A single whole body vibration session influences quadriceps muscle strength, functional mobility and balance of elderly with osteopenia and/or osteoporosis? Pragmatic clinical trial

Luanda Alves Xavier Ramos¹ · François Talles Medeiros Rodrigues² · Lívia Shirahige³ · Maria de Fátima Alcântara Barros⁴ · Antônio Geraldo Cidrão de Carvalho⁴ · Marcelo Renato Guerino⁵ · Ana Paula de Lima Ferreira⁶ · Ricardo Oliveira Guerra⁷ · Maria das Graças Rodrigues de Araújo^{6,8}

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Abstract

Background The purpose of this study verify the immediate effect of whole body vibration (WBV) on quadriceps muscle strength, functional mobility and balance in elderly patients with Osteopenia and/or Osteoporosis.

Methods This was a randomized pragmatic clinical trial with 34 elderly (32 women) randomly assigned to two groups: the experimental group (EG; $n = 17$) who underwent low-frequency (16 Hz) WBV and the control group (CG; $n = 17$) who performed the walk. Outcome measures were: quadriceps muscle strength measured by a maximal repetition test (1RM); functional mobility assessed by the Timed Up and Go (TUG) test and balance assessed by the Berg Balance Scale (BBS).

Results In within-group interaction, a significant increase was observed in quadriceps muscle strength (EG: $p = 0.047$) and balance (EG: $p = 0.012$; CG: $p = 0.007$). In between-groups interaction, a significant difference was not observed. There was an increase in the muscular strength of the EG and in the balance in both groups.

✉ Maria das Graças Rodrigues de Araújo
mgrodriguesaraujo@hotmail.com

Luanda Alves Xavier Ramos
luanda.xavier@hotmail.com

François Talles Medeiros Rodrigues
francoismedeirosfisiot@gmail.com

Lívia Shirahige
livia.sgn@gmail.com

Maria de Fátima Alcântara Barros
fatimalcantara@yahoo.com

Antônio Geraldo Cidrão de Carvalho
gecidrao@yahoo.com.br

Marcelo Renato Guerino
marceloguerino@hotmail.com

Ana Paula de Lima Ferreira
apllima@yahoo.com.br

Ricardo Oliveira Guerra
ricardoguerra2009@gmail.com

² Program in Physical Therapy, Laboratório de Cinesioterapia e Recursos Terapêuticos Manuais (LACIRTEM), Universidade Federal de Pernambuco (UFPE), Recife, PE, Brazil

³ Neuropsychiatry Program, Laboratório de Neurociência Aplicada (LANA), Universidade Federal de Pernambuco (UFPE), Recife, PE, Brazil

⁴ Department of Physiotherapy, Laboratório de Fisioterapia em Saúde Coletiva (LabFISC) do Núcleo de Estudos e Pesquisas Epidemiológicas em Fisioterapia e Saúde (NEPEFIS), Universidade Federal da Paraíba (UFPB), João Pessoa, PB, Brazil

⁵ Department of Physiotherapy, Laboratório de Eletrotermofototerapia (LETER), Universidade Federal de Pernambuco (UFPE), Recife, PE, Brazil

⁶ Department of Physiotherapy, Laboratório de Cinesioterapia e Recursos Terapêuticos Manuais (LACIRTEM), Universidade Federal de Pernambuco (UFPE), Recife, PE, Brazil

⁷ Department of Physiotherapy, Grupo de Estudos em Epidemiologia e Fisioterapia Geriátrica (GEFEG), Universidade Federal do Rio Grande do Norte (UFRN), Natal, RN, Brazil

⁸ Laboratório de Cinesioterapia e Recursos Terapêuticos Manuais (LACIRTEM). Department of Physiotherapy, Universidade Federal de Pernambuco CCS/UFPE, Av. Jornalista Aníbal Fernandes, S/N, Cidade Universitária, Recife, PE 50740-560, Brazil

¹ Laboratório de Cinesioterapia e Recursos Terapêuticos Manuais (LACIRTEM), Universidade Federal de Pernambuco (UFPE), Recife, PE, Brazil

Conclusion An WBV training session was able to alter the muscular strength of the LQ and the balance of the elderly with Osteopenia and/or Osteoporosis. It is suggested, however, that future studies involving larger sample number and/or populations should be developed to analyze the short-term effects of WBV.

Keywords Osteoporosis · Muscle strength · Postural equilibrium · Vibration · Walking

Introduction

Aging is characterized by a decline in organic functions and significant changes in the neuromuscular system, becoming an important risk factor for the development of osteometabolic diseases, since as the individual ages, the peak of bone mass is reached, starting a slow process of their loss [1]. Likewise, Sarcopenia is an age-related disorder characterized by a progressive reduction in muscle strength of up to 50% from 30 to 80 years, occurring greater losses in the lower limbs [2].

The appearance of osteoporosis (OP) and osteopenia (OPN), which are progressive osteometabolic diseases, is characterized by the accelerated loss of bone mass and deterioration of the tissue microarchitecture in which OPN is considered a starting frame that can evolve into the OP [3].

Osteometabolic diseases have a higher incidence in women, especially after menopause, and are increasingly prevalent due to aging populations and increased life expectancy [4].

It is estimated that OP and OPN affect more than 75 million people worldwide [5] and 15 million in Brazil [6], have become public health problems through the devastating effects on the physical and psychosocial health of their patients, and generated, in Brazil, between 2008 and 2010, an expenditure of approximately 290 million real in hospital care and outpatient procedures [7]. Thus, low bone mineral density, poor physical performance and sarcopenia leads to bone fragility and increased fracture risk [8].

In this context, the clinical objective should be to reduce the risk of fracture resulting mainly from falls, which will subsequently reduce morbidity and mortality [9]. Modifiable risk factors for the prevention of falls include increased muscle strength, mobility and balance, which has a relation between the latter and knee extensor muscle strength, so immediate implementation of a physical exercise program becomes crucial for the prevention of falls in OP and OPN patients [10], and the use of whole body vibration (WBV) is a practical, safe and low cost training modality [11].

WBV works by mechanical stimulation on an unstable basis that generates a sinusoidal vibration combining different frequencies and amplitudes. This mechanical energy is transmitted to the body in order to stimulate muscle recruitment by contractions triggered by the vibratory tonic reflex [11]. In the scientific literature, there is little evidence of the possible immediate benefits of WBV in this population. In previous studies performed

in patients with neurological dysfunction, it was observed that the acute effect increases muscle strength within 20 min after IVC stimulation [12], however there are still gaps in this effect in subjects with other comorbidities, such as Osteoporotic.

The present study has the primary objective of verifying the immediate response of WBV on quadriceps muscle strength, functional mobility and the balance of the elderly with OP and/or OPN and, secondly, to verify the immediate response in the hemodynamic variables.

Materials and methods

Design and location of the study

It is a controlled, randomized, single-blinded pragmatic clinical trial, following the guidelines established in the Consolidated Standards of Reporting Trials (CONSORT) [13]. The research was carried out in the Laboratório de Cinesioterapia e Recursos Terapêuticos Manuais (LACIRTEM) of the Physiotherapy Department of the Universidade Federal de Pernambuco (UFPE).

This study was approved by the Research Ethics Committee of the CCS / UFPE (opinion n° 2.452.339) and registered at www.clinicaltrials.gov (NCT03448276), respecting the ethical aspects of Resolution 466/12 of the National Health Council and the Declaration of Helsinki. All participants signed the Free and Informed Consent Form (FICF) after being informed of the objectives, risks and benefits of the research.

Sample characterization and allocation process

The sample was non-probabilistic for convenience, composed of 34 elderly with OP and /or OPN, with mean age between 60 and 88 years (70.94 ± 5.75) and body mass index (BMI) between 19.53 and 45.20 (29.71 ± 5.96).

The individuals recruited met the eligibility criteria and were randomly assigned to two groups: experimental group (EG; $n = 17$), training on the vibratory platform; and control group (CG; $n = 17$), the walk. The randomization was performed by a researcher not involved in any stage of the research, using the site www.randomization.com. Soon after the randomization, the order of the participants was deposited in numbered,

sealed and opaque envelopes, which were only opened at the time of the intervention. Regarding masking, two researchers were responsible for the progress of the research procedures, being one responsible for the evaluation and another for the implementation of the intervention protocol. The researcher responsible for evaluations and revaluations was not aware of which group the investor was allocated. The group allocation was not actively disclosed to participants nor was there contract between them.

Included in the study were: (I) Confirmed diagnosis of OP (≤ -2.5 standard deviations) and /or OPN (values between -1 and -2.5 standard deviations) by BMD examination [14]; (II) Age equal or superior to 60 years; (III) Ability to stand for at least thirty seconds without support; (IV) Without severe neurological disease, vascular disorders, labyrinth disorders and blindness; (V) No severe deformities of the spine and disc herniation (VI) No use of gaiters; (VII) No history of fractures in the lower limbs and spine in the last year; (VIII) Non-alcoholics and (IX) Inactive (0 to 5 points) or low active (6 to 11 points), according to the Habitual Physical Activity Questionnaire (HPAQ) [15].

The following were excluded from the study: (I) Individuals who presented hypertensive peak, nausea, dizziness and/or pain during training program (II) Inadequate execution during evaluation procedures, making it impossible to obtain data.

Evaluation and revaluation instruments and procedures

Primary outcome variables

Assessment of quadriceps muscle strength by the 1 repetition maximal test (1RM) The test consists of measuring the maximum amount of weight lifted by the subject only once during knee extension exercise (quadriceps) [16]. According to Pijnappels et al. [17], the strength of knee extensors is a good measure to identify elders at high risk of falls. A fixed muscular strengthening device (Mega II Movement) and dumbbells were used (to adapt the graduation of smaller loads).

A pre-session familiarization was performed before the test, in which the breathing technique was emphasized to avoid maneuvers of Valsava and the positioning of the patient in the equipment for a movement execution in a safe and effective way [18] a series of 5 repetitions with the weight of the machine. The exercise started with 10% of the patient's body weight, and if this repetition was completed, weight was added to the exercise until the maximum lifting capacity was reached, with no more than 5 attempts, with a 30 s interval between them [16, 18]. The

subjects performed the test bilaterally, starting with the non-dominant side. Values for the left and right leg were summed to obtain a composite score.

Balance evaluation by the Berg Balance Scale (BBS) Evaluates the functional balance through 14 situations represented by daily activities. The maximum score is 56 points and each item of the 14 situations has an ordinal scale of 0 (unable to perform the task) to 4 points (independently performed) [19]. A score of less than or equal to 45 is a sign of impaired balance [20].

Evaluation of functional mobility by Timed Up and Go Test (TUG) The test consists of asking the patient to lift a chair without support, walk 3 m, turn 180 degrees, walk back and sit again. Elderly people without functional mobility deficits are able to complete the test in less than 10 s [21]. It was performed three times at thirty-second intervals and the value obtained was the result of the average of the three collections (pre and post-session).

Secondary outcome variables

Hemodynamic variables Before and immediately after the session were measured, systolic (SBP) and diastolic (DBP) blood pressure measured by an aneroid sphygmomanometer and a stethoscope (Premium, China), using the right arm for gauging. Mean arterial pressure (MAP) was calculated according to the formula: $MAP = DBP + (SBP - DBP)/3$ [22]. Respiratory rate (RR) was measured by the expansion of the rib cage for 60 s; the heart rate (HR) and O_2 saturation (SpO_2) were monitored by a portable pulse oximeter (More Fitness, MF-416, China) [23, 24].

Intervention

Basic warming and stretching exercises

Before the session, subjects performed self-stretching of the upper limb (extensors and flexors of the arm and wrist with the patient standing), lower limb (flexors and extensors of the leg, knee and ankle with the patient standing), limb (anterior flexion with the patient standing) and cervical (flexion, extension, bilateral rotation of the cervical with the patient standing), 2 series being maintained for 30 s (Fig. 1a–j). Warm-ups were also performed, consisting of head and shoulder rotation for 30 s. All exercises were supervised by the responsible evaluator.

Protocol of the experimental group

The vibratory platform used in the study was the Kikos P204 - 110v (São Paulo, Brazil) whose direction of

Fig. 1 Stretching of the cervical region (**a, b, c**), flexors and extensors of the arm (**d, e**), flexors and extensors of the fist (**f, g**) flexors and extensors of the knee and ankle (**h, i**), posterior chain (**j**). Source: Research data, 2018

vibration is oscillatory lateral type. The established vibration frequency was 16 Hz and the displacement peak (amplitude) of 4 mm was determined by the width of the platform participants' position. The vibration time was 30 s, being a series of eight repetitions with recovery (between the repetitions) of 30 s, whit a total time of 8 min of intervention [25].

The subjects, barefoot, adopted a 40° squat position, verified with a universal goniometer. The calcans were supported on a silicone insole, consisting of a particular type of semi-rigid sole used to correct the distribution of body weight and biomechanical changes found in the foot. Only the forefoot and midfoot were in direct contact with the platform in order to reduce the transmission of vibrations to the head [26] (Fig. 2).

Fig. 2 Protocol on the vibrating platform Kikos P204 - 110v. Source: Research data, 2018

Control group protocol

Subjects were instructed to walk barefoot in a flat and rectangular space (37 m by 7 m) for 20 min, using a comfortable (self-selected) walking speed [27].

Data analysis

It was performed using the Statistical Package for Social Science (SPSS, IBM®, USA), version 23.0, with a significance level of 5% ($p < 0.05$).

The Shapiro-Wilk test evaluated the normality of the data. The statistic was performed using the Mann-Whitney tests in order to compare the quantitative variables and the Pearson chi-square test to associate the pre-session intergroup frequencies. Wilcoxon test for within-group interaction and Mann-Whitney tests for between-groups interaction values of 1RM, BBS, TUG, DBP, SBP, MAP, RR, HR and SpO₂ between the control groups and experimental. The effect size was calculated by Cohen's d. An effect size of 0.20 was considered a small effect, an effect size of 0.50 a moderate effect and an effect size of 0.80 a large effect [28].

Results

Fifty elderly patients with potential osteoporosis and /or osteopenia were contacted. Of these, 34 (32 women and 2 men) met the eligibility criteria and were randomized into two groups (EG, $n = 17$, CG, $n = 17$). No individual was excluded from the study after randomization, according to established criteria (Fig. 3).

At the beginning of the study (Table 1), both groups did not differ in sociodemographic, clinical and anthropometric data.

After the session, the muscular strength levels of quadriceps, balance and functional mobility were evaluated using the 1RM, BBS and TUG test, respectively. Significant within-group differences were observed for quadriceps muscle strength (EG: $p = 0.047$) and BBS balance (EG: $p = 0.015$; CG: $p = 0.007$). In the between-groups interaction, a significant difference was not observed for the muscle strength ($p = 0.204$; Effect Size = 0,12), balance ($p = 0.865$; Effect Size = 0,13) and functional mobility ($p = 0.168$; Effect Size = 0,45).

After the session, significant differences were observed in within-group interaction for RR (EG: $p = 0,000$; CG: $p = 0,006$), HR (CG: $p = 0.001$). In the between-groups interaction, a significant difference was not observed for the SBP ($p = 0,709$; Effect Size = 0,16), DBP ($p = 0.763$; Effect Size = 0,20), MAP ($p = 0.628$; Effect Size = 0,03), RR ($p = 0.444$; Effect Size = 6,32), HR ($p = 0.817$; Effect Size = 0,10) and SPO2 ($p = 0.845$; Effect Size = 0,09) (Table 2).

Discussion

In the scientific literature there have been studies that investigated the effects of WBV on short [29, 30] and long term [31–33] in several populations and methodologies. In the present study, a single WBV session was performed using low frequency (16 Hz) and amplitude of approximately 4 mm, checking changes in hemodynamic variable (RR), muscle strength (1RM) and balance (BBS) in elderly subjects OP and / or OPN.

Regarding muscle strength, Rogan et al. Verified in a systematic review with thirty-eight articles that the WBV has beneficial effects in the elderly with low levels of functionality [31]. Pessoa et al., Inferred that WBV could benefit healthy elderly individuals, increasing muscle strength [32]; and Raimundo, Gusi and Tomas-Carus, observed the efficacy of 8 months of low-frequency vibration compared to a walking-based program for postmenopausal women, indicating that both groups may prevent a decrease in muscle strength [33]. In the present study, it was observed an increase in the muscular strength in a single WBV session, pointing out that this may be a

Fig. 3 Flowchart of capture and randomization of participants.
Source: Research data, 2018

viable intervention for the increase of muscle strength, however, the methodological heterogeneity of the studies should be considered.

In postmenopausal women, Gusi et al. reported a comparison of low frequency WBV with walking, in which both groups performed three sessions for eight weeks, with significant improvement in balance in the group treated by vibration

Table 1 Socio-demographic, clinical and anthropometric data at baseline (pre-session)

Variables	EG (n = 17)	CG (n = 17)
Female/Male	16/1	16/1
Destroy/Loss	16/1	17/0
LumbarSpine (L1-L4)		
DMO [g/cm ²]	0,88 (±0,15)	0,94 (±0,19)
T- score	-1,86 (±1,06)	-1,49 (±1,72)
FemuralNeck		
DMO [g/cm ²]	0,72 (±0,13)	0,75 (±0,09)
T- score	-1,47 (±0,96)	-2,46 (±3,73)
Total Proximal Femur		
BMD [g/cm ²]	0,82 (±0,15)	0,84 (±0,13)
T- score	-1,02 (±1,03)	-1,05 (±1,08)
Age [years]	70,53 (±6,45)	71,35 (±5,14)
Weight [kg]	68,23 (±15,14)	68,97 (±13,44)
Height [cm]	1,51 (±0,08)	1,53 (±0,05)
BMI [kg/m ²]	30,01 (±6,21)	29,42 (±5,88)
1RM [kg]	8,81 (±5,70)	8,00 (±6,98)
BBS [score]	53,06 (±2,36)	52,59 (±3,64)
TUG [s]	7,65 (±1,19)	8,30 (±2,67)
SBP [mmHg]	130,00 (±13,17)	138,24 (±14,25)
DBP [mmHg]	76,88 (±11,38)	76,47 (±9,13)
MAP [mmHg]	94,69 (±10,61)	97,00 (±9,77)
RR [ipm]	14,25 (±2,32)	15,65 (±3,71)
HR [bpm]	75,81 (±13,13)	70,53 (±13,01)
SpO ₂ [%]	97,19 (±1,17)	97,29 (±1,49)

Data are expressed as frequency or mean (standard deviation). Abbreviations: Experimental Group, EG; Control Group, CG; First Lumbar Vertebra, L1; Fourth Lumbar Vertebra, L4; Bone Mineral Densitometry, BMD; Standard Deviations, T; Body Mass Index, BMI;; One Repetition Maximum, 1RM; Berg Balance Scale, BBS; Timed Up and Go, TUG; Systolic Blood Pressure, SBP; Diastolic Blood Pressure, DBP; Mean Arterial Pressure, MAP; Respiratory Rate, RR; Heart Rate, HR; Saturation, SpO₂

($p = 0.023$) [34]; Sucuoglu et al., found a significant increase ($p = 0.031$) for training on the vibratory platform, when compared to coordination and balance exercises performed at home for four weeks (20 sessions) [35]. These two studies corroborate our findings about the increase in balance, however, one should consider the great variability of WBV protocols and different tests. In addition, only 1 (2.70%) of the elderly evaluated in our study had a score equal to or less than 45 points, thus, 36 (97.30%) fit into an adequate level of balance.

Our study did not show significant benefits for functional mobility, however, Dutra et al. Observed a 9.2% improvement in the mobility of postmenopausal osteoporotic women submitted to WBV for 12 months [36]. Zhang et al. Found a significant reduction in TUG time from 40.47 ± 15.94 to 21.34 ± 4.42 s in fragile elderly patients who completed eight weeks (3 to 5 sessions) of WBV [37]. Thus, we believe that a single vibration session is not enough to induce lasting changes in motor function, although it should be taken into account that only 2 (5.40%) of the evaluated elderly presented values above 10 s, indicating that 35 (94.60%) had no functional mobility deficit.

On cardiovascular effect, significant changes in the RR variable was found in the study, differing from the Sonza et al. Findings, showing that a single 15 min WBV session does not affect hemodynamic variables ($p > 0.05$) in young people [29]. Already Silva et al., Verified short-term physiological changes in the WBV in the variables SBP ($p = 0.005$) and HR ($p = 0.001$) in ten healthy individuals, aged between 18 and 30 years [30].

The effect of WBV on physical performance can be explained by a possible mechanism of rapid contractions (vibratory tonic reflex) in chains that directly activate the neuromuscular system, resulting from the proprioceptive information carried to the Central Nervous System. The vibration transmitted by the lower extremities increases the number of muscle fibers of type Ia, with consequent excitation of the α -motor neurons, even after a single

Table 2 Values of the clinical variables in the control and experimental groups

Variables	Intervention Groups				Within Intervention		Between Interventions
	EG		CG		After-Before		After-Before
					Training		Training
	Before	After	Before	After	EG	CG	EG-CG
1RM [kg]	8,81 ± 5,70	10,81 ± 7,47	8,00 ± 6,98	8,09 ± 6,40	2,00 ± 4,09 ^a	0,08 ± 1,21	-2,72(-7,58 to 2,14)
BBS [score]	53,06 ± 2,36	54,35 ± 1,77	52,59 ± 3,64	54,06 ± 2,51	1,29 ± 1,72 ^a	1,47 ± 1,84 ^a	-0,18 (-1,42 to 1,06)
TUG [s]	7,64 ± 1,19	7,29 ± 1,18	8,29 ± 2,67	8,25 ± 2,75	0,35 ± 0,84	0,04 ± 0,71	0,31 (-0,23 to 0,85)
SBP [mmHg]	130,00 ± 13,17	133,75 ± 20,94	138,24 ± 14,25	136,47 ± 12,72	3,75 ± 15,44	1,76 ± 10,15	1,99 (-7,14 to 11,12)
DBP [mmHg]	76,88 ± 11,38	81,25 ± 9,57	76,47 ± 9,31	79,41 ± 8,99	4,38 ± 9,64	2,94 ± 7,72	1,44 (-4,66 to 7,54)
MAP [mmHg]	94,69 ± 10,61	98,75 ± 10,09	97,00 ± 9,77	98,43 ± 8,34	4,06 ± 6,88	1,43 ± 7,33	2,63 (-2,34 to 7,60)
RR [ipm]	14,25 ± 2,32	18,00 ± 2,85	15,65 ± 3,71	18,76 ± 3,03	3,75 ± 2,27 ^a	3,12 ± 3,57 ^a	0,63 (-1,46 to 2,72)
HR [bpm]	75,81 ± 13,13	77,25 ± 13,21	70,53 ± 13,01	78,65 ± 15,74	1,44 ± 6,85	8,12 ± 6,70 ^a	-6,68 (-10,50 to -2,86)
SpO ₂ [%]	97,19 ± 1,17	97,56 ± 1,09	97,29 ± 1,49	97,65 ± 0,79	0,38 ± 0,89	0,35 ± 1,22	0,03 (-0,72 to 0,78)

^a Statistical significance after training^b Statistical significance between groups after training

Data are expressed as frequency or mean (standard deviation) and estimated difference between the two population averages (confidence interval). Abbreviations: Experimental Group, EG; Control group, CG;; One repetition maximum, 1RM; Berg Balance Scale, BBS; Timed Up and Go, TUG; Systolic blood pressure, SBP; Diastolic blood pressure, DBP; Mean Arterial Pressure, MAP; Respiratory rate, RR; Heart rate, HR; Saturation, SpO₂

vibration platform training session, possibly resulting in balance and muscle strength gains [38].

Potential limitations can be considered in this study, as the sample size was modest. However, based on our results, there may be clinical value in the use of WBV for improve the efficacy of muscle-strengthening protocols, reflecting the possible benefits in functional mobility, muscle strength and hemodynamic variables.

We emphasize that to date, this is the first study that investigated the effects of a single WBV session on the muscular strength of the lower limbs, on functional mobility and on balance in the elderly with OP and / or OPN.

Conclusion

A single WBV training session was able to increase LQ muscle strength and the elderly balance with OP and / or OPN. It is suggested, however, that future studies involving larger sample numbers and / or populations should be developed to analyze the short-term effects of WBV.

Authors' contributions Acquisition of data: FTMR; Application of the protocols: LAXR e LS; Statistical analysis: MRG e ROG; Drafting the manuscript: MFAB e AGCC; Revision critical: APLF e MGRA; Approval of the final version: LAXR, FTMR, LS, MFAB, AGCC, MRG, APLF, ROG e MGRA.

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Compliance with ethical standards

Ethics approval and consent to participate This study was approved by the Research Ethics Committee of the CCS / UFPE (opinion no 2.452.339), respecting the ethical aspects of Resolution 466/12 of the National Health Council and the Declaration of Helsinki. All participants signed the FICF after being informed of the objectives, risks and benefits of the research.

Competing interests Luanda Alves Xavier Ramos, François Talles Medeiros Rodrigues, Livia Shirahige, Maria de Fátima Alcântara Barros, Antônio Geraldo Cidrão de Carvalho, Marcelo Renato Guerino, Ana Paula de Lima Ferreira, Ricardo Oliveira Guerra and Maria das Graças Rodrigues de Araújo declare that they have no competing interests.

Consent for publication There was previous and express consent to the use of the images.

Abbreviations

OP, Osteoporosis; OPN, Osteopenia; WBV, Whole body vibration; CONSORT, Consolidated Standards of Reporting Trials; LACIRTEM, Laboratório de Cinesioterapia e Recursos Terapêuticos Manuais; UFPE, Universidade Federal de Pernambuco; FICF, Free and Informed Consent Form; IBM, Body mass index; EG, Experimental Group; CG, Control group; HPAQ, Habitual Physical Activity Questionnaire; 1RM, One repetition maximum; BBS, Berg Balance Scale; TUG, Timed Up and Go; SBP, Systolic blood pressure; DBP, Diastolic blood pressure; RR, Respiratory rate; HR, Heart rate; SpO₂, Saturation; MAP, Mean Arterial Pressure; SPSS, Statistical Package for Social Science; L1, First lumbar vertebra; L4, Fourth lumbar vertebra; BMD, Bone mineral densitometry; T, Standard deviations

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