

6. Conclusions

6.1 Implications for research and practice

There is a need in general for more well-conducted and well reported randomised controlled studies which include larger sample sizes, longer intervention periods and extended follow-up. The studies with the most successful outcomes were carried out on those who were possibly the most ‘deconditioned’, the elderly. The future methodological design of WBV studies, it has been suggested by one peer reviewer of this report, may be determined by the population and the way in which it is administered. For
example, “…in the elderly or otherwise frail, a control group with no exercise might be suitable, whereas for a younger healthy population, superimposition of WBV on their current (resistance) training may be more useful”.

The improvements in balance and locomotion outcomes in the elderly, present promising evidence of gains in these areas following WBV and this is of obvious interest to ACC. Key improvements were shown in balance control and some locomotion parameters. For healthy older adults, ACC is currently focussing on the delivery of both the Otago Exercise Programme and group Tai-Chi exercise. These are currently available to community-dwelling individuals who have either had a fall in the last 12 months or have been deemed at high risk of a fall. To assess the impact of WBV in falls and fracture prevention, longitudinal studies with long-term programmes are needed.

For post-menopausal women, evidence is moderate for isolated strength gains but there is a paucity of literature with respect to balance and conflicting evidence regarding bone mineral density and serum markers of bone turnover. More research appears worthy and is necessary to clarify the effect on this group.

A single trial has used WBV following musculoskeletal injury and there is moderate evidence regarding flexibility improvements in young women. In terms of ACC’s profile in terms of injury prevention and rehabilitation, there is a need for further research to clarify the value in these groups. WBV may have the potential to prevent injury through flexibility gains and speed rehabilitation following injury.

WBV is promoted in gyms and fitness centres as a weight loss modality. With the ‘obesity epidemic’ both internationally and nationally well documented, the ability to add, even an expensive modality to the list for those needing to improve cardiovascular fitness and reduce fat mass may be positive. Further research needs to be done to explore the benefits and viability of this modality.

6.2 Implications for policy and purchasing decisions

Purchasing research for WBV training for falls prevention in healthy older adults may be an area of interest to ACC. The issue of safety (benefit vs harm) and compliance would need careful consideration in such a population, and considered in conjunction with overall costs (equipment purchase and issues of supervision).

WBV may also be relevant in other areas of interest to ACC, for example musculoskeletal rehabilitation and strength and bone density gains in post-menopausal women.
References


45. Gusi N. Low frequency vibratory exercise reduces the risk of bone fracture more than walking: a randomized controlled trial. *BMC Musculoskeletal Disorders*. 2006;7(92).


Appendix I: Search strategy

Example of Search Strategy Used:
Results: 1-27
Database: CDSR, ACP Journal Club, DARE, CCTR

Search Strategy:
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1 galileo.mp. [mp=ti, ab, tx, kw, ct, ot, sh, hw] (5)
2 vibration.mp. [mp=ti, ab, tx, kw, ct, ot, sh, hw] (535)
3 wbv.mp. [mp=ti, ab, tx, kw, ct, ot, sh, hw] (15)
4 whole body vibration.mp. [mp=ti, ab, tx, kw, ct, ot, sh, hw] (33)
5 (whole adj body adj vibration).mp. [mp=ti, ab, tx, kw, ct, ot, sh, hw] (33)
6 1 or 3 or 5 (45)
7 remove duplicates from 6 (44)
8 (whole adj brain adj volume).mp. [mp=ti, ab, tx, kw, ct, ot, sh, hw] (7)
9 (whole adj blood adj viscosity).mp. [mp=ti, ab, tx, kw, ct, ot, sh, hw] (125)
10 8 or 9 (132)
11 7 not 10 (39)
12 (power adj plate).mp. [mp=ti, ab, tx, kw, ct, ot, sh, hw] (0)
13 11 or 12 (39)
14 limit 13 to english language [Limit not valid in: CDSR,ACP Journal Club,DARE,CCTR; records were retained] (39)
15 Clinical trial/ (0)
16 Randomized controlled trial/ (0)
17 Randomization/ (19995)
18 Single blind procedure/ (0)
19 Double blind procedure/ (0)
20 Crossover procedure/ (0)
21 Placebo/ (0)
22 Randomized controlled trial$.tw. (20666)
23 Rct.tw. (2667)
24 Random allocation.tw. (1746)
25 Randomly allocated.tw. (9032)
26 Allocated randomly.tw. (1203)
27 (allocated adj2 random).tw. (833)
28 Single blind$.tw. (7556)
29 Double blind$.tw. (89358)
30 {(treble or triple) adj blind$}.tw. (195)
31 Placebo$.tw. (90802)
32 Prospective study/ (0)
33 or/15-32 (159354)
34 Case study/ (0)
35 Case report.tw. (265)
36 Abstract report/ or letter/ (0)
37 or/34-36 (265)
38 33 not 37 (159180)
39 exp Meta Analysis/ (149)
Whole Body Vibration Training

86 78 or 85 (309204)
87 Case report.tw. (265)
88 Letter.pt. (4123)
89 Historical article.pt. (45)
90 Review of reported cases.pt. (117)
91 Review, multicase.pt. (123)
92 or/87-91 (4667)
93 86 not 92 (304876)
94 Meta-Analysis/ (149)
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96 metaanaly$.tw. (147)
97 meta analysis.pt. (387)
98 (systematic adj (review$1 or overview$1)).tw. (4598)
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102 embase.ab. (1727)
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104 (psychinfo or psycinfo).ab. (392)
105 (cinahl or cinhal).ab. (663)
106 science citation index.ab. (183)
107 bids.ab. (31)
108 cancerlit.ab. (70)
109 or/101-108 (3031)
110 reference list$.ab. (1013)
111 bibliograph$.ab. (847)
112 hand-search$.ab. (414)
113 relevant journals.ab. (118)
114 manual search$.ab. (60)
115 or/110-114 (2083)
116 selection criteria.ab. (2912)
117 data extraction.ab. (1051)
118 116 or 117 (3442)
119 (review or review literature).pt. (2628)
120 118 and 119 (24)
121 comment.pt. (1402)
122 letter.pt. (4123)
123 editorial.pt. (272)
124 animal/ (0)
125 human/ (0)
126 124 not (124 and 125) (0)
127 or/121-123,126 (4660)
128 100 or 109 or 115 or 120 (9423)
129 128 not 127 (9381)
130 guideline.pt. (23)
131 practice guideline.pt. (13)

Accident Compensation Corporation
exp guidelines/ (451)
health planning guidelines/ (4)
guideline$ti. (483)
or/130-134 (795)
38 or 70 or 93 or 129 or 135 (312833)
136 and 14 (27)
remove duplicates from 137 (27)
from 138 keep 1-27 (27)
### Other databases and websites searched

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</table>
Appendix II: SIGN grading system

*Levels of evidence*

1++ High quality meta analyses, systematic reviews of RCT’s, or RCT’s with a very low risk of bias

1+ Well conducted meta analyses, systematic reviews of RCT’s, or RCT’s with a low risk of bias

1 - Meta analyses, systematic reviews of RCT’s, or RCT’s with a high risk of bias

2++ High quality systematic reviews of case-control or cohort studies

High quality case-control or cohort studies with a very low risk of confounding, bias, or chance and a high probability that the relationship is causal

2+ Well conducted case control or cohort studies with a low risk of confounding, bias, or chance and a moderate probability that the relationship is causal

2 - Case control or cohort studies with a high risk of confounding, bias, or chance and a significant risk that the relationship is not causal

3 Non-analytic studies, e.g. case reports, case series

4 Expert opinion

Note: For this report, non-randomised comparative studies are classified as “2”, with a 2+ given for high quality studies and a 2- allocated if there are significant methodological or reporting issues
## Appendix III: Study tables

<table>
<thead>
<tr>
<th>Study</th>
<th>Study inclusion/exclusion criteria</th>
<th>Exposure/comparison treatment (number of studies included)</th>
<th>Common outcomes among studies</th>
<th>Results</th>
<th>Validity/Applicability</th>
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<th>Conclusions</th>
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<td>Muscular performance – strength and power</td>
<td>Long-term WBV</td>
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<td>Thresholds for classifying studies as ‘high’ and other quality grades are questionable (e.g. 11/16 for long-term studies were classified as ‘high quality’ (69%))</td>
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<td>Both reviewers assessed papers against a methodological quality assessment (Van Tulder et al 1997 - /16 points for long-term studies and /13 for short-term studies)</td>
<td>Thorough search strategy</td>
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<td>Authors do not report if adverse event data is missing or whether there are in fact few adverse events</td>
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<td>Degree of evidence based on Van Tulder et al 1997</td>
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<td>Moderate evidence=one relevant high quality RCT and one or more relevant low quality RCT’s</td>
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<td>Review also rated quality of reporting on WBV parameters</td>
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<td>Studies were considered ‘positive’ or ‘negative’ if they reported significant change in at least one strength or power variables</td>
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<td>Fair conclusions from evidence</td>
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<td>Nordlund &amp; Thorstensson 2007</td>
<td>Systematic Review To review the literature concerning muscle strength and jump performance after longer-term WBV (all kinds)</td>
<td>Considered only those publications with a control group (n=12) Chronic effects defined as those as a result of repeated bouts of WBV over a time period of at least one week Literature search August 2005</td>
<td>Muscle strength and jump performance</td>
<td>Concluded that WBV provides no or only minor additional effects on muscle strength and jump performance as compared with performing the same exercises without WBV</td>
<td>Focussed question Thorough search strategy Search terms defined Appropriate inclusion/exclusion criteria Two reviewers – selection study validity rated Two-reviewers – validity Valid combination of studies Appropriate analysis All important outcomes considered Balance between benefit and harms Fair conclusions from evidence</td>
<td>Y N Y Y N N Y ? ? ?</td>
<td>Authors rightfully question a true control group (i.e. same exercises without vibration) Note this systematic review in contradistinction to Rehn et al and this report only appraised studies with a control group; this means, therefore, this may be more rigorous approach to forming conclusions regarding literature Useful discussion regarding nature of the control groups Substantial rigour or at least in this review is missing in terms of there being no objective study appraisal methodology used to evaluate methodological quality 1-</td>
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## Short-term training

<table>
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| Roelants et al 2006 | Non-randomised controlled study  
Subjects served as own control  
To determine if WBV affects muscle activity whilst performing standard body weight isometric exercises with and without WBV and that the change in muscle activity will be different for different exercises on the WBV platform | N=15  
All male  
Average age=21.2 years  
Physical education student volunteers | WBV:  
Powerplate  
35HZ, 2.5mm amplitude whilst performing the below exercises  
5 minute cycling warm-up  
Subjects performed 4 sets of 3 isometric exercises (high squat at 125° knee flexion, low squat at 90° knee flexion and one leg squat at 125° knee flexion) in random order  
1 minute rest between each set and each exercise | Outcomes:  
EMG recording  
Baseline EMG expressed as a % of Maximal voluntary contraction (MVC)  
Baseline EMG studies recording EMG in Vastus Lateralis (VL), Medialis (VM), Rectus Femoris (RF), Gastrocnemius (G)  
Muscle activity recorded over a 25 second period, 5 seconds before WBV began. After the WBV was complete subjects had to hold the same posture for a further 5 seconds  
Results:  
Statistically significant increases in MVC% for all muscles (p<0.05) after WBV compared to baseline mean average readings  
All other exercises indicated a substantial increase in MVC% compared to control (p<0.001)  
Statistically significant increases with WBV intervention in high squat (HS) (115.1%, low squat (LS) 49.1% and One legged squat, 151.4%)  
The largest increase in % MVC was seen in the one-legged squat exercise (34.6% in RF, 63.8% in VM, 82.4% in VL and 25.1% in G) (p<0.001)  
HS was not statistically significantly different from LS (p>0.05) | No adverse events reported  
Small sample  
Exercises performed in random order  
1 minute washout between exercises, unknown washout period between control and WBV 2+ |
### Study: Cormie et al 2006

#### Methods and Settings
- **Controlled trial**
- Purpose was to investigate the effects of a single bout of WBV on isometric squat and countermovement jump height performance.
- Subjects randomised to the order they received the control or intervention.
- All subjects involved in resistance training and sport.

#### Participants
- **N=9**
- Age range = 19-23 years
- All male

#### Intervention
- **WBV:**
  - Single bout (30 second) using Power Plate platform
  - 30 Hz, 2.5mm amplitude
  - Baseline recordings average of two recordings
- **Control:**
  - Exercise positions as above were performed on the inactivated vibration platform
  - EMG recordings for peak force in isometric squat (100° knee flexion for 3 seconds), countermovement jump (CMJ) and height for CMJ – all testing performed on a force platform
  - Two-day washout period between control and interventions

#### Outcomes and Results
- Squat peak force decreased for control and intervention groups immediately post WBV bout (no significant difference between control and intervention).
- Statistically significant difference between CMJ height in favour of the WBV period (WBV: Baseline=49.02 Post treatment=49.34 cm)
- (Sham: Baseline=50.67; post-treatment=49.34 cm)
- No EMG changes seen

#### Comments and Level of Evidence
- Adverse events not reported
- Non randomised study although control or intervention order randomised
- Small sample
- 2+
### Whole Body Vibration Training

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<tr>
<td>Cochrane &amp; Stannard 2005</td>
<td>Non-randomised controlled trial</td>
<td>N=18 Elite female hockey players Mean age=21.8 years</td>
<td>WBV: Galileo Sport 26 Hz, 6mm amplitude 6 exercises Standing upright with knees semi-locked isometric squat in 120° of knee flexion Kneeling on ground with arms straight and hands placed on platform Squatting at a tempo of 2s up and 2s down at 120° knee flexion Lunge position – left leg on platform, right leg on ground and vice versa Positions 1-4 held for 1 minute and positions 5 and 6 for 30 seconds The interventions administered not sooner than 24 hours following the previous intervention No vigorous activity otherwise within 24 hours of study procedure Control: 50RPM cadence cycling 5 minutes at 50watts on cycle ergometer Control was posturing/exercises as for WBV without the platform oscillating Warm up prior to each intervention</td>
<td>Outcomes: Arm Countermovement jump (6 reps, 10 second rest in between each; height measured using portable hand held computer to timing mat Grip Strength -3 reps of a 2 second gross grip contraction, standing, arms by side Sit and reach lower limb flexibility test - to a standard procedure on a sit and reach apparatus. Two repetitions each held for 2 seconds, separated each by 10 second rest Measured 15 seconds after each of the three interventions Results: Statistically significant between group improvement in favour of the WBV group in arm counter movement jump (p=0.001). An 8.1+/− 5.8% increase was seen in the WBV group immediately following vibration training Sit and reach test findings indicated a statistically significant improvement in sit and reach 8.2%+/− 5.4% compared to control and cycling interventions (5.3%/−5.1% and 5.3%/−4.9% respectively No difference was seen in hand-grip strength scores in any group although after each repetition, grip strength decreased (0.05)</td>
<td>Randomisation method not described Baseline demographics not reported Not stated if blinded assessor No mention of adverse events Authors suggest activation of the 1a inhibitory interneurons to the antagonist muscle (hamstrings) is responsible for the improvement in sit- and-reach scores The lack of change in the grip scores supports the theory that the effect of vibration is localised to the spinal level and not a centrally mediated phenomenon Improvements in ACMVJ due to improvement in spatial recruitment of motor neurones via the tonic vibration reflex and the gamma motor neurone input Small sample 2+</td>
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<tr>
<td>De Ruiter et al 2003a</td>
<td>Case series</td>
<td>N=12</td>
<td>WBV: Galileo 2000 30Hz; 8mm amplitude Barefoot on platform in 110° knee flexion; Single session; 5 x 1 minute bouts, 2 minute rests in between bouts 10 participants also continued for a further two weeks (5 sessions)</td>
<td>Maximal voluntary contractile force of knee extensors (MVC) and maximal rate of force rise (MRFR) Baseline knee extensor contractile and activation values similar between participants Assessed 90 seconds, 30, 60, and 180 minutes post WBV and at the end of the 2 weeks for those that continued; assessed left leg only 4 measures of each test, 1 minute rest in between Results: 90 seconds following WBV MVC reduced by 5% (p&lt;0.05), which was a greater reduction than the MFGC These parameters were no longer depressed at 180 minute assessment Two week outcomes indicated no improvement in any of the muscle parameters</td>
<td>No mention of blinded assessor No mention of adverse events or other safety issues Small sample The authors postulate the drop in MVC but not in MRFR may be due to a vibration induced increase in muscle temperature which could have countered any fatiguing effect of WBV. Hamstring co-contraction may have also contributed to the changes seen These finding do not support other studies that have shown muscle activation enhancement after several days of WBV Authors suggest that this incongruity is due to: the effect of vibration activating presynaptic 1a inhibition preventing further motor neurone recruitment And as WBV is applied to the feet, each joint will have a dampening effect Lastly vibration causes reciprocal inhibition of antagonist muscles</td>
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<tr>
<td>Torvinen et al 2002a</td>
<td>Controlled study, Subjects acted as their own controls</td>
<td>16 volunteers, 8 men, Aged 18-35 years, Body weight ranged 70-86kg (Male) and 51-70kg (females)</td>
<td>WBV: 4 minute vibration (Kuntotary, Finland) and sham interventions in a randomised order on different days</td>
<td>“No subjective adverse reactions nor exhaustive fatigue were reported after the 4-minute vibration bout” Four minute vibration loading did not induce any statistically significant change in the performance or balance tests at the 2 or 60 min tests</td>
<td>2+</td>
</tr>
<tr>
<td>Study Institute, Tampere University Hospital, Tampere, Finland Funding from Medical Research Fund of the Tampere University, Tampere, Finland</td>
<td>Setting: Medical School and Institute of Medical Technology, University of Tampere</td>
<td></td>
<td>2mm amplitude, Frequency increased in one minute intervals starting at 25 Hz and for the last minute was 40Hz</td>
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<td></td>
<td>Exclusion Criteria</td>
<td>Any cardio, respiratory, abdominal, urinary, gynaecological, neurological, musculoskeletal, or other chronic diseases such as Pregnancy, prosthesis, medication that affects musculoskeletal system, menstrual irregularities, and regular participation in impact type exercises more than 3 X per week</td>
<td>Day 1= the intervention (4 x 60 seconds light exercise programme) and tests of the stability platform, grip strength, and isometric extension strength of the lower extremities were carried out</td>
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<td>Day 2= Intervention and tests comprised of tandem walk, vertical jump and shuttle run</td>
<td>Day 1= the intervention (4 x 60 seconds light exercise programme) and tests of the stability platform, grip strength, and isometric extension strength of the lower extremities were carried out</td>
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<tr>
<td></td>
<td></td>
<td>The measurements were always done in the same order</td>
<td>Day 2= Intervention and tests comprised of tandem walk, vertical jump and shuttle run</td>
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<td></td>
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<td>Distance between the vibration and sham interventions was one to two weeks; administered in random order</td>
<td>Day 2= Intervention and tests comprised of tandem walk, vertical jump and shuttle run</td>
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<td></td>
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<td>Day 2= Intervention and tests comprised of tandem walk, vertical jump and shuttle run</td>
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<td></td>
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<td></td>
<td>Day 2= Intervention and tests comprised of tandem walk, vertical jump and shuttle run</td>
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</table>

Conclusions: 4 min long, 2mm-vertically vibrating vibration stimulus did not induce changes in the performance and balance tests.

Comments: Cross over study Components of the “light exercise programme” performed with WBV essentially unknown. The authors provide no information regarding drop out in the trial. Fairly small sample size Side effects mentioned 2+. 

**Whole Body Vibration Training**

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**Whole Body Vibration Training**

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<tbody>
<tr>
<td>Torvinen et al 2002b</td>
<td>Controlled Study Subjects acted as own controls</td>
<td>16 participants, 8 women (24-33yrs)</td>
<td>WBV: Four minute vibration (Kuntotary, Finland) and sham intervention in a randomised order on different days</td>
<td>Six performance Tests: Stability Platform, Grip Strength, Isometric extension, Tandem Walk, Vertical Jump, Shuttle Run</td>
<td>Conclusion: Single bout of whole body vibration transiently improves muscle performance of lower extremities and body balance in young healthy adults</td>
</tr>
<tr>
<td></td>
<td>Institute and Hospital setting in Tampere, Finland</td>
<td>66-83kg (Males) 51-70kg (Females)</td>
<td>Both sham and intervention groups received the two interventions on two occasions (different outcomes the alternate session). Washout period 1-2 weeks between sham and intervention. Vibration frequency increased each of the four minutes; 15Hz, minute 1, increasing 5 Hz per minute. 10mm amplitude</td>
<td>Performed 10 minutes before baseline and 60 minutes after intervention</td>
<td>Components: Small sample size, Components of the &quot;light exercise programme&quot; performed with WBV essentially unknown, Randomisation method is not specified</td>
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<tr>
<td></td>
<td>Exclusion Criteria: Cardiovascular, respiratory, abdominal, urinary, gynaecological, neurological, musculoskeletal, other chronic diseases, prosthesis, medication that affects musculoskeletal system, menstrual irregularities and regular participation in impact type exercise more than 3 X per week</td>
<td>Acceleration also increased alongside frequency starting at 3.5g; at its highest was 14g (30Hz)</td>
<td>Results: 2.5% (0.7cm) net benefit in the jump height (p=0.019) at 2 minutes post WBV 3.2% benefit (p=0.020) in the isometric extension of lower extremities – this reduced to 2.4% at 60 minute follow-up 15.7% improvement in body balance (p=0.049) at 2 minutes</td>
<td>Side effects mentioned</td>
<td></td>
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<td></td>
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<td></td>
<td>No difference between groups with respect to tandem walk or shuttle run at any time period</td>
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<td>2+</td>
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**Torvinen et al 2002b**

Effect of a vibration exposure on muscular performance and body balance

Supported by Grants from the Medical Research Fund of the Tampere University Hospital

Outcomes:

- Grip Strength
- Isometric extension
- Tandem Walk
- Vertical Jump
- Shuttle Run

Results:

- No subjective adverse reactions nor exhaustive fatigue were reported after the 4-minute vibration bout.
- 2.5% (0.7cm) net benefit in the jump height (p=0.019) at 2 minutes post WBV
- 3.2% benefit (p=0.020) in the isometric extension of lower extremities – this reduced to 2.4% at 60 minute follow-up
- 15.7% improvement in body balance (p=0.049) at 2 minutes

No difference between groups with respect to tandem walk or shuttle run at any time period.

No changes were seen in grip strength in either group at 2 or 60 minutes.
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<tr>
<td>Bosco et al 2000</td>
<td>Case series</td>
<td>N=14</td>
<td>WBV:</td>
<td>Outcomes:</td>
<td>No mention of blinded</td>
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<tr>
<td></td>
<td>Aim to investigate</td>
<td>Mean age=25</td>
<td>NEMES 30L</td>
<td>CMJ – change in</td>
<td>assessor/analysis of</td>
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<td></td>
<td>neuromuscular</td>
<td>years</td>
<td>26 Hz, 4mm amplitude,</td>
<td>Centre of gravity</td>
<td>treatment</td>
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<td></td>
<td>performance and</td>
<td>All males;</td>
<td>17g acceleration</td>
<td>height (average of 3</td>
<td>Small sample and case series</td>
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<tr>
<td></td>
<td>acute hormonal</td>
<td>involved in regular</td>
<td>10 x 60 second bouts</td>
<td>trials) Power from</td>
<td>information only</td>
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<td></td>
<td>responses to a single</td>
<td>sports</td>
<td>following a standard cycle</td>
<td>dynamic leg press (both legs)</td>
<td>As cortisol did not increase,</td>
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<tr>
<td></td>
<td>session of WBV</td>
<td></td>
<td>ergometer and stretching</td>
<td>using 160% of body</td>
<td>vibration did not result in a</td>
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<td></td>
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<td>warm-up (5 minutes each)</td>
<td>weight; 70% of 1repetition max (RM)</td>
<td>generalised stress reaction that</td>
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<td>60 seconds rest between bouts</td>
<td>EMG measured from</td>
<td>is common in high-intensity</td>
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<td></td>
<td></td>
<td></td>
<td>Subjects standing on toes</td>
<td>Rectus Femoris and Vastus Lateralis; to</td>
<td>exercises</td>
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<td></td>
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<td>on vibration platform with</td>
<td>calculate Power parameters</td>
<td>May suggest an inhibitory</td>
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<td></td>
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<td>100° knee flexion position</td>
<td>Hormone levels of Testosterone, Growth hormone and cortisol</td>
<td>influence on the hypothalamic</td>
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<tr>
<td></td>
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<td>Subjects to wear shoes to prevent bruising</td>
<td>Results:</td>
<td>neurosecretory centres</td>
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<td></td>
<td></td>
<td>Testosterone (mean increase from 22.7nmol/l to 24.3) and</td>
<td>It is postulated that Testosterone</td>
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<td>growth hormone increase (6.2 to 28.6) statistically significant</td>
<td>may influence the nervous</td>
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<td></td>
<td></td>
<td>(p=0.026 and p=0.014 respectively)</td>
<td>structures and explain the</td>
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<td>A statistically significant reduction in cortisol was seen after</td>
<td>increase in power</td>
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<td></td>
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<td></td>
<td></td>
<td>vibration (682-464nmol/l :p=0.03)</td>
<td>No mention of adverse events</td>
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<td>Significant increase in Power as measured during leg press</td>
<td>3</td>
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<td></td>
<td></td>
<td></td>
<td>following vibration (p&lt;0.003)</td>
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<td>EMG yrs significantly decreased compared to pre-vibration levels</td>
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<td></td>
<td></td>
<td>(p=0.008)</td>
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<td>CMJ performance improved (36.1cm to 37.6) p&lt;0.001</td>
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</table>
### Study
Rittweger et al 2000

### Methods and Settings
Case series
Set in a Research Institute in Germany

### Participants
37 young participants. (Initially 40 participants but 3 dropped out)
16 females and 21 males
Mean Age = 23.5yrs
Female subjects 169.9cm tall and 60.6kg weight (average)
Male subjects were on 181.4cm tall and weighed 75.2kg (average)

### Intervention
WBV:
Not specified whether the Galileo 900 or Galileo 2000 was used
Vibration exercise (VE) was performed in 2 sessions with a 26Hz, 10.5mm amplitude vibration on a ground plate in combination with squatting and an additional load
First Visit (BIC). Cycle ergometry from 3 min to exhaustion
2nd and 3rd visit (VIB1 and VIB2)
Exercise until exhaustion on a power plate. (26Hz)

### Outcomes and Results
3 drop outs

#### Outcomes:
Heart rate, oxygen uptake, knee extension, jump height and blood pressure were all measured

#### Results:
Heart rate after VE increased to 128 min⁻¹
Blood pressure increased to 132/52 mmHg.
Oxygen uptake in VE was 48.8% of VO2 max in bicycle ergometry
After VE, voluntary force in knee extension was reduced by 9.1%, and the decrease of EMG median frequency during maximal voluntary contraction was attenuated
Reproducibility in the two VE sessions was good. For heart rate, oxygen uptake and reduction in jump height, correlation coefficients of values from session 1 and from session 2 were between 0.67 and 0.7

### Comments and Level of Evidence
Exhaustive whole body VE elicits a mild cardiovascular exertion and that neural as well as muscular mechanisms of fatigue may play a role
No specific reasons why 3 subjects dropped out
One prominent side effect was an itching erythema in about half of the individuals
Small number of participants
3

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**Whole Body Vibration Training**

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<tr>
<td>Bosco et al 1999</td>
<td>Controlled study Patients other limb served as a control The limb to receive the intervention was randomised Study aim to analyse the effects of vibration on the neuromuscular behaviour of arm flexors in elite boxers</td>
<td>N=12 Italian national level boxers Excluded smokers</td>
<td>WBV: Galileo 2000</td>
<td>Mechanical power and EMG of biceps brachii recorded whilst performing 5 maximal dynamic elbow flexion exercises lifting a vibrating dumbbell (1 minute in between each repetition) following the intervention Baseline elbow flexion power measured with an extra load equal to 5% of their body mass Last two trials measured at baseline were averaged Limbs tested separately Results: Statistically significant improvement from baseline to follow-up in power in VT group (p&lt;0.001). No changes in average power in control limbs EMG to power ratio demonstrated a statistically significant decrease after VT (p&lt;0.01); this reduced in the control limbs but was not statistically significant Statistically significant increase in EMG (root-mean-square) as percentage of baseline EMG was seen from pre to first minute measure – these remained similar across all subsequent measures</td>
<td>Little information on baseline information of 12 subjects – are their demographics or other variables which introduce bias Assume all males although not stated Randomisation of limbs not described No raw data presented Authors attribute these improvements to neural adaptation – an improvement of neuromuscular efficiency of the elbow flexors 2+</td>
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<tr>
<td>Savelberg et al 2007</td>
<td>RCT</td>
<td>3 groups with different WBV frequencies</td>
<td>WBV: Galileo 900 3 set frequencies in position of 10° knee flexion 5 minute warm up on cycle followed by a session on the 3-4 bouts of WBV with a 60 second gap between bouts; 3 sessions per week for 4 weeks Session amplitude and duration altered after each week A=amplitude in mm D=duration in seconds Week 1: bout 1; A=5; D=60s Week 2: bout 2; A=as above Week 1: bout 3; A=5; D=120s Week 2: bout 2; A=7; D=120s Week 2: bout 3 and 4; as above Week 3: bout 1; A=9; D=60s Week 3: bout 2; A=9; D=120s Week 3: bout 3 and 4; as above</td>
<td>Outcomes: Mean peak torque at knee measured using Cybex II dynamometer before and after vibration Strength measured in 25 combinations of 5 knee joint angles (0, 35, 60, 85 and 110°) and 5 hip joint angles (60, 105, 130, 155 and 180°) 180° = full hip extension Contractions maintained for 2 seconds; 3 minutes rest between consecutive contractions Results: Peak torque increased 9.4% between baseline and post WBV in all participants (not otherwise specified) (159Nm-169.9Nm p=0.007) No correlation between frequency and position and outcomes between the groups However a significant negative correlation was found with subjects’ initial strength R=-0.534, p=0.009 Kne angle that generated maximum knee moment after WBV was 84.9° (77.0° at baseline)</td>
<td>May have implications for training position for WBV Unknown male: female subject ratio A controlled trial but not comparing WBV with other interventions; assessing the impact of different joint angles and frequencies and their effect on knee torque Shift in optimal knee joint angle thought to be due to an adaptation for the vasti muscles Truly unknown confounding effect of not having an appropriate control group No blinding No ITT or discussion of losses or side effects Small sample 1-</td>
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### Whole Body Vibration Training

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| Fagnani et al 2006 | RCT                  | N=26, 13 per group | WBV: Nemes-LCB040 8 weeks WBV in two different positions/exercises 35Hz, 4mm amplitude 1. Upright stance, knees in 90° flexion, hands on hips; 2. Single-leg squat in 90° of knee flexion, the other leg held in air, hands on hips; 3 x per week  
Weeks 1 and 2:  
Ex 1: 1.3 x 20 s, 1 min rest  
Ex 2: 3 x 15s, 30s rest  
Weeks 3 and 4:  
Ex 1: 3 x 30s, 1 min rest  
Ex 2: 3 x 20 s, 30 s rest  
Weeks 5 and 6:  
Ex 1: 3 x 45s, 45s rest  
Ex 2: 3 x 25s, 30s rest  
Weeks 7 and 8  
Ex 1: 1.4 x 1 min, 1 min rest  
Ex 2: 4 x 30s, 30s rest  | Outcomes:  
Countermovement jump flight time (starting in 90° flexion) and height of centre of gravity  
Flexibility (sit and reach)  
Isokinetic leg pres – power test and resistance test  
Measured at pre-test and after 8 weeks of training  
Baseline demographics similar in terms of outcome measure parameters and height, weight and age  
Results:  
CMJ- statistically significant improvement in WBV group (p=0.00002)  
Flexibility improved in WBV group compared to the control (p=0.00004; 22.6cm vs 19.59cm control)  
Leg press: significant improvement in WBV group in terms of peak force and total work (power test) (p=0.038, p=0.004) and resistance test (p=0.0011)  
No significant changes in any pre to post in the control group parameters  
No between group statistical comparisons undertaken at follow-up  
WBV group improvements in mean dynamic strength (11.2%), Jump height (8.7%) and flexibility (13%)  | No blinding  
No intention-to-treat  
No description of control treatment – it could be suggested this variability was responsible for the ‘no change’ results in the control group, and the changes seen may be as a result of the exercises undertaken on the platform as opposed to the vibration  
Two withdrawals reported due to extra-study injury  
Poor selection of flexibility measure for hamstring muscle group  
Small sample 1-
### Whole Body Vibration Training

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<thead>
<tr>
<th>Study</th>
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<th>Outcomes and Results</th>
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</thead>
<tbody>
<tr>
<td>Blottner et al 2006</td>
<td>RCT University hospital</td>
<td>N=20 healthy volunteers; all male Mean age 33 years Randomised to control or exercise groups (n= 10 each) 5 different campaigns to mitigate seasonal effects (5 x 2x2 subjects) Both groups underwent 55 days of bed-rest without any body raising higher than 45° from supine and no brisk leg movements</td>
<td>WBV: Galileo space device to be used in supine 20-30Hz – amplitude .5-1cm Vibration 2x daily bouts of 6 minutes each of 19-25 Hz, with 89 exercise sessions scheduled between the 55 days of bed rest (Wednesday afternoons and Sunday no treatment) All subjects underwent the below minimum exercise routine: Physiotherapy in bed rest consisted of passive ankle mobilisation and 'gentle muscle massage 2 x weekly to improve venous flow and to help minimise joint and/or muscle pain Control group: no additional activities</td>
<td>Outcomes: WBV reported to be well tolerated by subjects. Exercise progressions achieved through increases in vibration frequency. Lower limb was slightly more frequent in vibration subjects than controls (p=0.035). This meant the cancellation of 12 out of 770 exercise sessions Calf muscle size and function: measuring maximum voluntary isometric plantarflexion force at baseline before bed rest, immediately after re-ambulation (morning and afternoon); Averaged the best of three trials Muscle biopsies taken to identify muscle fibre types: Taken at day 2 into the study and the last day from Vastus Lateralis (VL) of right hip and from right soleus Results: Calf muscle size and function: Results indicated a statistically significant reduction (18.9%, p&lt;0.001) in maximum isometric voluntary plantar flexion force in the control group from baseline to immediately post bed rest. But not for the vibration group (p=0.98) In both groups, the loss between post intervention morning and evening assessments was reduced (9.2% vibration and 32.9% in control) Muscle fibre measures: An increase in Type II fibre size was evident in Soleus muscles in both groups; however, the control group showed a reduction in Type I whereas vibration group did not. Only the vibration group’s changes were statistically significant. There were insignificant changes in myofibre size in VL muscles in both groups; however both Type I and II fibre size reduced in control, whereas only Type I in the vibration group In terms of fibre type and distribution pattern, Type II fibre amount increased significantly, with type I relatively unchanged. In the vibration group, type distribution was unchanged. Other immunochemistry and immunoblot analyses undertaken</td>
<td>No detail re randomisation process Preservation of muscle fibre phenotype in vibration group Vibration may be less effective for recruitment of knee extensors/thigh flexors No mention of assessor blinding 1+</td>
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**Accident Compensation Corporation**
<table>
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<tr>
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</thead>
<tbody>
<tr>
<td>Mahieu et al 2006</td>
<td>RCT</td>
<td>N=33 Competitive skiers</td>
<td>WBV: Fitvibe standing</td>
<td>Both WBV and ER groups indicated a significant increase in box jump repetitions from baseline to 6 weeks and most isokinetic muscle strength values</td>
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<td></td>
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<td>Age range 9-15 years</td>
<td>2-4mm amplitude 24-28 Hz</td>
<td>Statistically greater increase in high box test in the WBV group compared with control (67.06 mean reps WBV vs 55.18 reps control, p=0.013; effect size 0.92). The only other significant difference between the two groups at follow-up was an increase in plantarflexor strength (90.09 WBV; 68.18 control, p=0.013) (effect size 0.92)</td>
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<tr>
<td></td>
<td>Laboratory setting</td>
<td>WBV group N=17, 11 boys</td>
<td>6 week programme, 3 sessions/week, 30 minute/session; total 1 day in between sessions</td>
<td>Outcomes: Measured at baseline and 6 weeks (at end of programme) Peak torque of major muscle groups e.g. plantar and dorsiflexors, knee flexors/extensors Box jump (30cm box, lateral jump, jumps in 90 seconds)</td>
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<td>Control: Resistance training group N=16, 8 boys</td>
<td>Activities: squat, deep squat, wide stance squat, one leg squat, calf-raise, ski movement, plate jumps and light jumping Two-minute rest in between exercises</td>
<td>Results:</td>
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<tr>
<td></td>
<td></td>
<td>Participants significantly older and larger in the WBV group</td>
<td></td>
<td>Note groups are not similar with respect to age, height and mass</td>
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<tr>
<td></td>
<td></td>
<td>Age: p=0.044 Height: p=0.031 Mass: p=0.015</td>
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<td>Single assessor</td>
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<td></td>
<td></td>
<td>No discussion of blinding</td>
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<td>No detail of randomisation method</td>
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<td>Side effects not mentioned</td>
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<th>Outcomes and Results</th>
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<tbody>
<tr>
<td>Deleciose et al 2005</td>
<td>RCT</td>
<td>N=25</td>
<td>WBV: Powerplate 1.7-2.5mm amplitude (increased over the study period) 35-40 Hz – altered over the study period 15 sessions over 5 weeks unloaded static and dynamic standard leg exercises 3 x weekly sessions prior to conventional sprint training sessions 9-18 minutes total exposure during a session Exercises included squat, lunge, calves, 6 exercises total, 3 sets of each, increasing duration of WBV from 30 seconds at start to 45 seconds at week 3. Finally 60 seconds’ exposure without rest at week 5.</td>
<td>5 drop-outs, WBV=3 N=4 due to injury or ill-health not related to study No reports of adverse effects of WBV “Most subjects reported they enjoyed the training and did not consider it physically strenuous although they generally reported a moderate degree of muscle fatigue at the end of each session”</td>
<td>Randomisation not described in detail No intention to treat strategy to deal with drop-outs Small sample Authors suggest the ‘no effect’ may be a result of (a) the athletes being highly trained prior to the study (b) the fact that the WBV stimulus was identical for all subjects and not customised, and (c) a lack of overload, as no participants were exercised to fatigue 1-</td>
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<td></td>
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<td>18 male</td>
<td>Control: Conventional sprint training and resistance training using specific guidelines</td>
<td>Outcomes: Isometric and dynamic knee extensor and flexor strength Maximal knee extension velocity, countermovement jump performance and sprint velocity Results: No significant improvement in either group over time for any of the outcomes, or interaction effects between groups (all p&gt;0.05 except not reported for sprint velocity)</td>
<td>1-</td>
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</table>
### Whole Body Vibration Training

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<th>Comments and Level of Evidence</th>
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<tbody>
<tr>
<td>Roelants et al 2004a</td>
<td>Non-randomised comparative trial</td>
<td>48 Untrained females</td>
<td>WBV:</td>
<td>Outcome measures:</td>
<td>Conclusions:</td>
</tr>
<tr>
<td>Effects of 24 weeks of whole</td>
<td>Exercise Physiology and Biomechanics laboratory, Belgium</td>
<td>21.3±2 yrs Average age.</td>
<td>Power Plate (N=18)</td>
<td>Body Composition was determined by means of underwater</td>
<td>24 weeks whole body vibration</td>
</tr>
<tr>
<td>body vibration training on</td>
<td></td>
<td></td>
<td>Performed unloaded static and</td>
<td>weighing.</td>
<td>training did not reduce weight,</td>
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<tr>
<td>body composition and</td>
<td></td>
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<td>dynamic exercises on a</td>
<td>total body fat or subcutaneous fat in previously untrained</td>
<td>total body fat or subcutaneous</td>
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<td>muscle strength in untrained</td>
<td></td>
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<td>vibration platform</td>
<td>females</td>
<td>fat in previously untrained</td>
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<td>females</td>
<td></td>
<td></td>
<td>35-40Hz, 2.5-5.0mm amplitude</td>
<td></td>
<td>females.</td>
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<tr>
<td>No funding mentioned</td>
<td></td>
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<td>Control:</td>
<td></td>
<td>WBV induced a gain in knee</td>
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<td></td>
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<td>The Fitness group (N=18)</td>
<td></td>
<td>extensor strength combined</td>
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<td></td>
<td>Followed a standard cardiovascular</td>
<td></td>
<td>with a small increase in fat</td>
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<td>(15-40min) and resistance training program</td>
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<td>free mass.</td>
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<td>including dynamic leg press and</td>
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<td>leg extension exercises (20-8 RPM)</td>
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<td>Training 3 X weekly for 24 weeks</td>
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<td>The control group (N=12) did not</td>
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<td>participate in any training</td>
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**Outcomes and Results:**
- **Body Composition**: Determined by means of underwater weighing.
- **Isometric (0º/s)** and **Isokinetic (50º/s, 100º/s, 150º/s) knee extensor strength**: Measured by means of a motor driven dynamometer (Technogym).

**Results:**
- Over 24 weeks there were no significant changes (p>0.05) in weight, in percentage body fat, nor in skin fold thickness in any of the groups.
- Fat free mass increased significantly in the whole body vibration group (+2.2%) only.

**Comments:**
- Controlled trial without randomisation. Subjects were put into groups depending on what motivated them.
- Clear exclusion criteria was described.
- Reasons why subjects dropped out and adverse reactions are clearly described.
- 2+
<p>| Study               | Methods and Settings                                                                 | Participants                                                                 | Intervention                                                                 | Outcomes and Results                                                                                                                                                                                                                                                                                                                                 | Comments and Level of Evidence |
|---------------------|--------------------------------------------------------------------------------------|------------------------------------------------------------------------------|-------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Roelants et al 2004b | Randomised controlled trial&lt;br&gt;Setting: Exercise Physiology and Biomechanics Laboratory, Leuven, Belgium | 89 post menopausal women aged 58-74&lt;br&gt;Inclusion Criteria: Off Hormone Replacement Therapy Not engaged in regular organised physical activities or strength training&lt;br&gt;Exclusion Criteria: Metabolic/neuromuscular diseases Osteoporosis Orthopaedic injuries Coronary artery disease Osteoarthritis | WBV: Powerplate 35-40Hz; 2.5-5mm amplitude&lt;br&gt;89 were randomly assigned to either the group (n=30), a resistance training group (RES, n=30) and a control group (n=29)&lt;br&gt;The WBV and RES group exercised 3 X per week for 24 weeks&lt;br&gt;The WBV group (using the Power Plate) performed unloaded static and dynamic knee extensor exercises on a vibration platform, which provokes reflexive muscle activity&lt;br&gt;Control: The RES group trained knee extensors by performing dynamic leg-press and leg extension exercises increasing from low (20 repetitions maximum (RM)) to high (8RM) resistance The control group did not participate in any training | Pre, mid (12 weeks) and post (24 weeks) isometric strength and dynamic strength of knee extensors were measured using a motor driven dynamometer&lt;br&gt;Speed of movement of knee extension was assessed using an external resistance equivalent to 1%, 20%, 40% and 60% of isometric maximum&lt;br&gt;Counter movement jump performance was measured using a contact mat&lt;br&gt;Results: Isometric and dynamic knee extensor strength increased significantly (p&lt;.001) in the WBV group 15.0 ± 2.1% and 16.1 ±3.1%, respectively. In the RES group, 18.4±2.8% and 13.9±2.7% respectively after 24 weeks of training with the training effects not significantly different between the groups (p=0.588)&lt;br&gt;Speed of movement of knee extension significantly increased at low resistance (1% or 20% of isometric maximum in the WBV group only (7.4±1.8% and 6.3 ± 2.0% respectively) after 24 weeks of training with no significant differences in training effect between the WBV and the RES groups (P=0.391;P=0.142)&lt;br&gt;Counter movement jump height enhanced significantly (p&lt;.001) in the WBV group (19.4±2.8%) and the RES group (12.9±2.9%) after 24 weeks of training (no between group difference between resistance and WBV (p=0.362)&lt;br&gt;Most of the gain in knee-extension strength and speed of movement and in counter movement jump performance had been realised after 12 weeks of training&lt;br&gt;Leg itching, erythema and oedema reported in over half participants, although resolved promptly after sessions. No other adverse events reported. | Conclusion: WBV is a suitable training method and is as efficient as conventional RES training to improve knee-extension strength and speed of movement and counter movement jump performance in older women As previously shown in young women, it is suggested that the strength gain in older women is mainly due to the vibration stimulus and not only to the unloaded exercises performed on the WV platform Comments: Reported adverse events No mention of randomisation process Good sample size Good time frame = 24 weeks (6 months) 1+ |</p>
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<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Cochrane et al 2004</td>
<td>RCT</td>
<td>N=24</td>
<td>WBV: Galileo 2000</td>
<td>Outcome measures:</td>
<td>Conclusion:</td>
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<tr>
<td></td>
<td></td>
<td>Non-elite athletic adults</td>
<td>26 Hz; 11mm amplitude</td>
<td>CMJ (Counter Movement Jump)</td>
<td>Short term WBV training does not enhance performance in non-elite athletes</td>
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<tr>
<td></td>
<td></td>
<td>8 women</td>
<td>Each participant underwent 9 days of either WBV or control treatment</td>
<td>SJ (Squat Jump)</td>
<td>Comments:</td>
</tr>
<tr>
<td></td>
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<td>Mean age=23.9±5.9 yrs</td>
<td>5 consecutive days separated by 2 days of recovery followed by another 4 consecutive days of treatment</td>
<td>Sprint over 5, 10 and 20m and agility</td>
<td>9 days is a short regime</td>
</tr>
<tr>
<td></td>
<td>Department of</td>
<td>Non-competitive sports with a training frequency of at least once per week and little experience in power, speed, and agility training</td>
<td>Two minute exposures separated by 40 seconds of rest of 5 different static postures</td>
<td>All performed by each participant before and after 9 days of either no training or WBV training</td>
<td>Randomisation not fully explained</td>
</tr>
<tr>
<td></td>
<td>Management, Massey</td>
<td>No specific inclusion or exclusion criteria were specified</td>
<td>Control:</td>
<td>Perceived discomfort of every participant was recorded after daily WBV exposure and non-exposure</td>
<td>Authors claim a greater exposure duration and recovery time are required for WBV treatment of non-elite athletes</td>
</tr>
<tr>
<td></td>
<td>University Palmerston North New Zealand</td>
<td></td>
<td>Each participant stood on the floor next to the Galileo machine doing exactly what the intervention group was doing</td>
<td>Results:</td>
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<tr>
<td></td>
<td>9 day duration</td>
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<td>No significant improvements in either group were seen between baseline and follow-up</td>
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<td></td>
<td>No significant differences between WBV and control groups for CMJ, SJ, sprints and agility at follow-up</td>
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<td>Perceived discomfort differed between the first and subsequent days of WBV training (p&lt;0.05), but no difference between WBV and control groups</td>
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<tr>
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<td>Comments and Level of Evidence</td>
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<tr>
<td>Ronnestad et al 2004</td>
<td>RCT</td>
<td>16 &quot;recreationally resistance trained men.&quot;</td>
<td>WBV:</td>
<td>Outcomes: Testing was performed at the beginning and at the end of the study and consisted of 1 repetition maximum (1RM) in squat and maximum jump height in countermovement jump (CMJ)</td>
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<td>Nemes LC; Squat WBV</td>
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<td></td>
<td>N=7</td>
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<td></td>
<td>40Hz</td>
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<td></td>
<td>Amplitude not stated</td>
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<td>Performed squats on a vibration platform on a Smith Machine</td>
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<td>Control:</td>
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<td>Squat (S) group (n=7) which performed conventional squats with no vibrations on a Smith Machine</td>
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<td>Testing was administered at the beginning and at the end of the 5 week training intervention</td>
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<td>Three workouts were carried out during the first 3rd and 5th weeks and two workouts during the 2nd and 4th weeks.</td>
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<td>Trial period was for 5 weeks</td>
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**Conclusion:**
This study points towards a tendency of superiority of squats performed on a vibration platform compared with squats without vibrations regarding maximal strength and explosive power as long as the external load is similar in recreationally resistance-trained men.

**Comments:**
Randomisation is not specified.
Low number of participants
Side effects not mentioned

1-
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</thead>
<tbody>
<tr>
<td>Verschueren et al 2004</td>
<td>RCT</td>
<td>70 Volunteers aged 56-74 years (post-menopausal women)</td>
<td>25 women trained for 6 months on a WBV (Power Plate) (n=25) or RES training (n=22) or Control group (23)</td>
<td>Outcomes: Hip bone density was measured using DXA at baseline and after the 6 month intervention Isometric and dynamic strength were measured by means of a motor-driven dynamometer Results: No vibration related side effects were observed. Vibration training improved isometric and dynamic muscle strength (+15% and +16% respectively; p&lt;0.01), and also significantly increased BMD of the hip (+0.93%, p&lt;0.05) No changes in hip BMD were observed in women participating in resistance training or age-matched controls (-0.60% and -0.62% respectively; not significant) Serum markers of bone turnover did not change in any of the groups</td>
<td>Conclusions: WBV training may be a feasible and effective way to modify well-recognised risk factors for falls and fractures in older women and support the need for further human trials Comments: Randomisation method is specified Good sample size Good time frame 1+</td>
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</table>

**Whole Body Vibration Training**
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</thead>
<tbody>
<tr>
<td>De Ruiter et al; 2003b</td>
<td>Non-randomised controlled Trial&lt;br&gt;Eleven week WBV on jump height, contractile properties and activation of human knee extensors&lt;br&gt;Study was supported financially by the Netherlands Olympic Committee. Netherlands Sports Confederation&lt;br&gt;Set in an institute in Amsterdam, The Netherlands</td>
<td>20 healthy physically active students were assigned to either the: control group (4 female, 6 male, age 19.9 (0.6 yrs; mean (SEM)) or the experimental group (4 female, 6 male 20.7 (0.5) yrs)&lt;br&gt;Time period= 11 weeks</td>
<td>WBV:&lt;br&gt;Galileo 2000&lt;br&gt;30Hz; 8mm amplitude&lt;br&gt;3 x weekly sessions&lt;br&gt;10 subjects stood 110º knee angle on a vibration platform 5-8 sets of 1 min vibration and 1 min rest in-between&lt;br&gt;Control:&lt;br&gt;10 subjects –same programme as above but stood beside the vibrating machine</td>
<td>Before, during and following the training period the subjects were tested Quadriceps, femoris isometric muscle force, voluntary activation, and maximal rate of voluntary force rise were all measured&lt;br&gt;Results:&lt;br&gt;Quadriceps femoris isometric muscle force, voluntary activation and maximal rate of voluntary force rise did not improve&lt;br&gt;The maximal rate of force rise during electrical stimulation was increased. Counter movement jump height was not affected by WBV</td>
<td>Eleven weeks of standard two legged WBV training without additional training loads did not improve functional knee extensor muscle strength in healthy young subjects&lt;br&gt;It does not appear that the subjects were “randomly assigned.” Rather, they were matched from MVC of the knee extensors and the ability of the subjects to voluntarily activate their muscles</td>
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**Whole Body Vibration Training**
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<tbody>
<tr>
<td>Russo et al 2003</td>
<td>RCT</td>
<td>29 post menopausal women</td>
<td>Muscle Power (measured by jump height)</td>
<td>Reflex muscular contractions induced by vibration training improve muscle power in post menopausal women</td>
<td></td>
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<tr>
<td>“High frequency Vibration” Training Increases muscle power in post menopausal women</td>
<td>Outpatient Clinic in a general hospital in Italy</td>
<td>Intervention group, n=14 Matched Control, n=15</td>
<td>Cortical bone density</td>
<td>No blinding or placebo</td>
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<tr>
<td>Funding not specified</td>
<td>Inclusion criteria: At least 1 year menopausal</td>
<td>WBV: Galileo 2000 Lateral oscillations 12-28Hz in first month of treatment; increased gradually over the month Acceleration .1-10g Subsequent 5 months, 28Hz remained consistent</td>
<td>Biomarkers of bone turnover Knee pain in WBV, n=1 Post-traumatic muscle pain in control, n=1</td>
<td>Randomisation not specified</td>
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<td>Exclusion Criteria: Women with metabolic bone disorders were excluded from the trial But included those receiving hormone replacement therapy</td>
<td>Participants stand on a ground based lateral oscillating platform for 3 X 2 minute sessions for a total of 6 minutes per training session</td>
<td>Results: Over 6 months muscle power improved by about 5% in women who received the intervention Compared to control which remained unchanged. (p=.004)</td>
<td>Limited timeframe Not many exclusion criteria specified</td>
<td>Small group</td>
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<td>Control: Controls did not receive any training</td>
<td>Muscle force remained stable in both the Intervention and control groups No significant difference was observed in bone characteristics</td>
<td>To avoid the effect of lack of calcium or Vitamin D, these were administered to all women throughout the trial</td>
<td>Limited timeframe</td>
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<td>Both groups were evaluated at baseline</td>
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<td>Adverse reactions and drop outs clearly described</td>
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<td>Compliance suboptimal</td>
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**Whole Body Vibration Training**
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<tr>
<td>Torvinen et al 2003</td>
<td>RCT</td>
<td>56 volunteers 21 men Aged 19-38 years</td>
<td>WBV: WBV Platform-Kuntotary-Finland Vibration Intervention, 4 min/day, 3-5X per week</td>
<td>No vibration related side effects or adverse reactions were observed</td>
<td>Conclusion: WBV had no effect on bones of young healthy adults, but instead, increased vertical jump height</td>
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<td>Setting: University Hospital of Tampere Finland</td>
<td>Exclusion Criteria: Any cardiovascular respiratory, abdominal, urinary, gynaecological, neurological, musculoskeletal or other chronic diseases, pregnancy, prosthesis, medications that could affect the musculoskeletal system, menstrual irregularities and participation in impact type exercises more than 3X per week.</td>
<td>During the 4-minute vibration programme, the platform oscillated in an ascending order from 25-45 Hz, corresponding to estimated maximum vertical accelerations from 2g to 8g Amplitude 2mm</td>
<td>The 8 month vibration intervention succeeded well and was safe to perform but had no effect on mass, structure, or estimated strength of bone at any skeletal site. Serum markers of bone turnover did not change during the 8 month period. At 8 months, a 7.8% benefit in the vertical jump height was observed in the vibration group (95% CI, 2.8-13.1%; p=0.003). The vibration intervention had no effect on other performance and balance tests.</td>
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Subjects were randomly assigned to the vibration or control group using computer generated random numbers. Randomisation was based on sex so equal numbers of each sex were in each group.
## Whole Body Vibration Training

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|Salvarani et al 2003  
Mechanical Vibration in the Rehabilitation of patients with reconstructed anterior cruciate ligament | RCT  
Set in Rehabilitation centre in Parma, Italy | N=20 subjects  
17 male  
The treatment group comprised of 10 subjects (mean age 29.7 years± 7.8 years)  
The control group had 10 subjects (Mean Age = 26.8yrs±5.2)  
Inclusion Criteria:  
All participants had received reconstruction of the anterior cruciate ligament (patella tendon)  
All followed the same Rehab protocol 1 month after surgery +received mechanical vibration  
No exclusion criteria were specified | WBV:  
Nemes  
One daily session of WBV (30Hz frequency for 1 minute) over a 2 week period + regular rehabilitation; 25° knee flexion, holding a static posture | Outcome Measures:  
Muscle force (isokinetic test of knee flexion/extension strength to determine if subject ready to return to preinjury activity levels) during extension of both lower limbs was evaluated by isometric contraction for 5 seconds  
Assessed at end of treatment and two weeks later  
Results:  
The treatment group (p=0.0018) and control groups (p=0.017) showed statistically significant increases in strength between baseline and end of treatment. Peak forces were not different in either group between end of treatment and two week follow-up (p=0.824 and p=0.086 respectively)  
The treatment group however significance was higher (p=0.00023 vs 0.0075)  
Mean force was significant for the treatment group only (p=0.02) | Conclusion:  
This could be useful in the rehabilitation of subjects who receive reconstruction of the anterior cruciate ligament  
Comments:  
No mention of side effects  
Randomisation method is described  
Small number of female participants and participants overall  
Short time frame- 2 weeks  
Subjects are already part of rehabilitation programme so this maybe influencing results 1- |
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<tr>
<td>Delecluse et al 2003</td>
<td>RCT Physical Education Laboratory University of Leuven, Belgium</td>
<td>67 Females, (21± 1.8 yrs) None of the volunteers were involved in regular exercise training</td>
<td>WBV: The acceleration of the vibration platform was between 2.28g and 5.09g Amplitude 2.5-5mm Frequency 35-40Hz 4 groups: WBV, placebo, resistance training and control group (no intervention) The WBV (N=18) and the placebo group (N=19) performed static and dynamic knee extensor exercises on a vibrational platform (Powerplate); the placebo group did platform exercises but with 0.4g acceleration Resistance training group (RES) (N=18) carried out knee extensors by dynamic leg press and leg extension exercises (10-20RM) Control group: (N=12) did not participate in any training 36 training sessions over a 12 week period for 3 X per week</td>
<td>Results: Adverse events: No reports of adverse events; patients described WBV as enjoyable and fatiguing Drop-outs Two each in Resistance, Placebo and WBV groups, 1 in control; dropped out due to other commitments Isometric dynamic knee extensor strength increased significantly (p&lt;0.001) in both the WBV group (16.6±10.8%, 9.0±3.2%) and the RES group (14.4±5.3%, 7.0±6.2%) The Placebo and Control group showed no significant increase (p&lt;0.05) Counter movement Jump height enhanced significantly (p&lt;0.001) in the WBV group only (7.6±4.3%)</td>
<td>Conclusions: Strength increases after WBV training are not attributable to a placebo effect WBV provokes reflexive muscle contraction and has the potential to induce strength gain in knee extensors of previously untrained females to the same extent as resistance at moderate intensity Randomisation is not mentioned Follow-up not mentioned 1-</td>
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<tr>
<td>Torvinen et al 2002c</td>
<td>RCT University Hospital of Tampere, Finland</td>
<td>56 healthy adult volunteers: 21 men Aged 19-38 years Exclusion Criteria: Same as Torniven 2003 (8 month trial)</td>
<td>WBV: Kuntotary Finland Four months WBV training 3-5X per week standing on a platform 4 x 60 second bouts of light exercise programme, light squatting, standing erect, standing relaxed with flexed knees, light jumping, body weight shifting and heel standing; Loading and frequency changed over time: 25-40Hz Amplitude stable at 2mm 2.5g-6.4g (with higher frequencies) Amplitude 2mm Control: Subjects were told not to change their current activity levels</td>
<td>Outcomes: Five performance tests involved: Vertical Jump Isometric extension Grip Strength Shuttle run Postural Sway Measures at baseline, 2 and 4 months Results: Four month WBV induced an 8.5% (95% CI, 3.7-13.5%, p=0.001) net improvement in jump height Lower limb extension strength increased after the 2 month vibration resulting in a 3.7% (95% CI, 3.7-13.5%, P=0.001) net improvement in the jump height. This benefit diminished at the end of the 4 month intervention WBV showed no effect on grip strength, shuttle run or balance tests Two withdrawals, one unrelated due to rib fracture and one due to patient undergoing unrelated orthopaedic surgery</td>
<td>Conclusions: WBV enhanced jumping power in young adults, suggesting neuromuscular adaptation to the vibration stimulus Dynamic or static balance was not affected by WBV Comments: Authors claim that after 4 months there was no significant difference in lower limb extension strength between the WBV and control group. The authors attribute this to the fact that the control group had a learning effect, whereby, they exhibited increased extension strength No mention of randomisation process Does not clearly describe what the control group does This paper led on to the 8 month trial</td>
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### Whole Body Vibration Training

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| Bosco et al 1998 | RCT | N=14  
Mean age WBV group=20.4 years  
Mean age control group=19.9 years  
Active healthy adults – handball or water polo 3 x week  
Gender not stated  
Randomly divided into experimental or control groups | WBV:  
Galileo 2000  
26 Hz, 10 mm amplitude, acceleration=54m/s²  
10 minute warm-up; 5 minute warm-up on cycling ergometer followed by 5 minutes of static stretching of quadriceps and calf muscles  
5 series of vibrations of 90 seconds each, separated by 40 seconds rests in between 10 days of WBV  
Control group:  
Untreated and told to maintain their typical activities and avoid strength or jump training | Outcomes:  
CMJ: Flight time and contact time of each jump to calculate centre of gravity height; Knee position standardised (90°) and hands on hips throughout  
Continuous jump (CJ (5 seconds)) to calculate average mechanical power and average rise of centre of gravity | No detail regarding randomisation procedure  
Small sample  
No discussion re adverse events/safety  
Little information on baseline characteristics i.e. potential confounders  
Authors explain findings by saying that neuromuscular action in CMJ is different than that found in 5s CJ  
Only the CJ activity results in a concurrent gamma-dynamic fusimotor input that may enhance primary afferent discharge |

1-
**Elderly** – studies that report mainly muscle power and lower limb strength effects of WBV relating to elderly clients are located in ‘long-term’ study table

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<tr>
<td>Kawanabe et al 2007</td>
<td>Non-randomised controlled trial</td>
<td>N=67; 4 men; Age range=59-86; mean age=72 years; N=27 exercise alone; N=40 WBV and exercise</td>
<td>WBV: Galileo Unknown model 4 minutes WBV, once per week over 2 months 12-20Hz Laterally oscillating platform Control: Exercise intervention (WBV group received concurrently) included balance, strength and 30 minute walking twice weekly</td>
<td>Outcomes: 10 metre walking time Walking step length Maximum one leg standing time (right and left) No serious adverse events such as fall-related injuries or cardiovascular effects observed Results: Significant improvements in reduction in 10 metre walking time in WBV group 9.0s-7.75*, pre and post, compared with control group (7.3-7.5s) Standing on one leg right 18.3s-31s* WBV vs 18.7s-18s* Standing on one leg left 16.7-32.5s* WBV vs 19.6-22.5* control Step length 61.2 cm-65cm* WBV vs 65.8cm-69cm* control All statistically significant (p&lt;0.05)</td>
<td>Small number of men although there was no difference between the two groups with respect to gender Note heterogeneous groups in terms of size No mention of other or a complete list of side effects Non-randomised? better outcomes to analyse function and balance available; particularly as all subjects appeared to be community dwelling No raw data to assess tolerance or compliance with interventions although reportedly no serious adverse events such as falls or cardiovascular events during the study period 2+</td>
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* approximate values as data graphed only
Bogaerts et al 2006  
**Methods and Settings**  
To investigate the effects of a 12 month WBV programme on postural control in healthy older adults  
Study undertaken at a University with close supervision of both treatment arms  

**Participants**  
N=220  
Community dwelling adults between 60-80 years of age  
Randomised to one of three groups  
1. WBV  
2. Fitness Programme (FIT)  
3. Control (no intervention)  
WBV=94; 48 males; mean age 66.8 years  
FIT=60; 30 males; mean age 66.8 years  
CON=66; 30 males; mean age=67.8 years  

**Intervention**  
**WBV:**  
Powerplate  
3 x weekly sessions maximum of 40 minutes/session  
Variable 30-40Hz frequency  
Exercises performed: squat, deep squat, wide stance squat, toes-stand, toes stand-deep, one legged squat, lunge  
No permitted use of rail after 3 months and at 6 months were to perform exercises with eyes shut  
There was a gradual increase in exercise number and complexity introduced as time went by. Also reduced rest in between exercises  

**Control:**  
FITNESS GROUP:  
Consisted of cardiovascular endurance, resistance, balance and flexibility to a maximum of 1.5 hours per week; 3 sessions per week; all supervised sessions  

**Outcomes and Results**  
Two withdrawals in FIT group prior to commencing  
Withdrawals due to personal reasons:  
6 WBV, 1 FIT, 4 CON  
11 WBV, 4 FIT, 1 CON due to health issues and 7 further due to knee pain (WBV=5, FIT=2)  
5% dropout in WBV vs 3% in fitness group  

Outcomes:  
Measured at baseline, 6 months and at end of programme (12 months)  

- **Sensory Organisation Test (SOT):** ability to use visual, vestibular and proprioceptive information to maintain balance. Consists of a platform that can be manipulated in terms of angle and direction*.  
- **Motor Control Test (MCT):** Measures the ability to coordinate automatic movement responses after unexpected forward and backward translations. Measured latency and response strength of active response  
- **Adaptation Test (ADT):** This test analyses the adaptation of the motor system to platform rotations causing the subject's toes to go up or down. Five rotations were tested giving a sway energy score (SES). A smaller SES represented the ability to react more efficiently  

**SOT results:**  
No changes, statistically significant or otherwise were seen in any group across C1-3 conditions at any time-point.  
The number of falls for C6 decreased significantly in WBV and FIT groups across all time points  

**Comments and Level of Evidence**  
“WBV may contribute to improvements in some aspects of postural control in community dwelling adults over 60 years of age”  
“The study however failed to show a significant benefit of any of the two training programmes on most aspects of postural control”  
Little discussion on withdrawals due to knee pain  
Non-blinded assessor  
Randomisation poorly described – unequal treatment groups – not explained  
Good sample size  
No intention to treat strategy discussed for likely missing data  
Analysed those that attended over 80% of classes (excluded a further 23 subjects)  
Total programme for which statistics are reported were for WBV=61, FIT=39; CON=61  

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Whole Body Vibration Training

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<td>(p&lt;0.05). No change was seen in CON. Interestingly the FIT group showed a greater falls reduction percentage than WBV from pre-mid assessment (approximately 79% WBV vs 87% FIT) Overall, however, all groups showed improvement in equilibrium scores from pre-mid and pre-post (p&lt;0.001) in all groups</td>
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<td></td>
<td>MCT results No groups showed change in response strength or latency for any condition</td>
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<td>ADT results A significant improvement was seen in the WBV group between pre and mid test and pre-post in toes down (p&lt;0.001 for both). The other groups showed no change over time. No between group differences were seen in the toes up, although SES improvements were seen across all groups from pre to post for toes up and down</td>
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*Six conditions tested: C1=normal vision and support surface; C2=eyes closed and normal support surface; C3=sway-referenced vision and normal support surface; C4=normal vision and sway-referenced support surface; C5=eyes closed and sway-referenced support surface and C6=sway-referenced vision and support surface.*
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<tr>
<td>Gusi et al 2006</td>
<td>RCT</td>
<td>University setting Close supervision of all participants To investigate the effectiveness of a reciprocating plate WBV system using frequencies lower than 20Hz and a walking programme on bone mineral density (BMD) and balance in post-menopausal women</td>
<td>WBV: Galileo 2000 – reciprocating platform 12.6 Hz; used barefoot 3 sessions of 30 minutes per week over 8 months; n=14 6 x 1 minute bouts within a session separated by 1 minute rests between 1 minute bouts Standing in 60° of knee flexion; 3mm amplitude 96 sessions over 32 weeks Each session commenced with a cycling warm up and stretch Treatment intensity increased over first 6 weeks 1 day of rest in between both WBV and walking group sessions each week Control: Walking group; n=14 1 hour of walking (2 x 5 minute stretching bouts within this time), 3 x per week for 8 months</td>
<td>Outcomes: Bone mineral density using DEXA scanning Postural control using the 'blind flamingo' test (single leg stance with the opposite hip and knee flexed to chest, eyes closed). The number of 'falls' i.e. times needed to regain balance during 30 seconds was recorded Results: Authors reported no vibration related side effect or adverse events occurred N=4 losses to follow-up in WBV group; 1 due to home accident; 2 due to lack of interest and 1 due to surgery N=4 losses to follow-up in control group (due to lack of interest) Compliance and baseline demographics similar between groups (compliance =78% overall Postural Control: WBV balance improved, and this was statistically significant (walking group did not improve over 8 months) (p=0.023) BMD: Femoral neck BMD only increase in WBV was significantly greater than in the walking group (p=0.011) – an increase of 4.3% Only lumbar spine BMD did not change in either group Body Mass Index (BMI) A statistically significant difference was seen in reduction in BMI between the two groups at 8 months (p=0.046)</td>
<td>No blinding of assessor Few details regarding randomisation process No intention to treat strategy although did report withdrawals/losses to follow-up Comparative studies (e.g. Russo et al) did not show improvement with a reciprocating plate although had 2 sessions only per week</td>
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<td>Bautmans et al 2005</td>
<td>RCT</td>
<td>Study aim is to examine the effect of 6 weeks of WBV in elderly rest home subjects as compared with sham treatment on function, strength and flexibility</td>
<td>N=24 elderly rest home residents WBV=13; control=11 15 female; 9 male Mean age 77.5 years</td>
<td>WBV: Powerplate 3 x per week, 1 day rest in between treatment days; 30-50Hz; 2-5mm amplitude patients performed 6 static exercises targeting lower limb muscles Exercise programme progressed frequency and exercise duration and exercise sequence during the 6 weeks in a standard manner Control: Standing on WBV platform with music played simulating sound from the vibrating platform and performed the same exercises as per the intervention group Concurrent gymnastics supervised by physical therapist twice weekly (chair based) administered to both groups</td>
<td>Outcomes: Timed Up-and-Go Grip strength Balance/Gait Upper and lower limb flexibility using ‘hand-behind-head’ and ‘sit and reach’ test Groups similar at baseline with respect to age, weight, height, body-mass index, medications and so on WBV attended 96% of sessions; control 86% Lower limb strength using Aristokin multi-joint dynamometer Assessed at baseline and at 6 weeks at completion of study intervention Results: 21 completers; however, reported on 10 in WBVC group and 11 in the control group Adverse events: One upper respiratory tract infection (withdrew); one groin pain, one fearful; one refusal to participate Dealt with other missing values by using ‘worse-ranked score’ analysis strategy and ‘last observation carried forward strategy’ However, the authors believed that as these distorted the mean values, they have reported only on n=10 in the WBV group Body balance and total Tinetti test scores were statistically significantly better at 6 weeks in the WBV group (Tinetti test overall score and body balance component) (13.9 vs 11.8 (p=0.001) (23.4 vs 21.3 (p=0.002 respectively)) Timed up-and-go scores were better in the WBV group also (15.3 vs 14.8 (p=0.029) All these remained significant when assessed using last</td>
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<td>observation carried forward and the worst rank score analysis (n=23) except for timed up-and-go which was no longer significant with the two ITT strategies used. No significant differences in leg extension work, force, power or maximum explosivity or flexibility scores using any of the three methods of statistical analysis reported between the groups was identified however, both groups improved significantly from baseline. No change in maximal force/power/explosivity in lower limb strength</td>
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<tr>
<td>Bruyere et al 2005</td>
<td>Randomised controlled trial</td>
<td>Forty two elderly volunteers</td>
<td>WBV: Galileo 2000 6 weeks of controlled whole body vibration training, 3 X per week</td>
<td>Outcomes: Gait and body balance measured using the “Tinetti test” (Max score 12 for gait, 16 for body balance, 28 for global score. Motor capacity using the Timed up and Go (TUG) test Health related quality of life (HRQOL) using the medical outcome study, 36 item- Short form Health Survey (SF-36) Results: After 6 weeks, the WBI group improved by mean/sd of 2.4±2.3 points on gait score compared with no score change in the control group (p&lt;.001) WBI group improved by 3.5±2.1 on the body balance score compared with a decrease of 0.3±1.2 pts in the control group (p&lt;0.01) TUG test time decreased by 11 ± 8.6 seconds, in treated group compared with an increase of 2.6 ±8.8 seconds in control group (p&lt;0.01) The intervention group had significantly greater improvements from baseline on 8 of 9 items on the SF-36 compared with the control group; these included physical social, vitality, pain aspects of function. The only parameter not showing a significant improvement was Health Change. Changes in blood pressure and heartbeat during sessions were clinically significant No adverse effects were observed</td>
<td>Conclusions: Controlled whole body vibration can improve elements of fall risk and HRQOL in elderly patients Small sample size Randomisation method is not described Follow-up after 6 weeks not carried out Longer and larger trial required Baseline characteristics were measured Adverse effects described-minor tingling of the lower limbs 1+</td>
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<td>Nursing home, Belgium</td>
<td>Aged 63-98 years Mean Age: 81.9 years</td>
<td>Frequency variable 10-26Hz, 3-7mm amplitude Stood on vertical vibrating platform for 4 series of 1 minute of vibration alternating with 90 seconds of rest. Blood pressure pulse was taken before the first series, immediately after the 2nd and 4th series and 2 minutes after the 4th series in each session Stood on vertical vibrating platform for 4 series of 1 minute of vibration alternating with 90 seconds of rest. Blood pressure pulse was taken before the first series, immediately after the 2nd and 4th series and 2 minutes after the 4th series in each session</td>
<td>Control: Physical Therapy; Standard exercise programme Gait and Balance exercises, training in transfer skill, strengthening exercises with resistance mobilisation of the lower limbs. 10 minutes, 3X per week during the 6 week study period</td>
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<td>Inclusion Criteria: Ambulatory No major cognitive disorders</td>
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<td>Exclusion Criteria: Patients with a high risk of thromboembolism, Or A history of hip or knee joint replacement</td>
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<td>Randomly assigned: 22 to vibration therapy + Physical therapy 20 assigned to physical therapy only</td>
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<td>Rubin et al 2004</td>
<td>Double-blind randomised controlled trial to examine effects of WBV for inhibiting bone loss in post-menopausal women 3-8 years post menopause. Study funded by Exogen.</td>
<td>Post-menopausal women; volunteers recruited from t.v. and radio and from within Osteoporosis centre N=70; 33 active and 37 placebo. 45-84 kg in weight due to equipment capacity. Excluded smokers and those that consumed &gt; 2 drinks of alcohol/day. Also excluded those that engaged in high impact physical activity more than three times per week.</td>
<td>Home-based WBV BEI LA 18 30Hz, 0.2 g acceleration. 32 women received WBV device. 32 a placebo device. 2 x 10 minute treatments daily separated by 10 hours each. 7 days/week for one year. Compliance recorded automatically by an electronic monitor. Placebo group 5kg higher than active treatment group (p&lt;0.03); BMI of placebo group 2kg/m² higher (p&lt;0.04)</td>
<td>N=56 completers 6 withdrawals (one active and five placebo) within first 3 months. N=46 with full final results for comparison. One headache in placebo group. Outcomes: BMD using DXA, proximal right and left femur, lumbar spine and distal one third of non-dominant radius. Scans done at 3, 6, and 12 months. At study completion serum and urine markers of bone turnover. Subjective experience of WBV. Compliance – as 80% of the prescribed time (56) + 37%. No significant differences between bone loss between baseline and 12 month follow-up between groups although trend for WBV group to lose less. ITT analysis indicated that in the active group femoral neck 0.69% of BMD was lost; 0.27% loss was seen in the placebo group. In the trochanter, the active group lost 0.07% vs 0.19% in placebo (no statistics provided). Lumbar spine results indicated a 0.51% loss in the active group vs 0.65% in the placebo group (p=0.45). For the 56 completers; The placebo group had consistently higher losses of BMD in all areas but these were not statistically significant from population averages. Regression analyses with the 46 full completers indicated that with 100% compliance it was predicted that BMD spine was to increase 7.1% increase in BMD, for BMD trochanter, 5.1% (p=0.085), for femoral neck 1.8% (p=0.54). For</td>
<td>Randomisation clearly described. Clear description of how the placebo was unlikely to be detected as an inactive device by participants. Did report on how recorded possible changes in activity levels of participants throughout study. Unknown if subjects were diagnosed as osteoporotic or not. Reported adverse events. Well designed and carried-out study. Poor data on radius BMD. Authors report difference in self-reported calcium intake in groups but do not state significance or discuss further. Authors stated only: “there was no influence of the mechanical treatment on the radius” Study indicates compliance with treatment is an issue. 1++</td>
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</table>
the placebo population a no association at trochanter and lumbar spine and a negative association for femoral neck (p=0.001)
Hydroxypoline levels in active group dropped 3% at 12 months vs 16 % in placebo group (p=0.07)
Phosphorus decreased 4% in placebo but gained 1.3% in active group (p=0.08)
No significant changes in other markers in either group were seen
Subjectively patients reported that treatment was difficult to schedule in
<table>
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<tbody>
<tr>
<td>Hannan et al 2004</td>
<td>RCT with a cohort of post-menopausal women specifically investigating compliance issues with WBV appliances</td>
<td>Inclusion criteria: &gt; or equal to 70 years of age; BMI &lt; 30 Recruited from a continuing care retirement community Subjects needed to be ambulatory and able to stand for more than 10 mins Excluded subjects with joint replacements</td>
<td>Exogen Optimass WBV Model MSI-1000 Mechanical stress device 30Hz; 0.3 g Home-based WBV 10 mins daily; 6 months Placebo, was same device without the vibration; both emitted an identical auditory tone Vertical displacement in active machines is reported as &quot;barely discernible&quot; Incentives given at 1, 3 and 5 month milestones during programme Staff supervised all sessions for all subjects in first two weeks Staff support was withdrawn over the remainder of the study Participants recorded start and end time using daily sign-in sheet Field staff contacted subjects if they missed 2 or more sessions; sheets were reviewed weekly</td>
<td>Physical Activity Scale for the Elderly (assessed activity levels) Patient satisfaction N=53 volunteers 4 lost interest after baseline assessment; 21 ineligible; 28 remained; the first 24 were enrolled N=12 WBV; 12 placebo 3 withdrawals; 21 completers Mean age 86 years (79-92 years range) Weight and BMI differed at baseline between groups Mean compliance 82.5% (range 7-100%) ITT; a priori group 92.7% compliance No compliance difference between groups Drop outs due to loss of interest (n=2) and one respiratory illness. Authors report no losses due to treatment effects of WBV. However, one episode of syncope over the 6 months and two further cases of respiratory illness Main reasons for missing sessions were vacation and illness. Satisfaction 95% reported overall satisfaction with use of the WBV. 5% had no opinion; satisfaction remained stable throughout the study</td>
<td>Randomisation including concealment allocation well reported Authors iterate compliance issue Good study that achieved its aim of assessing viability and compliance for congregate dwelling individuals 1++</td>
</tr>
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<tr>
<td>Runge et al 2000</td>
<td>Randomised crossover trial</td>
<td>N=39</td>
<td>WBV: Galileo 2000 2 months of intervention followed by 2 months of control treatment Treatment 3 x per week, 3 x 2 minutes</td>
<td>5 losses to follow-up 1 due to adverse event – inflammation of the forefoot Assessments undertaken every 2 weeks Reported assessment only was: Chair rise (46cm height) x 5 Statistically significant improvement in rising time by 18% 33/34 improved muscle power up to 36% “Control group no different”</td>
<td>Unclear and extremely limited reporting of entire study Control not described No evidence of a later publication providing further information 1-</td>
</tr>
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<tr>
<td>Iwamoto et al 2004</td>
<td>RCT</td>
<td>50 post-menopausal women with osteoporosis, aged 55-58 years of age.</td>
<td>WBV: Galileo – model not specified</td>
<td>Outcomes:</td>
<td>Conclusion:</td>
</tr>
<tr>
<td></td>
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<td>WBV and Alendronate osteoporosis medication</td>
<td>1. Lumbar BMD was measured by dual energy x-ray absorptionetry</td>
<td>Whole Body Vibration exercise using a Galileo machine appears to be useful in reducing chronic back pain, probably by relaxing the back muscles in post-menopausal osteoporotic women treated with alendronate</td>
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<td></td>
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<td>One alendronate daily (5mg, ALN) is the normal treatment of osteoporosis</td>
<td>2. NTX and serum ALP levels were measured by enzyme linked immunosorbent assay</td>
<td>Comments:</td>
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<tr>
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<td>Alendronate + WBV</td>
<td>3. Chronic back pain was evaluated by face value scores at baseline and every 6 months</td>
<td>12 months is a good length of time for a study period</td>
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<td></td>
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<td></td>
<td>Control:</td>
<td>Results:</td>
<td>Randomisation is not described even though the authors claim it is random</td>
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<td></td>
<td></td>
<td></td>
<td>Group taking medication only</td>
<td>The increase in lumbar BMD and the reduction in urinary NTX and serum ALP levels were not significant between the two groups</td>
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<td>Exercise consisted of WBV using a Galileo Machine (static posturing), 20Hz, frequency, once per week; duration of exercise=4mins</td>
<td>The reduction in chronic back pain was greater in the ALN+EX group than in the ALN group</td>
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<td></td>
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<td></td>
<td>Study duration=12 months</td>
<td></td>
<td>There is no control group who are not taking alendronate Drop outs and adverse reactions are described.</td>
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**Conclusion:**
Whole Body Vibration exercise using a Galileo machine appears to be useful in reducing chronic back pain, probably by relaxing the back muscles in post-menopausal osteoporotic women treated with alendronate.

**Comments:**
12 months is a good length of time for a study period. Randomisation is not described even though the authors claim it is random. There is no control group who are not taking alendronate. Drop outs and adverse reactions are described.
### Cardiovascular

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<tbody>
<tr>
<td>Kerschan-Schindl et al 2001</td>
<td>Case series</td>
<td>20 healthy adults</td>
<td>WBV: Galileo 2000</td>
<td>Outcomes: Alterations in muscle blood volume of the quadriceps and gastrocnemius muscles were assessed with power Doppler sonography and arterial blood flow of the popliteal artery with a Doppler ultrasound machine. Measurements were performed before and immediately after exercising. Authors report all participants displayed reddish erythema of foot and calf. Results: No changes to baseline Heart rate or blood pressure. Power Doppler indices which indicate muscular blood flow significantly increased after exercise. Doppler median scores for quadriceps improved from 1.5-3 (p=0.02) and in Gastrocnemius 1.0-2.0 (p=0.0001). The mean speed of blood flow velocity in the popliteal artery increased from 6.5 to 13.0 cm s⁻¹.</td>
<td>Conclusions: The authors claim that these results show that low frequency vibration does not have the negative effects on peripheral circulation known from occupational high-frequency vibration. Comments: Case series, no controls. Duration of experiment is not specified. No mention of drop-outs/withdrawals.</td>
</tr>
<tr>
<td>WBV exercise leads to alterations in muscle blood volume</td>
<td>Pre-post test</td>
<td>Aged between 25-35 yrs (8 females; mean age=28.5 ± 2.2 yrs) (12 Males; mean age=32.7 ± 3.3 yrs)</td>
<td>Subjects stood on a platform fixed on a sagittal axle which alternately pushes the right and left leg upwards and downwards at a frequency of 26hz; 3mm amplitude; peak acceleration=78 m/s⁻². Three sets of different positions were used. Each position was held for 3 minutes and the exercise was continued without break between the positions. The total workout was 9 minutes. Subjects performed WBV barefoot. Exercise 1: standing upright on platform, legs straight. Exercise 2: Standing upright, knees in 60-70° of knee flexion. Exercise 3: As above with 30° of hip external rotation.</td>
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<td>Funding not specified</td>
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**Whole Body Vibration Training**
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<tbody>
<tr>
<td>De Ruiter et al 2003a</td>
<td>Case series</td>
<td>12 students (untrained)</td>
<td>WBV:</td>
<td>Outcomes: MVC- Maximal Isometric force production MRFR – Maximal Rate of Force Rise of the knee extensors Results: At 90secs following vibration, maximal voluntary knee extensor force was reduced to 93(5%) [mean (SD), p&lt;0.05] and recovered in the next 0.3hour Voluntary activation remained significantly depressed (2-4%). Neither the electrically induced MRFR nor voluntary MRFR were significantly affected by WBV Six WBV training sessions in 2 weeks (n=10) did not enhance either voluntary muscle activity during MVC (99.2%) of the baseline value or voluntary MRFR (98.9%) of the baseline value</td>
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<td></td>
<td>Setting not mentioned</td>
<td>Average age= 23.3 (4.2) yrs of age</td>
<td>Galileo 2000</td>
<td></td>
<td>Conclusion: Short term WBV training does not improve muscle activation during maximal isometric knee extensor force production and maximal rate of force rise in healthy untrained students Small number of participants No controls 3</td>
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</table>
### Endocrine

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<tr>
<td>Di Loreto et al 2004</td>
<td>RCT</td>
<td>N=10 adult men. Good health as determined by medical history, physical examination and laboratory evaluation. Age ranged from 25-50 years and average age was 39.3 years. Body Mass Index ranged from 21-26 kg/m2 with the average being 23.5.</td>
<td>WBV: Unknown make or model. Volunteers were studied on two occasions before and after standing for 25 min on a ground plate either in the absence (control) or in the presence of vibration, set 30Hz whole body vibration. Time-frame=4 days</td>
<td>Outcomes: Glucose plus hormone&quot; Insulin, Glucagon, Cortisol, Epinephrine, GH, IGF-1, Free and Total testosterone</td>
<td>Conclusions: The authors conclude that these results demonstrate that the vibration exercise transiently reduces plasma glucose, possibly by increasing glucose utilisation by contracting muscles. This type of intervention is not expected to reduce fat mass in obese subjects. Comments: No exclusion criteria are specified. No mention of side effects. No mention of how many were controls or how they were assigned controls. Small number (n) =10. Small time frame for trial with no follow-up. Poorly designed Randomised Controlled Trial.</td>
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</table>

Di Loreto et al 2004

“Effects of WBV exercise on the endocrine system of healthy men.”

No funding specified
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<tr>
<td>Kvorning et al 2006</td>
<td>RCT Investigating the effect of a 9 week WBV programme compared with conventional resistance training</td>
<td>Healthy male adults, n=28 (S group=9, S+V group=10, V group=9) &quot;Moderately trained&quot;; no regular resistance training</td>
<td>WBV: Galileo 2000 Frequency: 20Hz for the first 5 weeks, then 25 Hz; amplitude remained the same throughout at 4mm Consistent foot position and squat technique to 90° knee flexion Sessions increased gradually (but consistently) over the 9 week period to a total of 20.5 sessions Squat group: 6 x 8 reps with a loaded bar (progressively loaded according to a specific protocol (Baechle et al 2000) S+V group: As above, loaded on WBV platform V group: As above but instead of a loaded squat, squatted with a broomstick</td>
<td>Outcomes: 1. Maximal voluntary isometric contraction (MVC) – one isometrically performed leg press test; EMG performed during MVC 2. Countermovement jump (3 maximal) 3. Single leg, leg press 4. Acute hormonal response to training – measured at end of first full session (week 2) and at end of last full session</td>
<td>Conclusions: WBV and resistance training did not increase MVC and countermovement jump compared to squat alone Inexplicable how and why MVC changes were lower in the S+V group as compared with the S group alone Hormonal changes had thought to be mediators of improved performance. This study may not have provided sufficient intensity to stimulate an increase in testosterone levels as seen in a previous study WBV does not change the acute hormonal response to a training session after a training period Comments: Raw data regarding hormone levels not reported No blinding No detail on randomisation method Side effects not mentioned 1-</td>
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Whole Body Vibration Training

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<td>Goto &amp; Takamatsu 2005</td>
<td>Controlled trial aiming to determine if a high catecholamine and growth hormone (GH) release is seen following a single bout of WBV. This may increase free fatty acids (FFA) and assist with lipolysis. Subjects randomised to the order of receiving WBV or control interventions.</td>
<td>N=8 Healthy young males Average age=23.4 years Active but not sports participants</td>
<td>WBV: Galileo 900 10 sets of 60s bouts; 1 min rests in between bouts 26 Hz 2.5mm Static squat and knees bent position (120° flexion) Control: Treatment was standing on platform without the vibration in position as above Control and interventions separated by 7 days</td>
<td>Outcomes: Free fatty acids; lipase; glycol; epinephrine (E), norepinephrine (NE), growth hormone at baseline, 0 20 60, 90, 120, 150, 180 and 210 minutes post sham or WBV Baseline levels similar between trials Significant increase in WBV group in NE (p=0.037) and E (p&lt;0.05) immediately post WBV but not for controls GH showed slight increases from baseline in both groups but these changes were not significant from baseline to follow-up or between groups FFA in the WBV group showed a gradual increase at 60 minutes with differences at 150, 180 and 210 minutes (p&lt;0.01) from baseline. Total FFA during the recovery period was not different between the groups Glycerol levels were unchanged in both groups following WBV but there was no statistically significant difference at any time point between the groups Only at the 150 minute in the control group was there a statistically significant increase in FFA (p&lt;0.05), although no statistically significant difference was found between control and intervention (p=0.185)</td>
<td>Small sample No mention of assessment blinding GH hormone increase has in previous studies been linked with a lipolytic effect. This may be due to the fact this sample comprised non trained participants: the response to WBV then may be different in trained vs untrained The effect of WBV on lipolysis still needs clarifying No mention of side effects 2+</td>
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<td>Van Nes et al 2006</td>
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<td>N=53</td>
<td>WBV:</td>
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<td>CVA subjects within 6 weeks of stroke - ischaemic and haemorrhagic</td>
<td>N=26 randomised to “Exercise therapy on music”</td>
<td>Galileo 900; 4 x 45 seconds stimulation at 30Hz, 3mm amplitude, 5 days per week, 6 weeks in semi squat position. One minute break between 45 second bouts</td>
<td>Loses to follow-up</td>
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<td>Block randomisation</td>
<td>N=27 in WBV group</td>
<td>Support given to maintain the WBV position for those that needed it</td>
<td>Two losses to follow-up at 6 weeks follow-up in control group due to CVA in one and refusal to continue for the other</td>
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<td>Patients recruited from three hospital centres</td>
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<td>Equal treatment parameters for exercise therapy on music in same body position</td>
<td>Berg Balance Scale (Primary outcome)</td>
<td>Both groups showed statistically significant improvements in most outcomes from baseline to immediate follow-up</td>
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<td>Both groups received concurrent treatment of 5 x 30 minute individual therapy sessions; 5 x 60 minute group therapy sessions, 3 x 30 min occupational therapy sessions, speech language and psychological input as required, per week</td>
<td>Others Barthel index, Rivermead Mobility index and so on</td>
<td>Results showed no statistically significant difference in improvements seen from baseline to first or second follow-up in any outcome although results also non-significant at 12 weeks, results seem to continue improving.</td>
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<td>Baseline comparisons indicated groups were similar except for statistically significant difference between stroke type (WBV, 59% ischaemic vs 85% control group; p&lt;0.05)</td>
<td>N=1 shoulder pain which necessitated cessation of treatment (reported unlikely to have been caused by WBV)</td>
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**Neurological conditions and diseases**

**Study**

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**Comments and Level of Evidence**

Unknown effect of significance of CVA type; authors perhaps should have stratified based on CVA type

“Exercise on music” control arm poorly described

Intention to treat strategy used in outcomes

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| Van Nes et al 2004 | Case series  
No controls  
Set in Medical Centre in The Netherlands                                                                                                    | N=23 ischemic stroke patients (13 men)  
Mean Age =58.1± 11.4 yrs  
8 patients had right hemisphere lesion and 15 have left hemisphere lesion  
**Inclusion Criteria:**  
Only one stroke in lifetime.  
Stand without support for 30 seconds.  
Understand goal and methods.  
Give informed consent  
**Exclusion Criteria:**  
Non-stroke related sensory motor functions  
Medication that could interfere with postural controls  
**Contraindications:**  
Pregnancy, recent fractures, gall or kidney stones, cardiac pacemaker, infectious disease, chronic patient who had stroke 6 months prior. Poor balance problems | **WBV:**  
Galileo 900 and 2000 used  
One series of four consecutive repetitions of 45 seconds WBV with a 1 minute pause between administrations | **Outcomes:**  
Balance assessed at 45 min intervals  
Postural instability is expressed as the root mean square (RMS) centre of pressure (COP) velocity | **Results:**  
No adverse events identified  
A stable baseline performance was observed from the first to second assessment for all tasks  
After WBV, the third assessment demonstrated a reduction in the RMS COP velocity in the anteroposterior direction when standing with the eyes closed (p<0.01), which continued until the fourth assessment | **Conclusion:**  
WBV maybe a promising candidate to improve proprioceptive control of posture in stroke patients  
**Comments:**  
Small number of participants  
Only preliminary results  
3 |
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<td>Schufried et al 2005</td>
<td>Double-blind RCT</td>
<td>N=12 Randomised 6 each into WBV or sham interventions; Enrolled those with ≤ 5 (including only those who are fully ambulatory) on the 0-10 scale on the Expanded Disability Status Scale (EDSS) Experimental: 1/5 male, female Sham: 2/4 male, female Average age 49.3 years WBV, 46 years sham</td>
<td>WBV: Zeptor-Med WBV 2.0-4.4Hz, 3mm amplitude; 5 x 1 minute bursts of vibration with 1 minute break in between Position: squat with slight flexion at hips, knees and ankles Control: Burst Transcutaneous electrical stimulation applied to the forearm for 5 x 1 minute bursts; of sufficient intensity to create a muscle contraction and simulate WBV</td>
<td>Outcomes: Ataxia Clinical Rating Scale (ACRS) EDSS Disability Score Posturography sensory organisation test (computer controlled moveable platform evaluating sway when patient exposed to one of 6 conditions Outcomes measured before, 15 minutes, one and two weeks after a single application bout Timed-up-and-go test Functional Reach Adverse events: n=1 increased fatigue; No drop-outs</td>
<td>Randomisation procedure not described in detail ? whether this is truly a double-blind RCT using TENS as a similar/sham treatment ? use of intention to treat. No reporting of any missing data although this is likely Small sample</td>
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**Whole Body Vibration Training**
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<tr>
<td>Ahlborg et al 2006</td>
<td>RCT investigating the effect of WBV compared with resistance training on impairment and functional outcomes in Cerebral Palsy adults</td>
<td>N=7 both groups Male=8</td>
<td>WBV: (NEMES-LSC); 3 x per week for 8 weeks; 6 minute sessions (including rests) at an intensity set by the patient based on their perceived exertion using the Borg Scale; 25-40Hz</td>
<td>Baseline groups comparable</td>
<td>WBV not compared with gold standard treatment for CP but rather with resistance training</td>
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<td>Control group - 4 men - mean age=30 years</td>
<td>Performed in static standing in 50° of hip and knee flexion; patients encouraged not to hold side rails</td>
<td>All participants attended at least 75% of the 24 training sessions</td>
<td>No intention to treat strategy</td>
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<td>Intervention Group-4 men – mean age = 32 years</td>
<td>Treatment preceded by an unspecified 5 minute ‘warm-up’ and followed by ‘stretching’</td>
<td>Adverse events: Stiffness following interventions; n=1 for WBV, n=3 for RT</td>
<td>Timed up and go does not seem the best measure to assess balance</td>
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<td>all except one spastic diplegic</td>
<td>Control:</td>
<td>Measures taken at baseline and at the end of the 8 week training period</td>
<td>Clinical relevance of small median changes in the GMFM need to be confirmed; also of concern is the use of only two components of the GMFM</td>
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<td>Resistance training</td>
<td>Results: No significant differences in muscle strength, 6-min walk or timed-up-and-go (TUG) between the groups at 8 week follow-up; no significant improvements in 6MWT and TUG from baseline to follow-up in either group</td>
<td>Spasticity and gross motor function differences between groups does not appear to have carried over to functional tasks, e.g. to timed-up and go, 6MWT</td>
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<td>3 x weekly for 8 weeks; Warm up and stretch as above; resistance training consisted of leg press 3 sets of 10-15 reps; 2 minutes in between sets; Progressive load of about 70% 1RM</td>
<td>Changes in peak torque from baseline to follow-up in both groups, no difference however between groups</td>
<td>Statistically significant decrease in knee extensor spasticity (p&lt;0.04) in WBV group in the stronger leg from baseline to 8 weeks</td>
<td>GFMF reported as validated in children but no evidence for adults</td>
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</table>
| | | | Standing and walking parameters on Gross Motor Function Measure statistically significantly improved compared to changes from baseline to follow-up (standing; median WBV=79-82%; walking; median WBV=69-72%; p<0.04)), however, the between-group difference was found not to be significant | Small sample | 1-
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<tr>
<td>Haas et al 2006</td>
<td>RCT – Parkinson's patients randomised to WBV followed by rest or rest then WBV</td>
<td>N=68; 53 male Mean age 65 Mean time since diagnosis; 5.9 years Subjects ranged in terms of disability from exhibiting bilateral disease with no balance impairment to being severely disabled but still able to walk and/or stand unassisted (Hoehn and Yahr scale, II-IV)</td>
<td>WBV: Zeptom brand; 5 x 1 minute sessions with variable frequency (6Hz mean frequency); 3mm amplitude Shoes on with knees slightly bent Patients withdrawn from L-Dopa overnight prior to intervention Group A= WBV followed by rest Group B= rest followed by WBV Control: “Rest period” (i.e. control treatment) not described All treatments were completed within a 2 hour period</td>
<td>Groups similar at baseline in terms of age, medication and disease duration Unified Parkinson's disease rating scale (UPDRS) – baseline average score before randomisation =29.9 +/- 11.9 No adverse events identified during study</td>
<td>Baseline comparisons did not extend to gender or UPDRS scores Randomisation process not described Did have consistent blinded assessor A lack of raw data in the results is evident and the relationship between these isolated results presented and the overall UPDRS score is not reported “Rest period” (i.e. control treatment) not described Unknown concurrent treatment Uncertain clinical significance of a the 4-5 point reduction in scores with this outcome measure No discussion of validity 2-</td>
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<tr>
<td>Turbanski et al 2005</td>
<td>RCT</td>
<td>N=52; male=38</td>
<td>WBV: Zeptor 6Hz; 3mm amplitude 5 series x 60 second bouts of WBV (single session)</td>
<td>Outcomes: Postural Sway as calculated by patients' ability to stand still for 32 seconds with arms at side; calculated platform displacements in antero-posterior and medio-lateral directions. Displacements summed for each trial. All patients tested in the on-phase at peak dose in the levodopa cycle. Results: Narrow standing: Improvements between baseline and follow-up sway in both groups in narrow standing (7.1% average reduction; p=0.04 in control, 14.9% reduction in WBV; p=0.00; No statistical difference however between the two groups at follow-up. Tandem standing: Both groups reduced postural sway from baseline to follow-up; WBV group by 24% (p=0.01) however was the only group to reach statistical significance (Control: 11.3%, p=0.16). A between group difference was found at follow-up in favour of the WBV group (p=0.04).</td>
<td>Randomisation not outlined in detail. Unsue if treatment phase required them to stand in narrow and/or tandem standing as for testing. Adverse events not reported. No baseline assessment of important factors to ensure groups were similar; authors have matched subjects but fail to discuss other important factors which may make groups heterogeneous. No mention of ITT or missing data. Comments: Authors discuss these changes in terms of: 1. motor control and proprioception; improved ability to shape muscle responses – either through faster corrective torque; optimised ability in proprioception; altered muscle spindle sensitivity Cortical changes; via neurotransmitter release; 3. Muscle stiffness; WBV reduces rigidity.</td>
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**Whole Body Vibration Training**
## Vascular

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| Lohmann et al 2007 | RCT  
To investigate the effect of short-duration high intensity, isometric weight bearing exercise, vibration exercise and vibration only on skin blood flow | N=45  
18-43 years  
Healthy university student volunteers  
22 males | WBV:  
Powerplate WBV; 5-6mm amplitude, 30Hz  
Randomised to one of three groups:  
Vibration only  
Subjects lay supine on floor with calves resting on vibration plate. 30 Hz, high amplitude oscillations; 3 x 60 second bouts with 10 seconds in between bouts  
Exercise only  
Isometric exercises held for 60 seconds consisted of partial squat, deep calves and calves  
Vibration and exercise  
Exercises as above undertaken on WBV platform at 30Hz, high amplitude oscillations | Outcomes:  
Laser Doppler measured skin blood flow (SBF) over right distal leg musculature  
Measured at baseline, immediately post intervention and 10 minutes post intervention completion  
Results:  
SBF:  
Only statistically significant change seen in vibration only group: following intervention (112.13 to 277.53 post; p=.001, and 215.71; p=0.04; 10 minutes post)  
Repeated measures Anova testing indicated a significance value of p<0.008 between groups at 10 minute follow-up  
Both other treatment arms showed a reduction in SBF immediately and at 10 minutes post intervention | No indication of randomisation method or blinded assessment  
Reasonably small sample  
Side effects not mentioned  
1- |
### Other

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<tr>
<td>Gilsanz et al 2006</td>
<td>Controlled study</td>
<td>N=50</td>
<td>WBV: LA18 BEI brand</td>
<td>Two drop outs due to them both commencing the oral contraceptive pill before the trial commenced (n=24 per group)</td>
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<td>Age range 15-20 years</td>
<td>30Hz, 3g acceleration</td>
<td>Baseline measurements taking at enrolment, 6 months and 12 months</td>
<td>Groups possibly heterogeneous at baseline due to recruitment methods. This may confound outcomes</td>
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<td>Healthy 'white' female subjects all having had a fracture in the past</td>
<td>Unknown amplitude</td>
<td>Recorded diet and physical activity over 1 year</td>
<td>The authors postulate the improvements seen may be due to &quot;fluid movement through the canalicular system of osteocytes and promoted by the interdependence of fluid pressure and frequency”</td>
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<td>Assessed 150 young females and those 50 females that were assessed with the lowest bone mineral density</td>
<td>Installed into the homes of all intervention participants. Machines recorded compliance with the 10 minute daily vibration required – one year duration WBV + calcium supplement</td>
<td>Physical activity not statistically different between the two groups at the end of the study</td>
<td>ITT and per protocol results</td>
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<td>Control: calcium supplement only</td>
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<td>Outcomes:</td>
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<td>Bone mineral density and muscle cross-sectional area in various spinal and lower limb muscles as measured by computed tomography and DXA scanning</td>
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<td>Results:</td>
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<td>Statistically significant increase in cross sectional femur area in control from baseline (p=0.05); however, all parameters from baseline increased in WBV group – axial and appendicular in terms of cortical bone, cross-sectional area and muscle area (p&lt;0.001=0.003)</td>
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<td>Between group differences at follow-up statistically significant in terms of absolute (p=0.002-0.05) and percentage change (p=0.002-0.04) in terms of: (p values for absolute changes below)</td>
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<td>Paraspinal musculature (p=0.007)</td>
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<td>Psoas muscle (p=0.002)</td>
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<td>Erector spiniae muscle (p=0.05) and Femoral cortical bone area (p=0.08)</td>
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<td>bone mineral density of the spine; significance values were almost identical for the same parameters</td>
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<td>The only appendicular parameter to reach statistical significance was the femur cortical bone area (p=0.04)</td>
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<td>Per protocol analysis</td>
<td>Compliance varied 1-100%</td>
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<td>Mean compliance 4.3% per day</td>
<td>A dose effect was seen regarding the erector spinae; with a significant increase seen at 20% compliance, 2 minutes/day</td>
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<td>No additional benefit was gained for those using the apparatus for &gt; 2mins/day</td>
<td>No significant difference was seen between DXA values (spine bone mineral content and density) between experimental and control groups although both groups showed significant increases in all parameters over time</td>
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<td>Van den Tillaar et al 2006</td>
<td>RCT</td>
<td>N=19 12 female  Mean age 21.5 years  Exercise science graduates  Graduates randomised after pre-test  No difference between hamstring length between genders at baseline (p=0.28)</td>
<td>WBV: Nemes Bosco WBV 28 Hz 10mm amplitude 30 second bout  Programme 4 weeks; 3x sessions/week Position in 90° knee flexion, on balls of feet, squat  Followed by three stretches each leg of 30 second hold-relax on hamstrings in sitting  Control:  Stretching routine only N=9, 6 women  Tested at baseline before randomisation and after each week of intervention</td>
<td>Outcomes: Hamstring flexibility (in degrees) after warm-up (5 minutes) 1 drop out due to injury, (unrelated to study)  Results: One drop out due to injury unrelated to intervention  Hamstring length similar at baseline between control and WBV groups (p=0.078)  Hamstring length averaged across the two legs as no difference statistically between right and left legs (p=0.37)  Both groups showed a significant increase in hamstring length at the end of training (p=0.024)  WBV increase occurred after week 1 and all weeks excepting weeks 3-4  Control group showed increase only after week 2  Significant final range of motion was better in the WBV group (26.8° vs 12.4° (p=0.002))  No correlation between baseline flexibility and final range (p=0.20)</td>
<td>Small sample  Blinded assessors (2)  Randomisation method poorly described  No mention of intention to treat  Possible reasons for gains put forward by authors: 1. increased blood flow resulting in increased elasticity of muscle and connective tissue 2. Enhanced stretch-reflex loop in quads 3. Pain inhibition from vibration increasing tolerance to muscle stretch 1+</td>
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<td>Fontana et al 2005</td>
<td>Single-blind RCT</td>
<td>N=25 healthy adult students with average activity levels</td>
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<td>History of back pain or neurological disorders were included in the exclusion criteria</td>
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<td>WBV group=14; 4 males</td>
<td>WBV:</td>
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<td>Control group=11; 4 males</td>
<td>Galileo 2000</td>
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<td>5 minutes of WBV, 18 Hz. Unspecified amplitude in the ‘isometric closed-chain position’ with knees slightly flexed, in slightly hyperlordotic position</td>
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<td><strong>Control:</strong></td>
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<td>Stood on platform for 5 minutes in above position</td>
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<td>Groups stood on markers 25 cm apart, maintaining an upright position whilst the pelvis was rotated. Finally positioned in the anterior or posterior pelvic tilt zone.</td>
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<td>Subjects underwent the control or intervention and were then asked to reproduce the starting position</td>
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<td><strong>Outcomes:</strong></td>
<td>Repositioning sense as measured by Fastrak 3D equipment that assessed lumbosacral positioning</td>
<td>Pilot studyClinical significance of repositioning sense unknownAuthors do not offer reasons why the WBV group improvedSmall sampleMay have implications for training position sense with injured clientsNo mention of side effects</td>
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<td><strong>Results:</strong></td>
<td>No reporting of adverse events</td>
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<td>Significant increase in lumbosacral positioning ability in the WBV group (p=0.008)(39% - .78 degrees).</td>
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<td>Control group indicated a reduction in repositioning accuracy by 42% (.55 degrees).</td>
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<td>Ward et al</td>
<td>Pilot RCT to determine if low level mechanical stimuli i.e. WBV has any impact on tibial and spinal bone mineral density in ambulant disabled children</td>
<td>Inclusion criteria: Children had to stand independently but have limited mobility Mean age of active group=6.9 years vs 11.2 years Mean overall age=9.1 years (range 4-19) 14 males, 6 females</td>
<td>N=20 Subjects were matched according to their spinal total bone mineral density scores (TBMD) (spine volumetric trabecular BMD) Each child in the pair was then randomly allocated to treatment or placebo 90Hz, 0.3g Placebo devices emitted no vibration but an audible tone as did the WBV devices WBV 10 minutes daily, 5 days/week for 6 months at home or school Automatic recording of compliance with regime</td>
<td>Outcomes: 1. Total bone mineral density of spine and tibia measured by CT scan: L1-3 or L2-3 BMD levels Proximal segment of non-dominant proximal tibia in all children Non-dominant was defined as the affected side in children with hemiplegia Diaphyseal cross sectional bone area, periosteal bone circumference (vCBMD, cortical thickness and muscle area</td>
<td>Blinded CT scan measurement ITT analysis used Heterogeneity with age and weight of active and placebo may have been significant – no statistics provided for baseline data This may be responsible according to the authors for the lack of diaphyseal change seen in the subjects which may have resulted in different sites of CT scan measurement Relatively small numbers Useful pilot study with appropriate reporting Authors suggest that lack of change in spinal BMD may be due to the dampening down effects of the body or a site-specific sensitivity to mechanical stimuli throughout body regions 1+</td>
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| Rittweger et al 2001 | Controlled study  
Set in the University of Berlin, Germany | 12 young healthy subjects  
(8 female and 4 male) were recruited from the University Campus  
Average Age=25.2 yrs  
Average height=172.1cm  
Average body mass=66kg | The following was performed with  
vibration and without  
vibration on a Galileo  
2000  
Standing, squatting  
and squatting with  
load  
26 Hz; 6mm  
amplitude  
Squatting in cycles of  
6s to 90° knee flexion  
Squatting with a 40%  
load of the subjects  
body weight  
The exercise regime  
lasted for 3 minutes  
per exercise  
Washout period of 10-15 minutes | Outcomes:  
“RPE” = (Perceived Exertion)  
Specific O₂ consumption (V₀₂) | Conclusion:  
The increased metabolic power in association with vibration is due to muscular activity and not passive vibration  
Unknown if order of interventions was randomised as not stated.  
Small sample size  
Side effects described 2- |
| | | | Results:  
Specific V₀₂ increased with vibration by 4.5.min⁻¹kg⁻¹ compared to non-vibration  
Squatting and additional load also increased V₀₂ by approximately the same amount  
e.g. squat with load V₀₂ with vibration=17.1,  
without vibration 12.1 mean average  
RPE values were greater in the vibration than in the non-vibration conditions for all three exercises; e.g. Squat with load exercise RPE with vibration=16.8, without vibration 14.4 mean average  
Metabolic power was more controlled by vibration than by voluntary performed tasks such as squatting  
Energy requirements of exercises with WBV considered to be the same as expended with “moderate walking” | |
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<tbody>
<tr>
<td>Rittweger et al 2000</td>
<td>Case series</td>
<td>37 young participants</td>
<td>Not specified whether the Galileo 900 or Galileo 2000 was used</td>
<td>3 drop-outs</td>
<td>Conclusions: Exhaustive whole body VE elicits a mild cardiovascular exertion and that neural as well as muscular mechanisms of fatigue may play a role</td>
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<td>Set in a Research Institute in Germany</td>
<td>21 males</td>
<td>Vibration exercise (VE) was performed in 2 sessions with a 26Hz vibration on a ground plate in combination with squatting and an additional load</td>
<td>Heart rate, oxygen uptake, knee extension, jump height and blood pressure were all measured</td>
<td>No specific reasons why 3 subjects dropped out</td>
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<td>Mean Age= 23.5yrs</td>
<td>First Visit (BIC) Cycle ergometry from 3 min to exhaustion</td>
<td>Results:</td>
<td>One prominent side effect was an itching erythema in about half of the individuals</td>
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<td>Female subjects: average height=169.9cm; weight=60.6kg</td>
<td>2nd and 3rd visit (VIB1 and VIB2) Exercise until exhaustion on a power plate (26Hz)</td>
<td>Heart rate after VE increased to 128min⁻¹</td>
<td>Small number of participants 3</td>
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<td>Male subjects: average height= 181.4; weight=75.2kg</td>
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<td>Blood pressure increased to 132/52 mmHg</td>
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<td>Oxygen uptake in VE was 48.8% of VO2 max in bicycle ergometry</td>
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<td>After VE, voluntary force in knee extension was reduced by 9.1%, and the decrease of EMG median frequency during maximal voluntary contraction was attenuated</td>
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<td>Reproducibility in the two VE sessions was good. For heart rate, oxygen uptake and reduction in jump height, correlation coefficients of values from session 1 and from session 2 were between 0.67 and 0.7</td>
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| Saggini et al 2006 | Case series          | N=10 6 females                                    | WBV for 6 months                                                              | Pain threshold to pressure of quadriceps, trapezius and deltoid muscles bilaterally using an algometer (standard device) | No mention re blinded assessment  
Details of strength measurement not reported and measured unknown muscle groups – although likely quadriceps  
Unknown frequency of WBV per week for the six months of treatment  
Compliance and supervision with regime not reported  
Small sample  
Limited raw data to support and verify results’ statements  
May have been useful to have explored in more detail the ‘worsening of symptoms’ in the first week. i.e. where and what 3 |
|               | To investigate the effects of a 6-month WBV exercise programme on Chronic Fatigue patients with respect to subjective wellness and muscle strength | All diagnosed with Chronic Fatigue using specified criteria                    | Galileo 2000                                                                     | Also questioned on subjective improvement regarding fatigue, muscle pain, mood, quality of life and work (visual analog scores) |                                                                                             |
|               |                      | No concurrent treatment                            | 18Hz, 10mm amplitude for 2 months increasing to 22 Hz for the remaining 4 months of the programme Total of 8 minutes to begin with every 48 hours | Peak torque (Cibex 6000 dynamometer) (?muscle group (s)) |                                                                                             |
|               |                      | Mean age=34.5 years                                | Commenced with 2 minutes each of 4 different exercise positions (upright, ½ squat, and single leg squat, left and right) | Results:  
All patients reported worsening of symptoms in week 1 which resolved from week 2 on  
Decrease in body mass index (p<0.05) over the 6 months  
Pain thresholds  
And improved* mood (mean 8.5 to 3), quality of life and work (mean 8.25-3.5) (all p<0.01) |                                                                                             |
|               |                      | Mean duration of symptoms 43.7 months              | Duration of exercise increased 20 seconds for each exercise every month until 4 minutes each position reached WBV followed by two stretches (15 s each) | Significantly higher pain thresholds to stimulation for quadriceps only (p<0.01) for left side, p=0.05 for right). No significant changes seen for the other regions  
Peak torque improved by 18% (p<0.006) |                                                                                             |

*results graphed only and figures reported in this table approximate
<table>
<thead>
<tr>
<th>Study</th>
<th>Methods and Settings</th>
<th>Participants</th>
<th>Intervention</th>
<th>Outcomes and Results</th>
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<tbody>
<tr>
<td>Priplata et al 2003</td>
<td>Case series</td>
<td>27 participants. 15 young volunteers (10 men and 5 women) and 12 elderly participants (8 women and 4 men)</td>
<td>Vibration: Participants were asked to stand quietly on vibrating gel-based insoles (position fixed with heels separated by 8cm) with their eyes closed and hands at their sides</td>
<td>Outcome Measures: Eight sway variables were used to assess balance including: Mean stabilogram radius (mm) the area swept by the stabilogram (mm²), maximum sway radius (mm) and the range of the anteroposterior and the mediolateral excursions (mm)</td>
<td>Conclusion: Noise based devices such as randomly vibrating insoles could ameliorate age-related impairments in balance control</td>
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<td>Preliminary Study</td>
<td>Mean age of young participants was 23 years (SD=2) Mean age of elderly volunteers was 73 years (SD=3)</td>
<td></td>
<td>Results: Application of noise resulted in the reduction in seven of eight sway variables in young participants but in all sway variables for older participants Elderly patients showed greater improvement than young people in two variables, mediolateral range (p=0.008) and critical mean square displacement (p=0.012)</td>
<td>Comments: Does not mention the length of time each participant was subjected to the intervention</td>
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<tr>
<td></td>
<td>Set in Boston University, Boston, USA</td>
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<td>3</td>
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Whole Body Vibration Training