Rejuvenation Research

TITLE: Effects of 24 weeks of Whole Body Vibration vs. Multi-component training on Muscle Strength and Body Composition in Postmenopausal Women: a randomized controlled trial.

RUNNING TITLE: Vibration vs. Multi-component training in women

AUTHOR FULL NAME: Elena Marín-Cascales[1], Pedro E. Alcaraz[1, 2], Jacobo A. Rubio-Arias[1, 2].

INSTITUTIONAL AFFILIATIONS:

[1] UCAM Research Center for High Performance Sport

[2] Department of Physical Activity and Sport Sciences, Catholic University of Murcia, Murcia, Spain.

ADDRESS OF CORRESPONDING AUTHOR:

Elena Marín-Cascales
Research Center for High Performance Sport
Catholic University of Murcia. Campus de los Jerónimos, s/n
30107, Guadalupe, Murcia, Spain.
TELEPHONE NUMBER: + 34 968 278566.
E-MAIL: emarin@ucam.edu

For this work we have received funding of the following organization: Catholic University of Murcia, No. pmafi/05/12.

Abstract

Background: The purposes of this study were to analyze the impact of 24 weeks of vibratory and multi-component training and to determine what type of training creates greater adaptations on body composition and isokinetic strength of the knee and ankle joints in postmenopausal women. **Methods:** Thirty-eight women (60.0 ± 6.3 years) were randomly assigned to whole body vibration group (WBVG), multi-component training group (MTG), or a control group (CG). **Results:** A significant decrease in total fat mass was observed in experimental groups. There were no changes in total lean mass and total BMD in both groups. WBVG and MTG showed significant increases in isokinetic strength for knee extensors at $60^{\circ}\cdot s^{-1}$ and at $270^{\circ}\cdot s^{-1}$. Regarding the ankle joint, there were significant increments in strength for plantar flexion at $60^{\circ}\cdot s^{-1}$ in WBVG and at $120^{\circ}\cdot s^{-1}$ in the two trainings groups. MTG showed a significant increase in strength for dorsiflexion at $60^{\circ}\cdot s^{-1}$. With respect to eversion and inversion, WBVG and MTG improved strength at $60^{\circ}\cdot s^{-1}$. Also, the WBVG showed increased strength in the ankle evertors at $120^{\circ}\cdot s^{-1}$ and both groups showed increased strength in the ankle invertors at $120^{\circ}\cdot s^{-1}$. **Conclusions:** 24 weeks of whole body vibration or multi-component trainings result in positive modifications in total fat mass. These trainings are effective in improving knee-extension and stabilizer muscles of the ankle joint strength.

Keywords: aging, isokinetic strength, menopause, DEXA, BMD.

1. Introduction

Hormonal deficits during postmenopause have a profound effect on health status in women, particularly since women spend around 30 years in postmenopause. The relationship between the loss in muscle mass and strength during the menopausal transition has been studied by different authors. Rolland et al. [1] showed that women experience a 0.6% decrease in muscle mass per year after menopause. Nevertheless, the decrements in muscle mass depend not only on age and menopause status [2], but also other factors that influence this loss, such as low physical activity [3], inflammatory effects [4] and lower leg strength [5].

After menopause, the cycle of bone formation and resorption undergoes an ‘uncoupling’ process, which leads to an increase in osteoclastic resorption activity and, in turn, a net loss of bone mass. In addition, there is a decrease in calcium absorption during the first phase of menopause [6]. During menopausal period, bone mineral density (BMD) reduces by 10% [7], which suggests that menopause has an effect on bone tissue and may explain why there is a major incidence of fractures in women. Thus, muscle and bone loss are two main factors that occur after menopause.

To attenuate the aging effects, especially in postmenopausal women, various modes of physical activity or training programmes are currently being used. Different studies have shown that multi-component training (MT), the combination of different exercise modalities, is a suitable method to prevent loss of BMD and to improve muscle strength in older women [8,9]. It has been demonstrated that mechanical stress can improve bone mass in premenopausal women [10], but not in postmenopausal women [11]. Nevertheless, there remains some controversy regarding the osteogenic potential to improve BMD using MT. In addition, there are many different protocols of MT; thus, further studies are necessary to elucidate the potential benefits this modality of exercise has in postmenopausal women.

On the other hand, Whole-Body vibration training (WBVT) on a platform has been suggested to be an appropriate intervention to improve muscle strength and body composition in order to counteract the loss of bone mass and muscle [9,12]. The mechanical stimulus generated by this training method is transmitted to the body where, in turn, stimulates the sensory receptors (muscle spindles). The activation of the sensory receptors results in the activation of the α-motoneurons to contract the muscle, and it has been suggested that this mechanism via vibration is comparable to that of the tonic vibration reflex [13,14]. Different studies have determined the impact of WBVT on BMD and muscle strength [15-17]. Tsuji et al. [18] studied the effect of 8 weeks of WBVT on lower-limb muscular strength in women (aged = 50-73 years) and showed significant improvements when compared with baseline parameters [18]. Marín- Cascales et al. [9] examined the effects of 12 weeks of vibratory exercise training in a group of 14 postmenopausal women, who performed static and dynamic exercises involving the muscles of the lower extremities. The study showed increases in isokinetic strength in the knee extensors and stabilizer muscles of the ankle joint, whereas there were no changes observed in bone density [9]. Lai et al. [15] investigated a longer intervention (6 months) of high frequency and magnitude WBV in a natural full-standing posture for 5 minutes, three times per week. The results showed increments in BMD of the lumbar spine in a group of 28 postmenopausal women after 6 months of vibration therapy [15]. Moreover, taking into account that approximately 3-4 months is needed to complete the bone remodeling cycle (bone resorption, formation and mineralization) [19], exercise training programs should last for at least 6-8 months to ensure that structural property changes are achieved. Although BMD improvements have been shown, the most effective WBVT program has yet to be determined in postmenopausal women [9].

Although previous studies have examined the effects of WBVT and MT on strength and body composition in postmenopausal women, the effectiveness of these trainings programs remain unclear, and it is not known whether WBVT has a greater effect on these variables than MT. Therefore, the aims of the current study were to analyze the impact of 24 weeks of vibratory and multi-component training, and to determine what type of training creates greater adaptations on body composition and isokinetic strength of the knee extensors and the stabilizer muscles of the ankle joint in postmenopausal women.

2. Methods

2.1. Experimental design

A quasi-experimental of 24 weeks, intra and inter-subjects design with pre, and post-test, with control group was conducted. Participants were matched by BMD and were randomly allocated to 3 groups: Whole Body Vibration Group (WBVG) (n=25), Multi-component Training Group (MTG) (n=25) and Control Group (CG) (n=15). Software: Research Randomizer, http://www. randomizer.org/form.htm was used as a method to randomize subjects.

The test session began with body composition measurements. After the first tests, isokinetic concentric strength of the knee extensors and ankle extensors, flexors, invertors and evertors were measured. All isokinetic tests were administered by the same investigator. All participants were instructed to maintain their normal daily routines and eating habits. Participants in CG did not train and performed only pre- and post-test at 24 weeks.

2.2. Subjects

Sixty-five postmenopausal women were recruited by non-probability convenience sampling. Participants were excluded if they: had a high level of osteoporosis (BMD<70g/cm^2), were being treated for a disease that can affect bone structure or neuromuscular system, had orthopedic prosthetic implants in the lower limbs and / or spine, had herniated discs, had ocular diseases that affected the retina, had severe cardiovascular diseases, had epilepsy, had a pacemaker or osteosynthesis implant, had practiced some type of physical activity regularly, and had a lower than 90% attendance to the stipulated program. Before the onset of the study all subjects signed an informed consent document about training and assessments would be developed. The design was approved by the Human Subjects Ethics Committee of the Local University.

2.3. Body composition

Subjects were placed in the supine position on the table and proceeded to record body composition and bone mass density measurements by dual-energy X-ray absorpiometry (DEXA) (XR-46, Norland Corp., Fort Atkinson, WI, USA). Total bone, fat and lean masses were assessed by the whole body scan. Areal bone mineral density (BMD = g · cm^{-2}) was calculated using the formula BMD = BMC x area^{-1}.

2.4. Isokinetic strength measurements

For isokinetic strength measurement a Biodex System 3 Pro isokinetic dynamometer (Biodex Medical System, NY, USA) was used. Concentric isokinetic strength was evaluated in the right knee and ankle joints.

A specific warm-up was performed prior to tests. Each subject performed a familiarization at the test velocity to become accustomed the movement, before commencing the test. Participants were instructed to generate maximum force as fast and as hard as possible.

For isokinetic strength measurement in knee extension the joint range was 90º, where 0º was up to the full extension. Participants sat on the seat and were held in with straps around distal trunk and thigh, so as to avoid the movement of the body. The check consisted of one set of five maximal concentric knee flexion and extension repetitions at $60º·s^{-1}$ and $270º·s^{-1}$.

In addition, isokinetic strength in dorsal and plantar flexion, and eversion and inversion was measured. For this, subjects remained seated at 90º for hip and knee joints. The thigh and foot were secured and supported so that the ankle placed at 90º with regard to the leg (tibia perpendicular to the sole of the foot). The test consisted of one set of five maximal concentric ankle plantar/dorsal flexion and eversion/inversion repetitions at $60º·s^{-1}$ and $120º·s^{-1}$.

In between trials, a 2-minutes rest period was imposed. The peak concentric torque obtained for each test. Isokinetic strength was normalized relative to body mass ($N \cdot m \cdot kg^{-1}$) (in Newton-meters per kilogram).

2.5. *Training*

The total duration of the intervention phase was 24 weeks. The experimental groups were exposed to a training stimulus with a frequency of 3 sessions per week and a total volume of 72 sessions. Rest period between each training day was at least 24 hours and a maximum of 72 hours. Before training sessions, participants performed a specific warm-up consisting in 8 min on a cycle ergometer at moderate intensity followed by active stretching, and joint mobility of the lower limbs. The characteristics and the progression of training programmes are presented in Table 1.

Table 1 near here

2.5.1. *Whole Body Vibration (WBV) training*

The WBVG exercised on a sinusoidal vertical vibration platform (Power Plate Next Generation; Power Plate North America, Northbrook, IL, USA). During sessions, subjects stood on the platform holding a half-squat (knee and hip angle 120º). The arms remained crossed and parallel to the floor with a shoulder flexion of 90º. Then, participants performed ankle plantar and dorsal flexion with the following work sequence (establishing a rhythm of 100 b.p.m.: 1 b.p.m for the concentric phase; and 5 b.p.m. for the eccentric phase). The amplitude (4 mm), working time (60 s) and recovery time (60 s) parameters remained constant for the 24 weeks of training. The training intensity was increased by increasing the frequency (35 - 40Hz). The familiarization lasted the first two weeks, being the working time of 45 s. The training volume was increased by increasing the number of sets per session (5 sets at the beginning and increasing by 1 or 2 sets per month to 11 sets the last weeks) (Table 1).

2.5.2. *Multi-component training*

Multi-component training consisted of a series of drop jumps and aerobic activity for 24 weeks. During the first month, small reactive vertical jumps (without knee and ankle flexion) were executed. Later, subjects performed drop jumps progressively starting at a height of 5 cm and finishing at 25 cm at the end of the programme (increases of 5 cm each month). The sets increased from 4x10 drop jumps to 6x10 each week. The drop jumps were the same each month but the load progression (imposed by height) was undulatory (the load increased during 3 weeks and decreased during one week).

Later, the aerobic exercise occurred. The load increased progressively over the 24 weeks. Subjects walked at an intensity range between 50-75% of reserve heart rate (Maximum Heart Rate - Resting Heart Rate) and the volume ranged between 30-60 min (Table 1). The gait speed used to establish the exercise intensity was determined prior to initial testing using a computer/heart rate monitor.

2.6. Statistical analyses

Statistical analysis of data was performed with the Statistical Package for the Social Sciences (SPSS, version 19, SPSS Inc, Chicago, Illinois) in the Windows environment. A descriptive analysis was performed to detail and analyze the characteristics of the sample participating in the study. Chi-square statistic was performed to analyze the homogeneity of the sample (number of participants).

For the inferential analysis, a Kolmogorov-Smirnov test was performed to establish the normality of sampling distribution and analysis of runs to observe the independence of observations. In order to determine the effect of independent variables on the dependent variable repeated measures ANOVA (General Linear Model) was performed for the entire sample. If there was a significant effect of time ($p \leq 0.05$), then an ANOVA test was performed to determine where the significant differences occurred for each group. If there was a significant interaction effect (time x group) ($p \leq 0.05$), a Tukey post hoc test was performed to determine were the significant differences occurred between groups.

3. Results

At the end of the protocol, the number of subjects was thirty-eight. Therefore, our data are based on the following sample: WBVG (n = 15), MTG (n = 13) and CG (n = 10). The distribution of the sample was homogeneous in terms of number of participants. The characteristics of the final subjects at baseline were: age (WBVG: 59.6 ± 5.9; MTG: 58.4 ± 7.4; CG: 62.4 ± 5.1 years), height (WBVG: 154.1 ± 4.3; MTG: 155.8 ± 7.0; CG: 155.4 ± 3.6 cm) and body mass (WBVG: 77.1 ± 13.5; MTG: 71.5 ± 9.9; CG: 72.6 ± 10.0). Twenty-seven subjects dropped out during the training period for personal reasons or health problems (Figure 1). None of the drop-outs left the program as a result of injuries or adverse responses to the intervention.

Figure 1 near here

3.1. Body composition

There was a significant decrease in body fat (%) in WBVG (*p* = 0.044), in total fat mass (Kg) in MTG (*p* = 0.009) and an increase in total fat mass in CG (*p* = 0.041) between pre- to post-test. There were no differences in BMI, total lean mass and total BMD in pre- and post-test in all groups (Table 2). In addition, there were significant differences in post-total fat mass between WBVG and CG (*p* = 0.028), and between MTG and CG (*p* = 0.001).

Table 2 near here

3.2. Isokinetic strength

KNEE

In the training groups was found a significant increase in the peak torque in knee extension at 60º·s^{-1} and at 270º·s^{-1} between pre- and post-test. Also, there were significant differences between MTG and CG in knee extension at 270º·s^{-1}.

ANKLE

There were significant improvements for plantar flexion at 60º·s^{-1} in WBVG and at 120º·s^{-1} in the two trainings groups between pre- and post-test. MTG showed a significant increase for dorsiflexion at 60º·s^{-1}. With respect to eversion and inversion, WBVG and MTG improved isokinetic strength at 60º·s^{-1}. Only WBVG presented changes in eversion at 120º·s^{-1}, and there were a significant increase in WBVG and MTG in inversion at 120º·s^{-1}. Figure 2 presents relative gains in the peak torque between pre and post-test for each group.

Figure 2 near here

There were no significant differences between WBVG and MTG in knee and ankle strength tests. No significant differences were found in CG between pre and post-test in any of the strength measurements. Table 3 presents the concentric isokinetic knee extensor strength, as well as the gains in peak torque for plantar and dorsal flexion and for eversion and inversion between pre- and post-test.

Table 3 near here

4. Discussion

The aims of the present study were to evaluate the impact of two training protocols, WBVT and MT, during 24 weeks on the changes in body composition and isokinetic strength of the knee extensors and the stabilizer muscles of the ankle joint, and to determine which training protocol produces greater adaptations of these variables in postmenopausal women.

With respect to total BMD, there were no significant changes in WBVG after treatment. No differences were found between groups. In order to determine the effect of vibration training, Leung et al. [20] conducted a study to test the long-term effects of low-magnitude high-frequency vibration on fall and fractures rates, muscle performance and bone quality in postmenopausal females (over 60 years). Women were randomly assigned to a control group or to the WBVT group (five times per week at 35Hz) for 18 months. There were no changes in total hip and lumbar spine BMD in the vibration group, which provides is in accordance with our findings. However, Verschueren et al. [16] showed a significant increase in BMD of the hip and maintained constant of lumbar spine BMD using the similar frequency and amplitude as the present study. Thus, there is a need to examine the optimum vibration load in this population to improve BMD, as well as to perform specific measurements of BMD.

Interestingly, MTG also showed no significant differences in total BMD. Multi-component training can be a strategic option to help prevent osteoporosis by increasing bone mass. Movaseghi et al. [21] analyzed 3 years of a moderate multi-component exercise training in a group of postmenopausal women (57 years old) who performed different exercise modalities that included static and dynamic stretching, aerobic exercises (using fitness ball, steps, dumbbells, bar and elastic resistant bands for the lower and upper extremities), exercises with machines (such as tread-mill walking and slow running without any incline), recumbent cycling (with no or little resistance) and elliptical training. They reported an improvement in BMD and bone mineral content (BMC) of the femoral neck region and lumbar spine. In contrast, Karinkanta et al. [22] showed that combined resistance and balancejumping training did not increase femoral neck bone mass after 12 months in elderly women. Similarly, Stewart et al. [23] demonstrated that a mixed protocol including resistance and aerobic exercises had no effect on total BMD in men but reduced total BMD in women. As there are a variety of different training protocols used in WBVT and MT, it is difficult to compare between studies and determine which protocol produces the best adaptations.

There was a significant decrease in percent body fat mass in WBVG (-1.1%), decrease in total fat mass (kg) in MTG and an increase in total fat mass (kg) in CG following 24 weeks of training. There were significant differences between experimental groups compared to CG in percent body fat mass. These results agree with a previous work carried out by Fjeldstad et al. [24], who concluded that 8 months of WBVT (frequency 15–40 Hz and amplitude 3 mm) reduced total fat mass in postmenopausal women. Following these results, Garatachea et al. [25] found that WBVT increased energy consumption in young men and suggested that vibration training may induce changes in the metabolic rate in the legs, which may explain the improvements in oxygen consumption in the lower extremities [25]. A recent review presented a plausible explanation for this phenomenon in that the increase in energy expenditure may be associated with the inhibition of adipogenesis and increase in muscle mass [26]. As intramuscular fat increases following menopause [27], it would be interesting to examine the effect of WBVT has on intramuscular fat mass.

After 24 weeks of the training intervention, there were no significant changes in total lean mass in both training groups. These results are similar to those found by Beck et al. [12] who evaluated the effect of 8 months of WBVT on lean mass in postmenopausal women. On the contrary, Kukuljan et al. [28] assessed the body composition after 12 month of multi-component training programme of high intensity progressive resistance with weight-bearing impact exercise in older adults (50-79 years) and obtained significant improvements in lean mass. Even though some investigations indicate the existence of estrogen receptors on muscle tissue that might contribute to the synthesis of muscle mass [29], its loss is associated with the attenuation of anabolic hormones such as testosterone or growth hormone blood concentrations, especially in elderly women [30]. In the present study, the absence of improvement in lean mass may be explained by lower levels of these hormones in postmenopausal women. In addition, it is possible that the subjects in this study presented a higher anabolic resistance [31]. This may lead to an inability of the muscle to maintain adequate protein synthesis and an imbalance between muscle protein anabolism and break-down [32]. This phenomenon has been shown to increase with aging [33], thus can explain the lack of muscle mass gain. It is well-known that there is a positive correlation between muscle mass and bone mass (an improvement in muscle mass produces changes in bone tissue) [34]. Therefore, the absence of BMD increments in the current study could also be explained by the lack of significant differences on muscle mass gain, possibly due to an insufficient training stimulus (intensity) in WBVT and MT.

On the other hand, WBVG showed significant improvements in isokinetic strength of the knee extensors muscles at $60º·s^{-1}$ and $270º·s^{-1}$ after 24 weeks. In addition, WBVG showed significant increases for ankle plantar flexion and inversion at both speeds. Ankle eversion improved in WBVG at $60º·s^{-1}$ and $120º·s^{-1}$ between pre-test and post-test. These findings are in accordance with those of several researchers, which confirmed that WBVT increases the dynamic strength of the lower extremity muscles [17]. Ebid et al. [35] investigated the effects of 8 weeks of lower limb WBVT on leg muscle strength in adults. After vibratory training, there was a significant improvement in knee extensor and ankle plantar flexor strength compared with the control group. Interestingly, our results reveal an improvement in dorsiflexion and inversion in WBVG after 24 weeks of training. To our knowledge, this study is the first to examine gains in ankle dorsiflexors using WBVT. In healthy, physically active participants, Martínez et al. [36] found no significant changes on the reflex response mechanism following 6 weeks of vibration training in any of the ankle muscles involved (peroneus longus, peroneus brevis and anterior tibialis). Also, Melnyk et al. [37] observed no changes in the reflex activity of the long peroneal and tibialis anterior following 4 weeks of WBVT in 26 young adults (age: 25.6 ± 2.5 years). However, in a previous study, we observed increases in strength during eversion and inversion in postmenopausal women [9]. Previous research has reported that strength gains following WBVT are the result of the tonic vibration reflex, provoking length changes in the muscle that stimulate the muscle spindles [38]. The literature shows that the vibratory stimulus generates greater training adaptations in muscle groups that are nearer to the vibration platform [39]. Moreover, several authors have suggested that WBVT activates the fast twitch fibers, which are responsible for explosive actions and produce higher values of strength [17]. This would explain the increases in strength observed in the present study where the force was generated at higher speeds (120º·s^{-1} and 270º·s^{-1}).

In relation to strength gains, MTG showed significant increases in knee extensors at 60º·s^{-1} and 270º·s^{-1}. There were also improvements in strength during plantar flexion and inversion in MTG at both speeds. Ankle dorsiflexion and eversion increased at 60º·s^{-1} in MTG. Kang et al. [40] analyzed the impact of a 4-week protocol that combined balance, strengthening and stretching exercises in elderly women. The participants in the experimental group showed a significant increase in strength of the upper and lower body. Only one study has investigated isokinetic strength gains of the ankle musculature using multi-component exercise programmes, and observed improvements in isokinetic strength of the ankle evertors and invertors following a 12 week protocol consisting of aerobic exercise and drop jumps in postmenopausal women [9]. The present study showed increases in isokinetic strength in all the major ankle muscles responsible for ankle dorsiflexion/plantarflexion and eversion/inversion. The increase in dorsiflexor strength may be explained by its role in absorbing the impact produced by drop jumps. The improvement in plantar flexion strength may be due to the action of the ankle joint when walking during the intervention.

In conclusion, 24 weeks of WBVT or MT are feasible and result in decrease in total fat mass in healthy postmenopausal women. This decrement attenuates the risk of obesity in this population. Additionally, significant increases in muscle strength of the knee extensors and stabilizer muscles of the ankle joint may reduce the overall risk of falls and fractures in older women. As the changes were similar between the two experimental groups, we cannot conclude that vibration training is better than a multi-component protocol. Further investigations are needed to confirm these short-term findings and to explore the most favorable load and protocol for treating the symptoms of postmenopause.

The main limitations of the current research were: 1) the high experimental drop-out over the course of the 24-week study, thereby reducing the sample size, 2) a lack of specific measurements of BMD (lumbar spine and femoral neck) and 3) assessments that have transfer with activities of daily life.

Acknowledgments

We gratefully acknowledge the help of Salvador Romero for conducting the DEXA measurements.

References

1. Rolland YM, Perry HM, 3rd, Patrick P, Banks WA, Morley JE. Loss of appendicular muscle mass and loss of muscle strength in young postmenopausal women. J Gerontol A Biol Sci Med Sci. Mar 2007;62(3):330-335.
2. Tanko LB, Movsesyan L, Mouritzen U, Christiansen C, Svendsen OL. Appendicular lean tissue mass and the prevalence of sarcopenia among healthy women. Metabolism. Jan 2002;51(1):69-74.
3. Hansen RD, Allen BJ. Habitual physical activity, anabolic hormones, and potassium content of fat-free mass in postmenopausal women. Am J Clin Nutr. Feb 2002;75(2):314-320.
4. Schaap LA, Pluijm SM, Deeg DJ, Visser M. Inflammatory markers and loss of muscle mass (sarcopenia) and strength. Am J Med. Jun 2006;119(6):526 e529-517.
5. Kenny AM, Dawson L, Kleppinger A, Iannuzzi-Sucich M, Judge JO. Prevalence of sarcopenia and predictors of skeletal muscle mass in nonobese women who are long-term users of estrogen-replacement therapy. J Gerontol A Biol Sci Med Sci. May 2003;58(5):M436-440.
6. Bullamore JR, Wilkinson R, Gallagher JC, Nordin BE, Marshall DH. Effect of age on calcium absorption. Lancet. Sep 12 1970;2(7672):535-537.

7. Garnero P, Sornay-Rendu E, Duboeuf F, Delmas PD. Markers of bone turnover predict postmenopausal forearm bone loss over 4 years: the OFELY study. J Bone Miner Res. Sep 1999;14(9):1614-1621.

8. Carvalho MJ, Marques E, Mota J. Training and detraining effects on functional fitness after a multicomponent training in older women. Gerontology. 2009;55(1):41-48.

9. Marin-Cascales E, Rubio-Arias JA, Romero-Arenas S, Alcaraz PE. Effect of 12 Weeks of Whole-Body Vibration Versus Multi-Component Training in Post-Menopausal Women. Rejuvenation Res. Dec 2015;18(6):508-516.

10. Vainionpaa A, Korpelainen R, Leppaluoto J, Jamsa T. Effects of high-impact exercise on bone mineral density: a randomized controlled trial in premenopausal women. Osteoporos Int. Feb 2005;16(2):191-197.

11. Sugiyama T, Yamaguchi A, Kawai S. Effects of skeletal loading on bone mass and compensation mechanism in bone: a new insight into the "mechanostat" theory. J Bone Miner Metab. 2002;20(4):196-200.

12. Beck BR, Norling TL. The effect of 8 mos of twice-weekly low- or higher intensity whole body vibration on risk factors for postmenopausal hip fracture. Am J Phys Med Rehabil. Dec 2010;89(12):997-1009.

13. Burke D, Schiller HH. Discharge pattern of single motor units in the tonic vibration reflex of human triceps surae. J Neurol Neurosurg Psychiatry. Aug 1976;39(8):729-741.

14. Hagbarth KE, Eklund G. Tonic vibration reflexes (TVR) in spasticity. Brain Res. Aug 1966;2(2):201-203.

15. Lai CL, Tseng SY, Chen CN, et al. Effect of 6 months of whole body vibration on lumbar spine bone density in postmenopausal women: a randomized controlled trial. Clin Interv Aging. 2013;8:1603-1609.

16. Verschueren SM, Roelants M, Delecluse C, Swinnen S, Vanderschueren D, Boonen S. Effect of 6-month whole body vibration training on hip density, muscle strength, and postural control in postmenopausal women: a randomized controlled pilot study. J Bone Miner Res. Mar 2004;19(3):352-359.

17. Delecluse C, Roelants M, Verschueren S. Strength increase after whole-body vibration compared with resistance training. Med Sci Sports Exerc. Jun 2003;35(6):1033-1041.

18. Tsuji T, Yoon J, Aiba T, Kanamori A, Okura T, Tanaka K. Effects of whole-body vibration exercise on muscular strength and power, functional mobility and self-reported knee function in middle-aged and older Japanese women with knee pain. Knee. Dec 2014;21(6):1088-1095.

19. Frost HM. The skeletal intermediary organization. Metab Bone Dis Relat Res. 1983;4(5):281-290.

20. Leung KS, Li CY, Tse YK, et al. Effects of 18-month low-magnitude high-frequency vibration on fall rate and fracture risks in 710 community elderly--a cluster-randomized controlled trial. Osteoporos Int. Jun 2014;25(6):1785-1795.

21. Movaseghi F, Sadeghi H. Effect of Three-year Multi-Component Exercise Training on Bone Mineral Density and Content in a Postmenopausal Woman with Osteoporosis: A Case Report. Iran J Public Health. May 2015;44(5):701-704.

22. Karinkanta S, Heinonen A, Sievanen H, et al. A multi-component exercise regimen to prevent functional decline and bone fragility in home-dwelling elderly women: randomized, controlled trial. Osteoporos Int. Apr 2007;18(4):453-462.

23. Stewart KJ, Bacher AC, Hees PS, Tayback M, Ouyang P, Jan de Beur S. Exercise effects on bone mineral density relationships to changes in fitness and fatness. Am J Prev Med. Jun 2005;28(5):453-460.

24. Fjeldstad C, Palmer IJ, Bemben MG, Bemben DA. Whole-body vibration augments resistance training effects on body composition in postmenopausal women. Maturitas. May 20 2009;63(1):79-83.

25. Garatachea N, Jimenez A, Bresciani G, Marino NA, Gonzalez-Gallego J, de Paz JA. The effects of movement velocity during squatting on energy expenditure and substrate utilization in whole-body vibration. J Strength Cond Res. May 2007;21(2):594-598.

26. Cristi-Montero C, Cuevas MJ, Collado PS. Whole-body vibration training as complement to programs aimed at weight loss. Nutr Hosp. Sep-Oct 2013;28(5):1365-1371.

27. Forsberg AM, Nilsson E, Werneman J, Bergstrom J, Hultman E. Muscle composition in relation to age and sex. Clin Sci (Lond). Aug 1991;81(2):249-256.

28. Kukuljan S, Nowson CA, Bass SL, et al. Effects of a multi-component exercise program and calcium-vitamin-D3-fortified milk on bone mineral density in older men: a randomised controlled trial. Osteoporos Int. Jul 2009;20(7):1241-1251.

29. Maltais ML, Desroches J, Dionne IJ. Changes in muscle mass and strength after menopause. J Musculoskelet Neuronal Interact. Oct-Dec 2009;9(4):186-197.

30. Hakkinen K, Pakarinen A. Muscle strength and serum testosterone, cortisol and SHBG concentrations in middle-aged and elderly men and women. Acta Physiol Scand. Jun 1993;148(2):199-207.

31. Rennie MJ, Wilkes EA. Maintenance of the musculoskeletal mass by control of protein turnover: the concept of anabolic resistance and its relevance to the transplant recipient. Ann Transplant. 2005;10(4):31-34.

32. Short KR, Nair KS. The effect of age on protein metabolism. Curr Opin Clin Nutr Metab Care. Jan 2000;3(1):39-44.

33. Breen L, Phillips SM. Interactions between exercise and nutrition to prevent muscle waste during ageing. Br J Clin Pharmacol. Mar 2013;75(3):708-715.

34. Calendo LR, Taeymans J, Rogan S. [Does muscle activation during whole-body vibration induce bone density improvement in postmenopausal women?--A systematic review]. Sportverletz Sportschaden. Sep 2014;28(3):125-131.

35. Ebid AA, Ahmed MT, Mahmoud Eid M, Mohamed MS. Effect of whole body vibration on leg muscle strength after healed burns: a randomized controlled trial. Burns. Nov 2012;38(7):1019-1026.

36. Martinez F, Rubio JA, Ramos DJ, Esteban P, Mendizabal S, Jimenez F. Effects of 6-week whole body vibration training on the reflex response of the ankle muscles: a randomized controlled trial. Int J Sports Phys Ther. Feb 2013;8(1):15-24.

37. Melnyk M, Schloz C, Schmitt S, Gollhofer A. Neuromuscular ankle joint stabilisation after 4-weeks WBV training. Int J Sports Med. Jun 2009;30(6):461-466.

38. Johnston RM, Bishop B, Coffey GH. Mechanical vibration of skeletal muscles. Phys Ther. Apr 1970;50(4):499-505.

39. Roelants M, Verschueren SM, Delecluse C, Levin O, Stijnen V. Whole-body-vibration-induced increase in leg muscle activity during different squat exercises. J Strength Cond Res. Feb 2006;20(1):124-129.

40. Kang S, Hwang S, Klein AB, Kim SH. Multicomponent exercise for physical fitness of community-dwelling elderly women. J Phys Ther Sci. Mar 2015;27(3):911-915.

Figure Legends

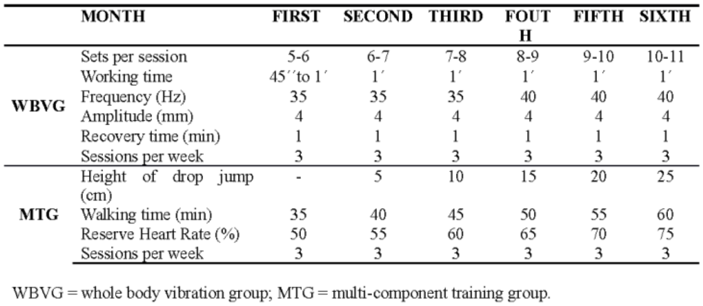
Figure 1. Trial profile. WBVG = whole body vibration group; MTG = multi-component training group; CG = control group.

Figure 2. Changes in Peak Concentric Torque (N• m• kg^{-1}) for ankle dorsiflexion, plantar flexion, eversion and inversion. WBVG = whole body vibration group; MTG = multi-component training group; CG = control group. *Significant difference from pre- to post-training ($p \leq 0.05$). **Significant difference from pre- to post-training ($p \leq 0.01$). ***Significant difference from pre- to post-training ($p \leq 0.001$).

Figure 1. Trial profile. WBVG = whole body vibration group; MTG = multi-component training group; CG = control group.

Effects of 24 weeks of Whole Body Vibration vs. Multi-component training on Muscle Strength and Body Composition in Postmenopausal Women: a randomized controlled trial.
(doi: 10.1089/rej.2016.1877)

Figure 2. Changes in Peak Concentric Torque (N• m• kg^{-1}) for ankle dorsiflexion, plantar flexion, eversion and inversion. WBVG = whole body vibration group; MTG = multi-component training group; CG = control group. *Significant difference from pre- to post-training ($p \leq 0.05$). **Significant difference from pre- to post-training ($p \leq 0.01$). ***Significant difference from pre- to post-training ($p \leq 0.001$).



	MONTH	FIRST	SECOND	THIRD	FOUTH	FIFTH	SIXTH
WBVG	Sets per session	5-6	6-7	7-8	8-9	9-10	10-11
	Working time	45´´to 1´	1´	1´	1´	1´	1´
	Frequency (Hz)	35	35	35	40	40	40
	Amplitude (mm)	4	4	4	4	4	4
	Recovery time (min)	1	1	1	1	1	1
	Sessions per week	3	3	3	3	3	3
MTG	Height of drop jump (cm)	-	5	10	15	20	25
	Walking time (min)	35	40	45	50	55	60
	Reserve Heart Rate (%)	50	55	60	65	70	75
	Sessions per week	3	3	3	3	3	3

WBVG = whole body vibration group; MTG = multi-component training group.

Table 1. Characteristics of training programmes.

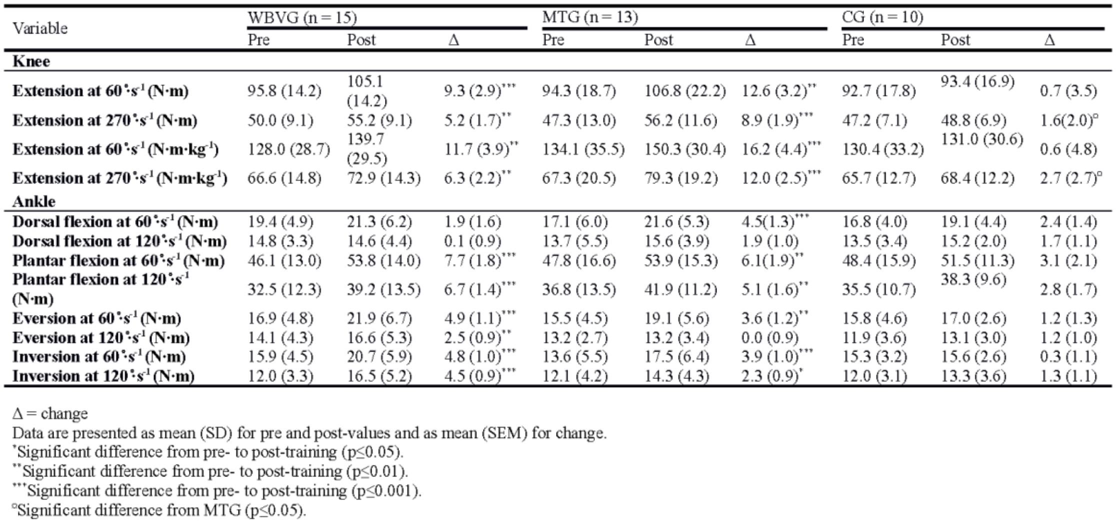
Rejuvenation Research
Effects of 24 weeks of Whole Body Vibration vs. Multi-component training on Muscle Strength and Body Composition in Postmenopausal Women: a randomized controlled trial.
(doi: 10.1089/rej.2016.1877)

Variable	WBVG (n = 15)			MTG (n = 13)			CG (n = 10)		
	Pre	Post	Δ	Pre	Post	Δ	Pre	Post	Δ
Body Fat (%)	46.0 (6.1)	44.9 (6.1)	-1.1(0.5)*	42.2 (4.2)	41.2 (3.3)	-1.0 (0.6)	40.4 (4.7)	41.3 (5.1)	0.9 (0.7)
Fat Mass (Kg)	37.8 (11.7)	36.8 (11.6)	-1.0 (0.0)	31.6 (6.3)	29.9 (5.9)	-1.7 (2.0)**	30.5 (7.6)	31.7 (7.4)	1.2 (0.0)$^{*\dagger\circ\circ\circ}$
Lean Mass (Kg)	40.5 (3.9)	41.3 (4.4)	0.8 (0.6)	39.9 (5.2)	39.9 (6.1)	-0.1(0.6)	42.2 (4.4)	42.0 (5.7)	-0.1(0.7)
BMD$_{total}$ (g·cm^{-2})	0.924 (0.105)	0.927 (0.119)	0.002 (0.03)	0.918 (0.103)	0.927 (0.098)	0.000 (0.02)	0.886 (0.091)	0.892 (0.097)	0.006 (0.013)

BMD = bone mineral density; Δ = change
Data are presented as mean (SD) for pre and post-values and as mean (SEM) for change.
[*] Significant difference from pre- to post-training ($p \leq 0.05$).
[**] Significant difference from pre- to post-training ($p \leq 0.01$).
[†] Significant difference from WBVG ($p \leq 0.05$).
[°°°] Significant difference from MTG ($p \leq 0.001$).

Table 2. Changes in body composition parameters

Rejuvenation Research
Effects of 24 weeks of Whole Body Vibration vs. Multi-component training on Muscle Strength and Body Composition in Postmenopausal Women: a randomized controlled trial.
(doi: 10.1089/rej.2016.1877)



Variable	WBVG (n = 15)			MTG (n = 13)			CG (n = 10)		
	Pre	Post	Δ	Pre	Post	Δ	Pre	Post	Δ
Knee									
Extension at 60°·s^{-1} (N·m)	95.8 (14.2)	105.1 (14.2)	9.3 (2.9)***	94.3 (18.7)	106.8 (22.2)	12.6 (3.2)**	92.7 (17.8)	93.4 (16.9)	0.7 (3.5)
Extension at 270°·s^{-1} (N·m)	50.0 (9.1)	55.2 (9.1)	5.2 (1.7)**	47.3 (13.0)	56.2 (11.6)	8.9 (1.9)***	47.2 (7.1)	48.8 (6.9)	1.6(2.0)°
Extension at 60°·s^{-1} (N·m·kg^{-1})	128.0 (28.7)	139.7 (29.5)	11.7 (3.9)**	134.1 (35.5)	150.3 (30.4)	16.2 (4.4)***	130.4 (33.2)	131.0 (30.6)	0.6 (4.8)
Extension at 270°·s^{-1} (N·m·kg^{-1})	66.6 (14.8)	72.9 (14.3)	6.3 (2.2)**	67.3 (20.5)	79.3 (19.2)	12.0 (2.5)***	65.7 (12.7)	68.4 (12.2)	2.7 (2.7)°
Ankle									
Dorsal flexion at 60°·s^{-1} (N·m)	19.4 (4.9)	21.3 (6.2)	1.9 (1.6)	17.1 (6.0)	21.6 (5.3)	4.5(1.3)***	16.8 (4.0)	19.1 (4.4)	2.4 (1.4)
Dorsal flexion at 120°·s^{-1} (N·m)	14.8 (3.3)	14.6 (4.4)	0.1 (0.9)	13.7 (5.5)	15.6 (3.9)	1.9 (1.0)	13.5 (3.4)	15.2 (2.0)	1.7 (1.1)
Plantar flexion at 60°·s^{-1} (N·m)	46.1 (13.0)	53.8 (14.0)	7.7 (1.8)***	47.8 (16.6)	53.9 (15.3)	6.1(1.9)**	48.4 (15.9)	51.5 (11.3)	3.1 (2.1)
Plantar flexion at 120°·s^{-1} (N·m)	32.5 (12.3)	39.2 (13.5)	6.7 (1.4)***	36.8 (13.5)	41.9 (11.2)	5.1 (1.6)**	35.5 (10.7)	38.3 (9.6)	2.8 (1.7)
Eversion at 60°·s^{-1} (N·m)	16.9 (4.8)	21.9 (6.7)	4.9 (1.1)***	15.5 (4.5)	19.1 (5.6)	3.6 (1.2)**	15.8 (4.6)	17.0 (2.6)	1.2 (1.3)
Eversion at 120°·s^{-1} (N·m)	14.1 (4.3)	16.6 (5.3)	2.5 (0.9)**	13.2 (2.7)	13.2 (3.4)	0.0 (0.9)	11.9 (3.6)	13.1 (3.0)	1.2 (1.0)
Inversion at 60°·s^{-1} (N·m)	15.9 (4.5)	20.7 (5.9)	4.8 (1.0)***	13.6 (5.5)	17.5 (6.4)	3.9 (1.0)***	15.3 (3.2)	15.6 (2.6)	0.3 (1.1)
Inversion at 120°·s^{-1} (N·m)	12.0 (3.3)	16.5 (5.2)	4.5 (0.9)***	12.1 (4.2)	14.3 (4.3)	2.3 (0.9)*	12.0 (3.1)	13.3 (3.6)	1.3 (1.1)

Δ = change

Data are presented as mean (SD) for pre and post-values and as mean (SEM) for change.

*Significant difference from pre- to post-training (p≤0.05).

**Significant difference from pre- to post-training (p≤0.01).

***Significant difference from pre- to post-training (p≤0.001).

°Significant difference from MTG (p≤0.05).

Table 3. Changes in isokinetic strength.

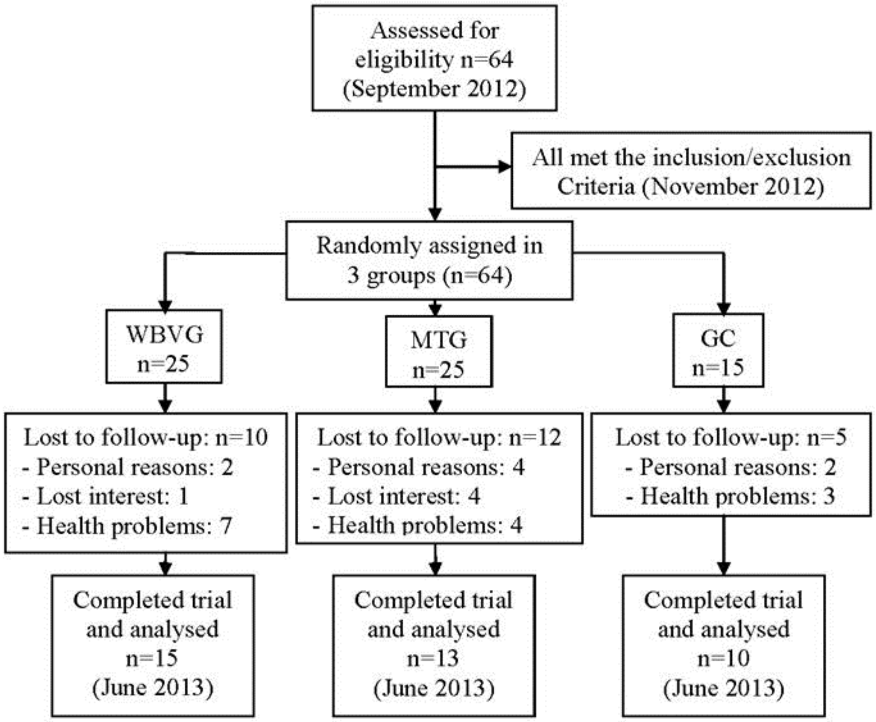
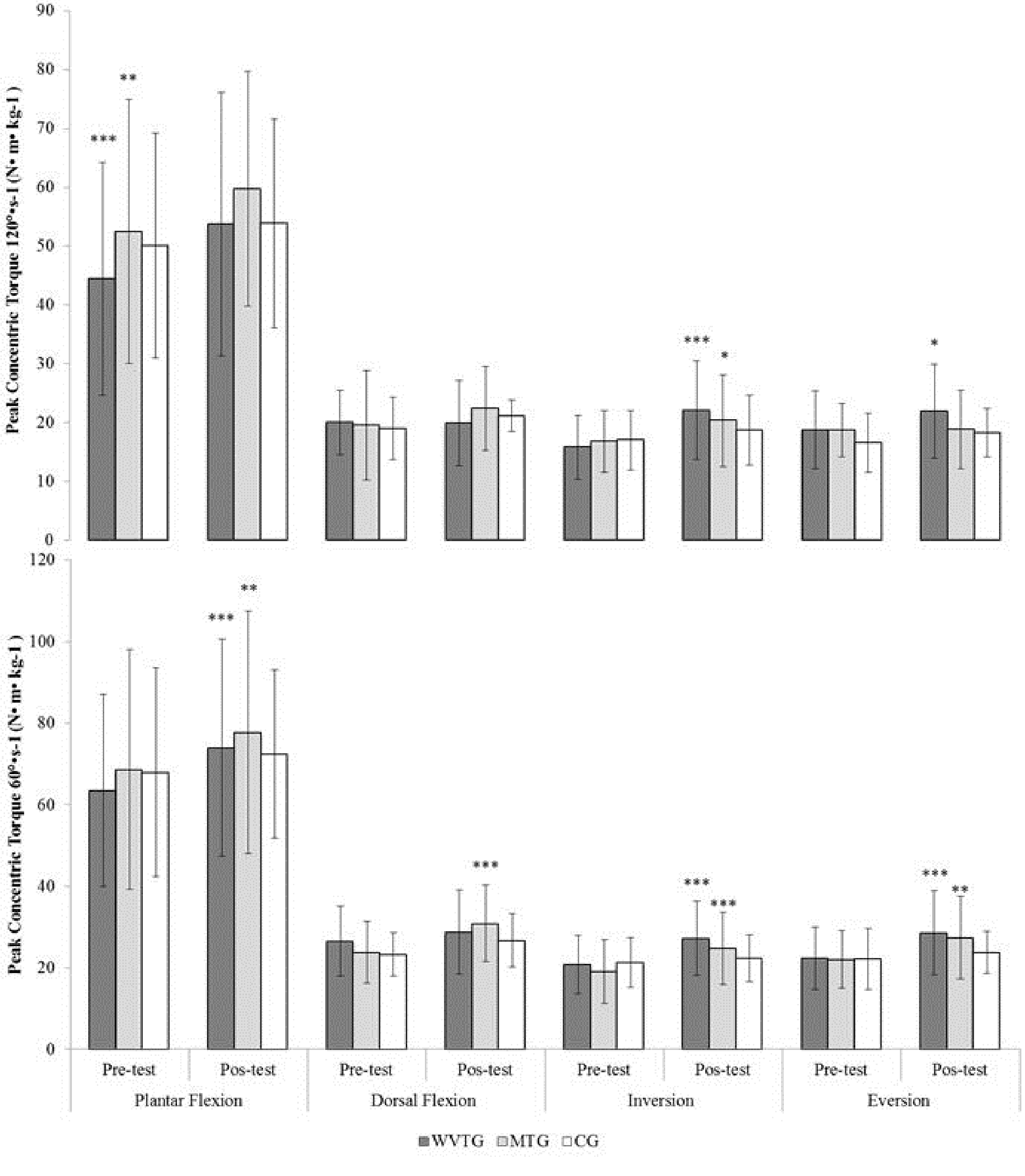


Figure 1. Trial profile.


Peak Concentric Torque 120º•s-1 (N• m• kg-1)
90
80
70
60
50
40
30
20
10
0
***
**
***
*
*
Peak Concentric Torque 60º•s-1 (N• m• kg-1)
120
100
80
60
40
20
0
***
**
***
***
***
***
**
Pre-test
Pos-test
Pre-test
Pos-test
Pre-test
Pos-test
Pre-test
Pos-test
Plantar Flexion
Dorsal Flexion
Inversion
Eversion
■WVTG ▨MTG □CG

F

Rejuvenation Research

igure 2. Changes in Peak Concentric Torque (N• m• kg-1) for ankle dorsiflexion, plantar flexion, eversion and inversion