Do Two Whole-Body Vibration Amplitudes Improve Postural Balance, Gait speed, Muscle Strength, and Functional Mobility in Sedentary Older Women? A Crossover Randomized Controlled Trial (2022)

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In a new study, published in The Journal of Bodywork & Movement Therapies, a joint Brazilian and Spanish research team utilized Power Plate® to compare outcomes in postural balance, muscle strength, and functional mobility using 2 mm and 4 mm amplitude vibration. The research team selected sedentary females ages 60-80 with prevalent comorbidities (such as arthrosis and hypertension) and age-related decreases in balance and strength that are the most common indicators of events, such as falls, that diminish functional independence. Exercise modalities able to attenuate these risk factors are therefore important to addressing the acute challenges in geriatric healthcare. Using 35hz frequency, subjects were exposed to a single dose of Whole Body Vibration (WBV) totally 20 mins, with static posture, at 2 mm and 4 mm amplitudes. The results of the study demonstrated an improvement in both lower-limb muscle strength and functional mobility after a single dose of WBV. Further, improvements were measured with statistically greater significance using 4 mm than 2 mm amplitude vibration. The findings of this study are consistent with other research that demonstrates positive outcomes on muscular strength and functional mobility using WBV. However, the short time period between the intervention and outcome has significant implications. It suggests that not only is Power Plate an effective preventive therapy for age related factors contributing to falls, but also a novel and well tolerated alterative modality that can rapidly produce meaningful outcomes for at risk groups in key areas relating to quality of life and the maintenance of functional independence.

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Introduction:

Deleterious effects of aging such as postural imbalance, muscle strength loss, and increased risk of falls are commonly observed in individuals over 60 years of age and considered predictors for functional dependence (Cruz-Jentoft et al., 2019). Physical exercise programs have demonstrated effectiveness in slowing these effects and have contributed to a longer life, although some conventional programs may have low adherence by this population. (Hughes et al., 2019; Rivera-Torres et al., 2019).

The training provided by whole-body vibration (WBV) can be considered an alternative modality for improving both muscle function and quality of life (Ritzmann et al., 2018; Yang et al., 2015). However, the exercise protocols vary among studies regarding frequency, amplitude, magnitude, duration, the number of sessions, positioning, performing dynamic exercises, or maintaining a static posture, which influences the physiological responses induced by WBV and results in diverging outcomes (Santos et al., 2021; van Heuvelen et al., 2021; Bemben et al., 2018; Gomes et al., 2018; Goudarzian et al., 2017).

Amplitude has been described from a wide usage range (0e20 mm) amongst the parameters used to prescribe exercise with WBV (van Heuvelen et al., 2021), providing different results in the literature, and its effects are little discussed (Cochrane, 2011; Fischer et al., 2019).

Regarding the use of WBV to increase postural balance (Delafontaine et al., 2019), muscle strength (Santin-Medeiros et al., 2017; Smith et al., 2016) and functional mobility in older adults (Goudarzian et al., 2017) and amplitude variability (0.5 and 8 mm) among the studies, it is observed that the use of different amplitudes may not be sufficient to achieve the expected results in clinical practice, so that studies need to be developed to determine more accurate ranges and which safely promote these benefits in the older population.

Despite the high amplitude variability, studies using WBV training with 2 mm and 4 mm amplitudes in older adults demonstrated improvements in the above-mentioned outcomes, promoting acute and chronic neuromuscular effects, especially when the 4 mm amplitude was used (Tsuji et al., 2014; Ramos et al., 2019). However, other studies using the same amplitude did not find any effect after WBV training, thus its efficacy using those parameters is inconclusive (Gomes et al., 2018; Sitjà Rabert et al., 2015), in turn indicating the need for further studies.

Thus, considering WBV as an alternative training method for the older adult population, and the need to adapt the best prescription of WBV for older adults regarding the outcomes described above, the current study aims to evaluate the effects of a single WBV session on postural balance, muscle strength, and functional mobility when performed with 2 and 4 mm vibration amplitudes. The study hypothesis is that the 4 mm amplitude improves those outcomes when compared to the 2 mm amplitude after a single WBV session.

Method:

2.1. Design and setting

This is a pilot study from a crossover randomized controlled trial that followed the CONSORT guidelines (Schulz et al., 2010). This study was carried out at the Laboratório de Fisioterapia Car-diopulmonar and at the Laboratório de Cinesioterapia e Recursos Ter-apêuticos Manuais of the (insert institution) Department of Physiotherapy from October 2019 to February 2020. This study was approved by the Research Ethics Committee of the Centro de Ciências da Saúde/(insert institution) (registry No. 3.617.829) and registered in the Brazilian Registry of Clinical Trials (REBEC) (RBR-2HPJJK), respecting the guidelines of Resolution No. 466/12 of the National Health Council. Participants signed the Informed Consent Form after being informed of the objectives, risks, and benefits of the study.

2.2. Inclusion and exclusion criteria

A total of 14 older women aged 60e80 years who could walk independently were included in this study. Participants should have a body mass index (BMI) between ⊠22 (underweight) and ⊠27 (overweight) and be considered sedentary (<10 min/week of physical activity) or irregularly active (<150 min/week of physical activity) according to the International Physical Activity Questionnaire (IPAQ) (Matsudo et al., 2012). Participants with any neurological, hearing or cognitive deficit that would make it impossible to understand the verbal cues were excluded. Furthermore, those individuals who presented electronic implants (pacemaker, brain stimulators), prosthetics, pins or plates in the lower limbs, had epilepsy, diagnosis of a malignant tumor, recent unconsolidated fracture, thromboembolism risk, infectious diseases, or were insulin-dependent individuals; had non-treated hypertension, osteoporosis or osteopenia, those who could not adapt to the exercise protocol or who refused to sign the Informed Consent Form were also excluded.

2.3. Randomization and allocation procedure

Two WBV protocols were developed for this study, coded as Protocol A (AP, 2 mm amplitude) and Protocol B (BP, 4 mm amplitude). The participants underwent a single WBV session with a previously randomized amplitude, undergoing the other session after a one-week washout period (Milanese et al., 2018). Fig. 1 represents the flowchart of the volunteers (Fig. 1).
Randomization for session order (A and B protocols) was done by a researcher not involved in the study, and performed with the randomization.com software program 30 min before the intervention. Black and opaque sealed envelopes were used with a number referring to each participant to ensure allocation concealment, which were later delivered to the researcher responsible for the intervention. The researcher responsible for evaluating out-comes was blinded to the participants' allocation. Participants involved in the research remained blind to the order of the protocols.

2.4. Outcomes

Static postural balance was considered the primary outcome in this study, and muscle strength and functional mobility were considered the secondary outcomes.

2.5. Outcome assessment

The volunteers were informed about the evaluation procedures before the initial assessment. Functional tests were previously performed so that the participants could become familiar with them and avoid the learning effect (Ruiter et al., 2003). Data on age, BMI, presence of comorbidities, falls risk and IPAQ assessment were collected for sample characterization. The functional tests were performed before and immediately after each WBV protocol one week later. All adverse effects presented by patients were registered after the training session (itching and fatigue).

2.5.1. Static postural balance

Postural balance was evaluated using a baropodometric plat-form (Sensor Medica, Freemed™ model, Rome, Italy), considering the medial-lateral (CoPx) and anteroposterior (CoPy) center of pressure (CoP) coordinate displacement, expressed in mm (Heuvel et al., 2009). The subjects remained on the platform with bipedal support with their feet slightly separated (shoulder width), arms relaxed alongside their body, and staring forward for 20 s with open eyes for the assessment.

2.5.2. Lower limb muscle strength

The 30-s sit-to-stand test was used to assess muscle strength (Fahlman et al., 2007). The volunteers stand up from the sitting position on a chair, feet resting on the floor, knees flexed at 90º, arms crossed over their chest, and with their spine against the chair (Lord et al., 2002). After a verbal cue, they performed the movement of sitting and standing up from the chair as many times as possible for 30 s. The test was timed in seconds by the researcher and the number of repetitions with complete movements were counted.

2.5.3. Functional mobility

Functional mobility was assessed through the Timed Up and Go Test (Podsiadlo and Richardson 1991). For this test, patients were instructed to get up from a chair (seat height 46 cm), walk 3 m, return, and sit again (Podsiadlo and Richardson 1991). The time to perform this task was verified by the researcher and the results expressed in seconds.
Heart rate and peripheral oxygen saturation (digital pulse oximeter (IMFtec, IMFtec-H model, Brazil), respiratory rate (count the total number of respiratory incursions for an entire minute) and blood pressure were measured [using a manual aneroid sphygmomanometer (Premium, adult model, Brazil) and stethoscope (Premium, Rappaport model, Brazil)]. All vital signs were evaluated before and after each WBV session for control and were not part of the study outcomes.

2.6. WBV protocol

The vibrating platform used in the study was the Power Plate model MY3® (London, UK). A frequency of 35 Hz and 2 and 4 mm vertical vibration amplitudes were used to perform the protocol, with the volunteer in a static position, knees semi-flexed at 30º (measured with a goniometer), and their feet 20 cm apart (Braz-Júnior et al., 2015). The volunteers kept their head and eyes for-ward, barefoot and their arms on the platform during training. The vibration duration was 60 s interspersed with 60 s of rest, totaling 20 min of exercise (Pollock et al., 2012).

2.7. Statistical analysis

The measurements between the 2 mm and 4 mm groups were compared after checking data for normality with the Shapiro-Wilk test. Considering that data distribution was not normal, the Fried-man test was used with post hoc Wilcoxon test for the main outcome variables (static balance, lower limbs strength, distance walked in the 10MWT, and mobility). The Wilcoxon test was used for the main outcomes (2 mm post-intervention was compared with 4 mm post-intervention) to verify the effects of the 2 mm and 4 mm WBV interventions. The paired t-test was used when necessary for the variables with normal distribution.
Effect size calculation for the intervention was performed using the equation r ¼ z/√N, considering the z-statistics obtained from the Wilcoxon test and N being the number of observations from the study (Field 2009). We considered Cohen's reference to interpret the effect size values: 0.1 to 0.3 ¼ small, 0.3 to 0.5 ¼ moderate and above 0.5 ¼ strong effect (Lakens, 2013).
The percentage change for each outcome was calculated as the mean difference (D)[post-pre intervention] for each outcome, divided by the mean value for this variable in the pre-intervention, and then multiplied by 100. Data analysis was performed using the SPSS version 20.0 software (SPSS Inc., Chicago, IL) for Windows, and a significance level lower than 0.05 was considered.

Results:

The study sample consisted of 14 older women (63.3 ± 4.63 years), with a BMI of 26.40 ± 2.99 kg/m2, sedentary (5, 35.7%) or irregularly active (9, 64.3%), with hypertension (10, 71.4%), diabetes (4, 28.6%), arthrosis (8, 57.1%) and osteoporosis (6, 42.9%) as their main comorbidities (Table 1).
Two older women reported itching (n ¼ 6, 42.9%) and fatigue (n ¼ 2, 14.3%) as adverse effects, which disappeared 2 h after the end of the intervention. The other participants (n ¼ 6, 42.9%) re-ported no discomfort during the study period.
According to the analysis performed by Friedman's test, we can observe that WBV resulted in better strength [c2 (3) ¼ 22.983, p < 0.000] and mobility [c2 (3) ¼ 26.476, p < 0.000] outcomes when performed

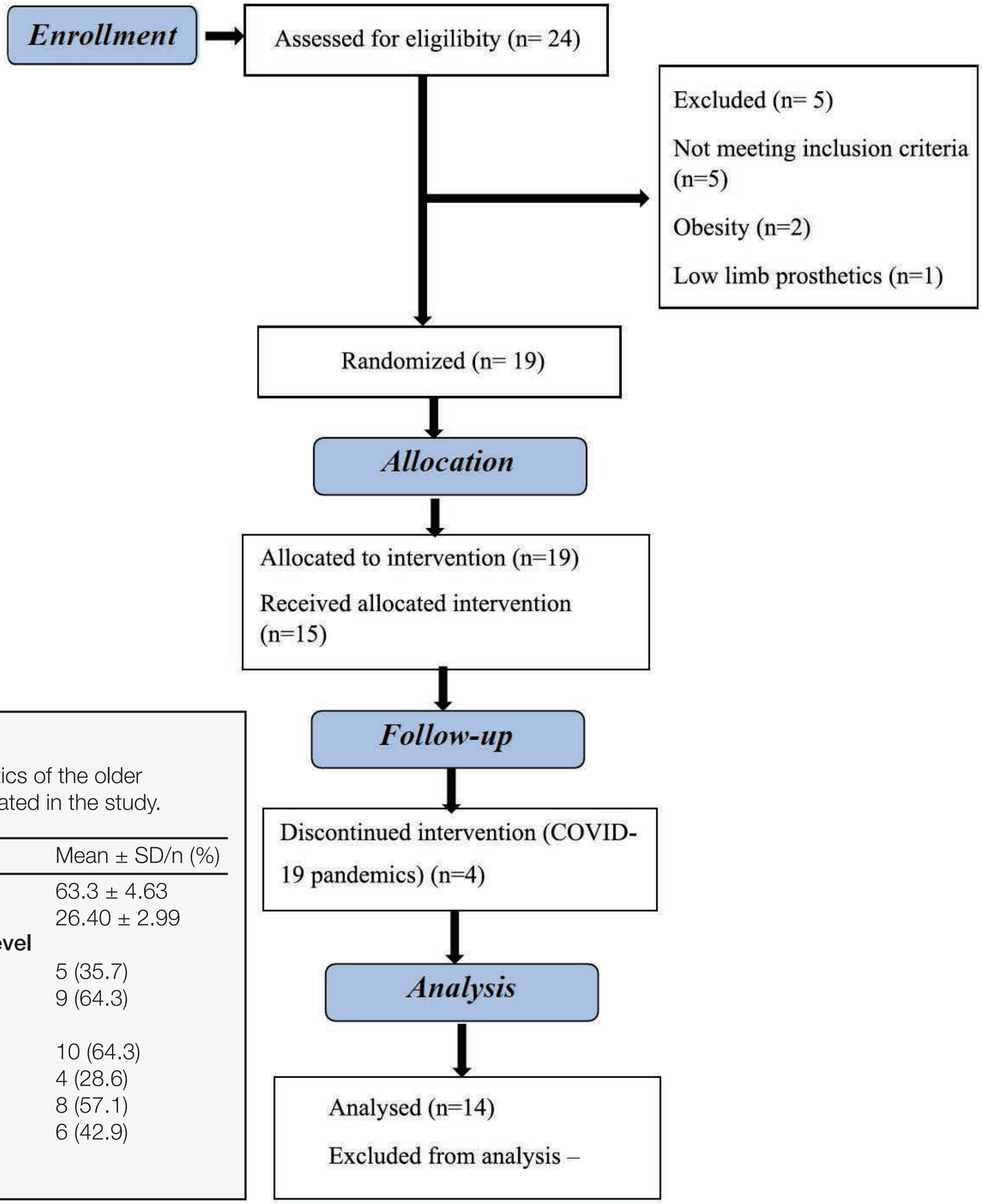

Table 1
Baseline characteristics of the older women who participated in the study.

Variables (n ¼ 14)	Mean ± SD/n (%)
Age (years)	63.3 ± 4.63
BMI (kg/m2)	26.40 ± 2.99
Physical Activity Level	
Sedentary	5 (35.7)
Irregularly active	9 (64.3)
Comorbidities	
Hypertension	10 (64.3)
Diabetes Mellitus	4 (28.6)
Arthosis	8 (57.1)
Osteoporosis	6 (42.9)

Fig. 1. Participant enrollment and randomization flow chart.

with 4 mm amplitude. We performed Wilcoxon's post hoc to identify the difference between these outcomes, as can be seen in Table 2 (Table 2).
According to the Friedman test results, a trend toward significance was observed in the anteroposterior postural balance test when WBV was performed with 4 mm amplitude, with a moderate effect size indicating greater stability with the 4 mm protocol when compared with the 2 mm protocol (-1.70 vs, e 0.55 mm, z ¼ -1.886, p ¼ 0.059 and 0.35 size). Moreover, no difference was observed at the end of training when applying the 2 mm or the 4 mm amplitude on the medial-lateral postural balance.
Moreover, the 4 mm protocol promoted an increase in strength (p ¼ 0.001) and reduced the time to complete the mobility test (p < 0.000). The mean difference (D) in the 4 mm amplitude WBV was significantly greater for strength (p ¼ 0.005), with an effect size of 0.90.
When we analyzed the effects of 2 mm and 4 mm WBV training on these outcomes, significant differences in favor to the 4 mm amplitude when compared to the 2 mm protocol were observed in both the strength (13.28 vs. 12.29 repetitions, z ¼ - 2.379, p ¼ 0.017) and the mobility test (9.24 vs. 10.06 s, z ¼ -2.166,p ¼ 0.030), with moderate effect sizes (0.45 and 0.41, respectively).
No changes were observed in the evaluated outcomes for the 2 mm amplitude.

Discussion:

A single WBV session with a 4 mm vibration amplitude not was sufficient to acutely improve static postural balance in older women, perhaps because they were healthy and irregularly active. However, significant differences were observed in muscle strength and functional mobility.

4.1. Static postural balance

Despite postural balance not changing after WBV exposure with an amplitude of 2 or 4 mm in the current study, a trend toward significance was observed in the anteroposterior postural balance test with the 4 mm protocol. Gomes et al. (2018) also did not report improvements in static postural balance after a single WBV session in active older women using a 4 mm vertical vibrating platform, 30 and 45 Hz frequencies, knees flexed at 110º and three sets of 60 s of vibration (Gomes et al., 2018). Vertical platforms induce very stable vibration patterns, predominantly moving in the vertical direction and more symmetrically, presenting few vibrations in the horizontal direction, and not significantly influencing the improvement of postural balance (Pel et al., 2009; Sañudo et al., 2013).

Ramos et al. (2019) reported improvement in postural balance in older women after a single WBV session using a side alternating vibration platform, with different frequency, vibration time and knee flexion angle from our study, but with the same 4 mm amplitude (Ramos et al., 2019). The vertical vibratory stimulus in our study was possibly not enough to transmit to the hip joint. This can be achieved through platforms with lateral vibration, as the postural balance disturbance in the older adults is better stimulated by hip movement, and hip displacement is directly related to static postural balance (Horak and Nashner 1986; Winter, 1995). Side alternating vibration platforms alternately produce vibratory stimulus between the feet and act with a wide adjustment range for frequency and vibration amplitude (5 Hze30 Hz; 0 mme20 mm), thus allowing to choose a more precise protocol when compared to vertical vibration platforms (Abercromby et al., 2007; Cochrane 2011; Rittweger 2010). These platforms which induce very stable lateral vibration contribute to improved postural balance by producing mediolateral and anteroposterior vibrations, being considered a more unstable surface (Pel et al., 2009; Sañudo et al., 2013).

4.2. Muscle strength

According to our results, lower-limb muscle strength in the older women was significantly improved when the 4mm-WBV protocol was used. A probable explanation for this result can be attributed to the effects of WBV on muscle function. WBV training induces short and rapid changes in the size of muscle fibers, stimulating reflex muscle contraction, which results in increased muscle activity, thus promoting a more efficient increase in muscle strength (Abercromby et al., 2007; Pollock et al., 2012). In addition, the muscle adjustment response generated by damping vibratory stimuli is considered another mechanism for increasing muscle function (Cochrane 2011).
The study by Ramos et al. (2019) also observed an increase in quadriceps femoris muscle strength in older women after a single WBV session. Although the amplitude used was similar to ours (4 mm), the frequency was lower (16 Hz), knee flexion angle was around 40, vibration exposure lasted 8 min, and the vibration used was lateral (Ramos et al., 2019). Unlike vertical vibration platforms, side alternating vibration platforms promote an asymmetric disturbance of the legs, as a greater distance between the feet and the platform rotation axis results in higher vibration amplitude (Abercromby et al., 2007), possibly providing more significant effects on the lower limb muscles (Abercromby et al., 2007b).

Table 2
Pre- and post-session values for balance, sit-to-stand, and timed up and go test (TUG).

Outcomes	Intervention	Pre-intervention	Post-intervention	Mean difference (Δ)	95% CI for the difference	% of change
Static Balance	WBV 2 mm	−0.17 ± 2.55	−4.59 ± 13.77	4.41 ± 13.32	−12.10; 3.28	137.70 ± 632.60
Medial-lateral	WBV 4 mm	−0.17 ± 2.55	−1.89 ± 2.76	1.72 ± 2.44	−3.13; −0.30	42.31 ± 226.94
Static Balance	WBV 2 mm	−1.49 ± 1.86	−0.55 ± 1,91	0.94 ± 2.22	−0.34; 2.22	13.60 ± 163.81
Anteroposterior	WBV 4 mm	−1.49 ± 1.86	−1.70 ± 1.26	−0.21 ± 1.56	−1.11; 0.69	4.85 ± 134.72
Sit-to-stand	WBV 2 mm	11.79 ± 2.86	12.29 ± 3.45	0.50 ± 1.45§	- 0.34; 1.33	4.14 ± 11.99
	WBV 4 mm	11.89 ± 2.86	13.28 ± 2.72#¥	1.50 ± 1.34	0.72; 2.27	14.73 ± 14.99
TUG	WBV 2 mm	11.22 ± 3.14	10.06 ± 3.44	- 1.16 ± 1.77	- 2.18; - 0.14	10.71 ± 17.51
	WBV 4 mm	11.22 ± 3.14	9.24 ± 2.57*¥	- 1.97 ± 2.24	- 3.27; - 0.67	16.24 ± 16.44

CI: Confidence interval; TUG: timed up and go test; WBV: whole body vibration; # Mean difference between 4 mm pre- and post-intervention, $p = 0.001$; * Mean difference between 4 mm pre- and post-intervention, $p < 0.000$; ¥Mean difference between 2 mm pre- and 4 mm post-intervention, $p < 0.000$; §Δ significant difference between 2 mm and 4 mm interventions, $p = 0.005$ (Paired *t*-test). Friedman test with post hoc Wilcoxon sign ranks test.

Although we discussed the use of frequencies between 30 and 40 Hz on lower limb muscle activation, this study restricted the results to the quadriceps femoris muscle (Ramos et al., 2019). Thus, the difference between the results can be justified by the natural frequency of the quadriceps muscle, which is between 8 and 11 Hz (Wakeling and Nigg 2001), and approaching the frequency of the vibratory platform used by the authors. According to Friesenbichler et al. (2014), the WBV exercise performed with a vibration frequency close to the natural frequency of the muscle promotes greater transmissibility to the muscular system, enhancing the results.

4.3. Functional mobility

The functional mobility of older women improved when the WBV was performed with an amplitude of 4 mm, reducing the execution time of the TUG test. Similar findings were obtained in the study by Miller et al. (2018), who reported a reduction in the TUG execution time and enhanced muscle power after a WBV session. The protocol in that study was similar to ours, differing only in frequency (30 Hz) and vibration duration (6 min) (Miller et al., 2018). Our results can be attributed to the increase in lower limb muscle strength. According to the literature, the greater the knee extensors and flexors muscle strength, the greater the movement speed of getting up from a chair, and the shorter the execution time of the TUG test (Falsarella et al., 2014; Martinez et al., 2015; Vikberg et al., 2019).
The reflex response of the lower limb muscles and the activation of the tonic and phasic muscles to stabilize the center of gravity on the base of support are observed during the TUG, especially the knee flexors and extensor actions during the sitting and standing up movements (Serra et al., 2016; Vikberg et al., 2019).

4.4. Adverse events

There we no severe adverse effects in this study related to WBV. Some patients showed transient fatigue and itching, which dis-appeared a few hours after the intervention, and no volunteers quit participation in the study. Studies conducted by other authors also reported transient adverse effects (Abercromby et al., 2007; Sitjà-Rabert et al., 2015), which also did not hinder the continuity of the protocol. The present study was focused on determining the best parameters for prescribing a WBV protocol for older women to achieve the proposed outcomes, and the results show this relevance.

4.4.1. Limitations

We should consider that the fixed frequency of 35 Hz and the use of two amplitudes (2 and 4 mm) provided by the vibrating platform model used limited verifying the effects on the outcomes evaluated from other frequency and amplitude ranges used in clinical practice. The measurement of vibration magnitude is an important parameter to be evaluated in future studies, since it was not performed in this study. However, we understand that despite this, it was possible to verify its effects on some of the outcomes, drawing attention to the need for additional studies with other frequencies, amplitudes, magnitude and types of vibration.

Conclusion:

The present study concludes that the acute effects of a single WBV session with an amplitude of 4 mm not was sufficient to improve the static postural balance in sedentary women, but improved the lower limb muscle strength and functional mobility. Future research needs to be developed with a larger sample size and a greater number of sessions in the long term including follow-up to ensure the prescription of effective WBV training protocols for the outcomes evaluated in the present study, because we under-stand that WBV may provide benefits for individuals in this age group.

5.1. Clinical relevance

WBV exercise is safe and well tolerated by older women, and is an alternative exercise modality. The specific WBV protocol for the older adult population would contribute to better adherence to physical exercise and promote greater safety in clinical practice.

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Declaration of interest
Credit authorship contribution statement

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data
Supplementary data to this article can be found online at https://doi.org/10.1016/j.jbmt.2022.05.010.

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