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Effects of eight months of whole body vibration training on hip bone mass in older women

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Abstract

Objective: **The aim of this study was to examine the effect of 8 months of whole-body vibration training on bone mass in octogenarian women.**

Method: **Thirty-seven women (aged 82.4 [SD=5.7] years) voluntarily participated in this study. The vibration group (n=19) trained on a vibration platform twice a week (20 Hz and 2 mm) whereas controls (n=18) did not participate in any training program. Bone mass was measured by dual-energy X-ray absorptiometry at the hip region. General linear repeated measures ANOVA (group by time) was used to examine the effect of whole body vibration on bone mass changes.**

Results: **After the intervention, in all the hip regions (total hip, femoral neck, trochanter, intertrochanter, Ward's area), no statistically significant changes in bone mass were found.**

Conclusion: **Eight months of whole body vibration training (twice a week) in elderly women do not produce osteogenic effects.**

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Key words: *Osteoporosis. Aging. Exercise.*

EFECTO DE 8 MESES DE ENTRENAMIENTO EN PLATAFORMA DE VIBRACIONES SOBRE LA MASA OSEA DE CADERA EN MUJERES MAYORES

Resumen

Objetivo: **El objetivo de este estudio fue examinar el efecto de 8 meses de entrenamiento vibratorio sobre la masa ósea en mujeres octogenarias.**

Métodos: **37 mujeres (edad 82.4 [SD=5.7] años) participaron voluntariamente de este estudio. El grupo de intervención (n=19) entrenó sobre la plataforma vibratoria 2 veces por semana (20 Hz and 2 mm), mientras que el grupo control (n=18) no participó de ningún programa de entrenamiento. La masa ósea de la cadera fue medida mediante el absorciometría fotónica dual de rayos X. El test de ANOVA de medidas repetidas fue utilizado para determinar el efecto de la intervención sobre los cambios de masa ósea, así como los cambios intra-grupo a lo largo del período de intervención.**

Resultados: **Después de la intervención, no fueron encontrados cambios estadísticamente significativos en la masa ósea en ninguna de las regiones de la cadera (total de cadera, cuello de femur, trocánter, intertrocanterea, area de Ward).**

Conclusiones: **Nuestra intervención basada en la aplicación exclusiva de entrenamiento vibratorio de cuerpo entero (2 veces a la semana) en mujeres octogenarias no produce efectos osteogénicos en la región de la cadera.**

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Palabras clave: *Osteoporosis. Envejecimiento. Ejercicio.*

Introduction

Aging increases the incidence of bone fractures due to the loss of bone mass (osteoporosis)[1], particularly in postmenopausal women[2]. It is well established that lifelong physical activity is key for improving and maintaining bone mineral density (BMD) and reducing the risk of falling[3]. Therefore, an active lifestyle may help to reduce the prevalence of hip

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fractures[4,5]. Additionally, some indicators of physical fitness capacity (i.e. maximal handgrip strength) are positively associated with BMD levels[6].

Despite the importance of exercise and physical fitness for improving the population's health, older women spent about two thirds of waking time in sedentary behavior[7] and therefore, at risk of suffering chronic diseases. For this reason, new interventions designed to improve BMD have recently appeared. Currently, whole body vibration (WBV) training is indicated to enhance BMD and physical fitness in older adults[8-12].

However, the evidence for WBV training effectiveness in older adults is limited. Three meta-analyses[13,14,15] have examined the effects of WBV training on BMD. In the meta-analysis published by Sitjà-Rabert et al.[14] a positive effect in femoral neck BMD was found. Similarly, Slatkovska et al.[15] reported significant improvements on hip BMD in postmenopausal women. In contrast, in Lau et al.[13] WBV had no significant overall effect on hip BMD in older women. These contradictory results could be due to the different number of studies included in the meta-analyses and the weights assigned to each one. The weights correspond to the relevance of each study used to get the overall pooled estimate. The weight is defined by the Statistical Standard Error (SEE); the higher the SEE the smaller the weight. In this regard, Sitjà-Rabert et al.[14] used two studies, Gusi et al.[16] and Verschueren et al.[12] to compute the overall estimate. The weight assigned by the authors to each study was 13.5%[12] and 86.5%[16]. In contrast, in the meta-analysis published by Lau et al.[13] the weights were 34.2% (Verschueren et al.)[12] and 65.8% (von Stengel et al.)[17]. Finally, Slatkovska et al.[15] comprised of three works, the studies of Verschueren et al.[12] (weight: 87.8%), of Gusi et al.[16] (weight: 5.5%) and of Rubin et al.[18] (weight: 6.8%). Therefore further intervention studies in older adults may help to clarify the current understanding of the effects of WBV on bone mass.

The handgrip strength test is an easy, reliable and valid method to identify older adults at risk of disability[19]. Low muscle strength levels may reflect a predominant catabolic status over anabolic signals, leading to sarcopenia and osteoporosis[20]. In fact, maximal handgrip strength is associated with bone fracture[21]. As expected, in older adults aged between the seventh and eighth decade of life, handgrip strength is positively associated with BMD in the forearm[22], femoral neck[23-25], total femur[23], spine[24,25], total hip[24] and total body[25]. It is unknown if this association is also valid for older women in the 9th decade of life (80-89 years old).

The objectives of this study were to evaluate the impact of 8 months of WBV training on changes of BMD in older women and to examine the association between maximal handgrip strength and BMD in this population.

Methods

Participants

Thirty-seven older women (mean age: 82.4 [SD=5.7] years, range 71–93 years, ≥79 years: 75.7%) in two day centers for older adults from Vitoria (Spain) were recruited for the study. Subjects were randomly assigned to one of two groups (WBV group or control group (CON) using random numbers. Inclusion criteria were: sex (women) and no participation in other exercise programs in the last month. Participants were excluded if they were men and diagnosed with diabetes, epilepsy, gallstones, kidney stones, cardiovascular diseases or having joint implants. The WBV group included a total of 19 older women (mean age: 82.3 [SD=5.1] years) who trained on a vertical vibration platform (Fitvibe Excel Pro, Bilzen, Belgium) twice a week for 8 months, with at least one day of rest between sessions. The training program consisted of 18 exercises (see Table I). At least one researcher supervised each training session. The CON group included 18 older women (mean age: 82.2 [SD=6.4] years). All participants were instructed to maintain their usual lifestyle throughout the course of the study. A minimal compliance with the protocol of 80% of the sessions was established.

After the loss of 6 subjects during follow up (1 left the institution, 2 claimed to have back pain and 3 people decided to stop training voluntarily) in the WBV group (see Figure 1), our study design had a statistical power of 80% to detect a difference between the group mean and a hypothetical mean of 0.74 $g \cdot cm^{-2}$ with a significance level (alpha) of 0.05 (2-tailed).

WBV Training Program

The WBV training was designed following the recommended training guidelines[26]. Overloading is one of the basic training principles. Briefly, to induce physical adaptations the training stimuli must be progressively increased[26]. Thus, the training load was progressively increased based on the body position (Table I and Table II).

Written informed consent was obtained from all the subjects. The study was performed according to the principles established with the Declaration of Helsinki for Human Research of 1964 (last modified in 2008) and approved by an Ethics Committee from the University of Zaragoza.

Assessment of Handgrip Strength

A spring-type dynamometer (Smedley-Sportstek, VIC, Australia), range 0-100 kg, was used to measure the maximal handgrip strength (kg)[27]. Subjects were in a standing position, arms at their side not touching

Table I
Description of exercises

Exercise	*Description*
1	Seated on a chair next to machine with legs parallel and feet on the platform (angle of knee flexion: 90°)
2	As exercise 1, with legs in internal rotation and feet on the platform
3	As exercise 1, with legs in external rotation and feet on the platform
4R	As exercise 1, with right leg stretched and left foot on the platform
4L	As exercise 1, with left leg stretched and right foot on the platform
5	As exercise 1, with both feet touching the platform with metatarsal support
6R	Standing next to machine with right leg on the platform and left leg on the floor
6L	As exercise 6R, with left leg on the platform and right leg on the floor
7	Squat 45° next to platform - standing pulling the strings behind (the strings were tied to the platform)
8	As exercise 7 - standing with torso slightly blended, pulling the straps up
9	Squat 45° on platform - with feet together
10	Squat 45° on platform - with feet separated
11	Squat 45° on platform - with knee internal rotation
12	Squat 45° on platform - with knee external rotation
13	Squat 45° on platform - legs hip-width
14	Squat 45° on platform - standing on platform with torso slightly blended, pulling the strings up
15	Squat 45° on platform - pulling the strings through a flexion of arms
16	Squat 90º on platform - feet together
17	Squat 90º on platform -with feet separated
18	Squat 90º on platform -legs hip-width

their body and keeping the elbow bent slightly. The test was administered on the dominant hand. After the voice command, subjects had to squeeze the dynamometer with as much force as possible (maximum isometric force). Movements of other body parts were not allowed. The highest score out of 2 attempts was recorded[24]. The assessment of maximal handgrip strength has shown high test-retest reliability in frail older women[28].

BMD Assessment

BMD was examined by dual-energy X-ray absorptiometry (DXA) (Norland Excell Plus, Norland Inc., Fort Atkinson, USA). Areal BMD ($g \cdot cm^{-2}$) was determined at the hip (total hip, femoral neck, trochanter, intertrochanter, Ward's area) on each subject. Based on the definition provided by the World Health Organization, osteoporosis was defined as T-scores ≤-2.5[29]. Also, a T-score ran-

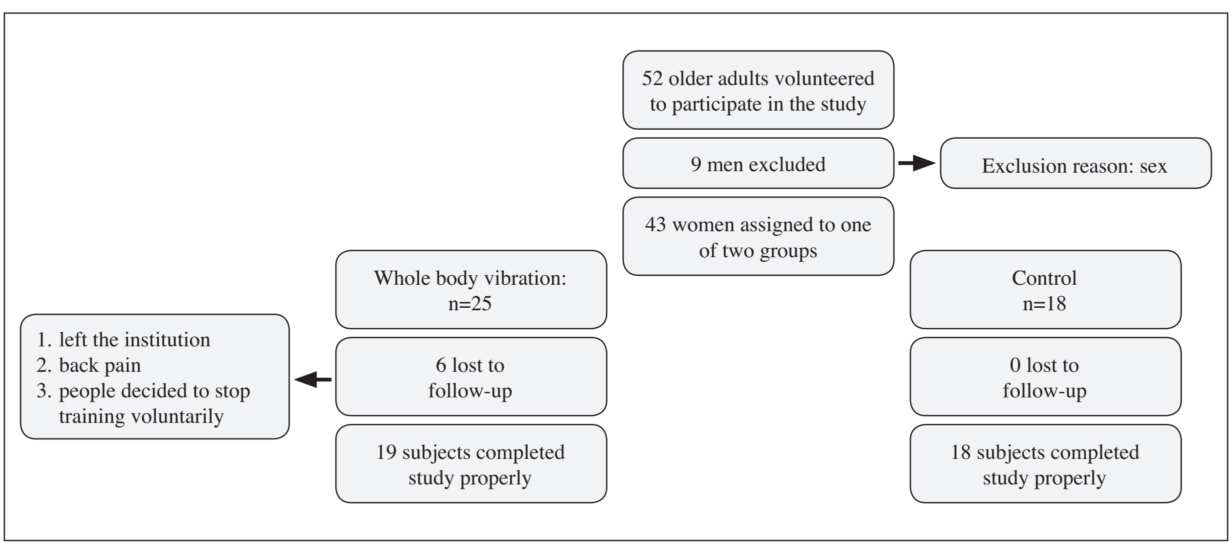

Fig. 1.—Flow diagram for subject assignment in this study.

Table II
WBV training

Week	*Series (exercise*)*	*Duration of each exercise/ rest (s)*	*Duration of session (min:s)*	*Week*	*Series (exercise*)*	*Duration of each exercise/ rest (s)*	*Duration of session (min:s)*
1	2 (1,2,7,3,8,5)	30	6:00	17	2 (13,9,10,17,11,12)	30	6:00
2	2 (1,2,7,3,8,5)	30	6:00	18	2 (13,8,15) 1 (9,10,18,17,11,12)	30	6:00
3	2 (1,8,4R,4L,6D,6L)	35	6:50	19	1 (10,9,11,12) 2 (17,18), 4 (11)	35	6:50
4	2 (1,8,4R,4L,6D,6L)	35	6:50	20	2 (15,13,9,10,11,12)	35	6:50
5	2 (1,2,7,3,8,5)	30	6:00	21	2 (9,10,11,12,13,15)	30	6:00
6	2 (1,2,7,3,8,5)	30	6:00	22	2 (9,10,11,12,13,15)	30	6:00
7	2 (1,8,4R,4L,6D,6L)	35	6:50	23	2 (11,12,13,17,18,15)	35	6:50
8	2 (1,8,4R,4L,6D,6L)	35	6:50	24	2 (13), 3 (17,18) 4 (15)	35	6:50
9	2 (1,2,7,3,8,5)	30	6:00	25	2 (11,12,13,17,18,16)	30	6:00
10	2 (1,2,7,3,8,5)	30	6:00	26	2 (11,12,13,17,18,16)	30	6:00
11	2 (1,8,4R,4L,6D,6L)	35	6:50	27	2 (9,10,11,12,13,16)	35	6:50
12	2 (1,8,4R,4L,6D,6L)	35	6:50	28	2 (9,10,11,12,18,15)	35	6:50
13	2 (13,10,9,17,18) 1 (11,12)	30	6:00	29	2 (9,10,11,12,13,16)	35	6:50
14	2 (13,12,11,10,9) 1 (17,18)	30	6:00	30	2 (9,10,11,12,18,16)	35	6:50
15	2 (17,13,10,9,13,18)	35	6:50	31	2 (9,10,11,17,18,16)	35	6:50
16	2(18,13,11,12,13,17)	35	6:50	32	2 (9,10,11,17,18,16)	35	6:50

*Exercise: see table 1; work and rest durations for each exercise were similar.
Frequency of vibration was 20 Hz and amplitude 2 mm (peak to peak).

ged between -2.5 and -1 is classified as osteopenia and a T-score ^{3} -1 is regarded as normal[29]. A T-score indicates the difference between the subject´s measured BMD and the mean BMD of healthy young adults, matched for gender and ethnicity, and expressing the difference relative to the young adult population standard deviation (SD), as in the following formula: *T-score = (measured BMD – young adult mean BMD)/Young adult population SD*.

Data Analysis

Mean and SD were used as descriptive statistics. Kolmogorov–Smirnov tests showed normal distribution of the studied variables. General linear repeated measures ANOVA (group by time) was used to determine the effect of the intervention on bone mass and grip strength. Finally, the risk of having osteoporosis at the neck femoral was examined by binary logistic regression analyses (odds ratio (OR) and 95% confidence interval (CI)), entering the osteoporosis test results (yes or no) as depended variable and the maximal handgrip strength values at baseline as independent variable. Age was included as a covariate.

For all statistical tests a p-value < 0.05 was considered to be statistically significant. All analyses were performed using the Statistical Package for Social Sciences software (SPSS, v.18.0 for WINDOWS; SPSS Inc., Chicago, IL, USA). The study power of our design was calculated using StatMate software, version 2.0 (GraphPad, San Diego, USA).

Results

Based on T-scores values derived from DXA, the percentage of older women presented with osteoporosis and osteopenia was 53% and 38%, respectively. As shown in table III, the ANOVA analysis found no statistically significant differences between CON and WBV groups for BMD in all the hip regions at baseline [$F(0, 0)=0.61$; $p=0.44$] and after the follow-up [$F(0, 0)=0.17$; $p=0.68$]. Similarly, no statistically significant changes in the total BMD were found within groups [$F(0, 1)=1.04$; $p=0.68$

Table III
Absolute values of hip BMD in WBV and CON groups at baseline and at follow-up

BMD (g/cm²)	*WBV group*				*Control group*			
	Pre-training Mean (SD)	*Post-training Mean (SD)*	*% change*	*P values*	*Pre-training Mean (SD)*	*Post-training Mean (SD)*	*% change*	*P values*
Total hip	0.76 (0.11)	0.74 (0.10)	-2.88%	0.315	0.79 (0.12)	0.76 (0.15)	-4.32%	0.152
Femoral neck	0.62 (0.09)	0.61 (0.08)	-1.75%	0.343	0.64 (0.11)	0.63 (0.10)	-2.71%	0.162
Trochanter	0.57 (0.09)	0.56 (0.09)	-2.88%	0.267	0.59 (0.09)	0.56 (0.12)	-3.65%	0.188
Intertrochanter	0.91 (0.14)	0.88 (0.13)	-2.94%	0.296	0.94 (0.15)	0.90 (0.20)	-4.33%	0.144
Ward´s area	0.41 (0.11)	0.40 (0.09)	-2.04%	0.607	0.42 (0.12)	0.42 (0.14)	-0.14%	0.973

CON: control group; WBV: whole body vibration group; BMD: bone mineral density; SD: standard deviation *p* values in the table are within group changes. *p<0.05* within group changes.

and F(0, 1)=2.14; p=0.15 for pre-post values in the CON and WBV groups respectively].

ANOVA showed no significant time x group effect for grip strength. Consequently, there were no significant differences in handgrip strength between groups at baseline and post-training [F(20, 29)=0.69, p=0.41 and F(13, 30)=0.44, p=0.51 respectively]. Similarly, during the intervention both groups did not modify their maximal handgrip strength values [CON group: -0.56 [SD=2.45] kg, F(0, 1)=0.15, p=0.70; WBV group: -0.25 [SD=2.54] kg, F(0, 1)=0.77, p=0.39]. Finally, no association was found between handgrip strength and osteoporosis risk at the neck femoral area using a logistic regression model (OR = 1.16; 95% CI 0.95–1.41).

Discussion

The two main findings of this longitudinal study were: 1) compared with the CON group, 8 months of low-frequency WBV training program did not produce significant changes of BMD in the hip of older women; and 2) no association was found between handgrip strength values and osteoporosis risk in older women.

Although it has been suggested that WBV may be an effective intervention to increase or maintain BMD[18,30,31], our results cast doubt about the efficacy of WBV to enhance BMD in older women (mean age, 82 years). Our findings agree with previous long term WBV training studies (≥12 months; 25-35 Hz; three times per week) in which non-significant changes in total hip and femoral neck BMD were found in postmenopausal women aged between 47 and 65 years [17,18,32,33]. In contrast, several studies carried out in women aged 54-74 years demonstrated osteogenic effects on the hip region. All these studies had at least 6 months of duration, frequency ranged between 12.6-40 Hz and subjects trained 3-5 times per week[12,16,31]. The non-osteogenic effect found in the present study may be explained by several factors. First, the mechanical loads of low magnitude were applied in our intervention. The osteogenic effects of exercises characterized by the application of loads of high magnitude and short duration (i.e. jumps) are well established[4]. Secondly, mechanical signals produced by exercise may be less osteogenic in older people than in younger people[4]. The osteoblast cellular senescence and age-related changes in growth factors and hormone levels may attenuate the positive effects of exercise on the bone[34]. Thirdly, the weekly training may affect the effects on BMD because studies that used a high frequency of training (5 weekly sessions), a high frequency of vibration (30Hz) and high amplitude (5mm) reported positive changes on bone mass[31]. Finally, the participant's body composition may influence the results of the WBV training. For example, although no effects of 12 months of WBV training on hip and spine BMD were reported by Rubin et al.[18], in their post-hoc analysis the women with lower weight increased hip BMD versus the rest of the sample. In summary, our data does not support the implementation of WBV programs in octogenarian women for the prevention and treatment of osteoporosis. However, some benefits on bone mass may be achieved under certain circumstances.

In addition, we found no association between handgrip strength and osteoporosis risk, which differs from two studies conducted in postmenopausal women (~67 years old)[25,35]. Again, methodological differences among studies may explain these results. According to Foley et al.[36] all studies designed to examine the relationship between muscle strength and BMD should adjust by weight or height, because these anthropometric variables are positively correlated with muscle strength. Therefore, we think that the associations shown in the younger populations are spurious or indeed, weaker than traditionally reported.

The present study examined the effect of WBV on bone mass in older women. Strengths were the long duration of the training program (8 months). Moreover, the program was not excessively demanding for participants (2 weekly sessions). Unfortunately, some potential moderators or confounding factors such as diet, use of drugs, nutritional supplements or smoking habits, and physical activity levels were not registered. Further studies are needed to increase the present knowledge of the impact of WBV training on bone mass in older people.

Conclusions

The present study shows that 8 months of WBV training in octogenarian women did not elicit bone mineral gains in the hip region (total hip, trochanter, intertrochanter, femoral neck and Ward's area). Therefore, the use of vibratory platforms in octogenarian women to counteract osteoporosis doesn't seem to be justified. Contrary to the findings in younger populations, handgrip strength may be an inappropriate tool for osteoporosis risk assessment (mean age, 82 years).

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