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Effects of supervised whole body vibration exercise on fall risk factors, functional dependence and health-related quality of life in nursing home residents aged 80+

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- WBV-based intervention in a nursing home setting is effective in reducing fall risk factors.
- Q3 WBV-based intervention is effective to improve quality of life in nursing home residents aged 80+..

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Effects of supervised whole body vibration exercise on fall risk factors, functional dependence and health-related quality of life in nursing home residents aged 80+

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ABSTRACT

Objective: To test the feasibility and effectiveness of whole-body vibration (WBV) therapy on fall risk, functional dependence and health-related quality of life in nursing home residents aged 80+ years.
Design: Twenty-nine 80–95 years old volunteers, nursing home residents were randomized to an eight-week WBV intervention group) ($n = 15$) or control group ($n = 14$). Functional mobility was assessed using the timed up and go (TUG) test. Lower limb performance was evaluated using the 30-s Chair Sit to Stand (30-s CSTS) test. Postural stability was measured using a force platform. The Barthel Index was used to assess functional dependence and the EuroQol (EQ-5D) was used to evaluate Health-Related Quality of Life. All outcome measures were assessed at baseline and at a follow-up after 8 weeks.
Results: At the 8-week follow up, TUG test ($p < 0.001$), 30-s CSTS number of times ($p = 0.006$), EQ-5Dmobility ($p < 0.001$), EQ-5DVAS ($p < 0.014$), EQ-5Dutility ($p < 0.001$) and Barthel index ($p = 0.003$) improved in the WBV intervention group when compared to the control group.
Conclusions: An 8-week WBV-based intervention in a nursing home setting is effective in reducing fall risk factors and quality of life in nursing home residents aged 80+.

1. Introduction

Falls are a major public health problem worldwide. Most incidents of falling are observed in older adults. At least 30% of people over the age of 65 experiences a fall each year, and this percentage increases up to 50% for those over 80 years [1]. Thus, falls are the leading cause of mortality [2] and morbidity [3] in older adults and account for extensive health care and social costs [4]. The incidence is about three times higher in institutionalized older adults compared to independently-living older adults [5]. Moreover, independence in activities of daily living are compromised in fallers [6]. Therefore, health-related quality of life is often reduced in this population group [4].

It has been well established that balance, postural control and mobility function decline with aging [7]. Also, muscle weakness and reduced strength [8] (identified as major modifiable risk factors for falls [9]) are part of the aging process. Moreover, older adults living in a nursing home often have reduced mobility and poor balance when compared with their peers living in the community [10]. Hence, feasible and effective interventions to modify these fall-related risk factors are warranted among the older adult population. Within this context, exercise is one of the most common strategies for fall prevention [11], even for those living in nursing homes [5].

There is also strong evidence for the effectiveness of strength and balance exercise intervention programs for fall risk reduction [12,13], even for older adults living in nursing homes [5,14]. However, an appropriate the appropriate combination of vibration frequency and amplitude (dose) is necessary for successful fall risk reduction [15]. Therefore, it has been stated that high-dose exercise programs produce more significant results than a lower-dose strategies [16]. Such programs seem to be feasible among individuals over 80 years of age [17], but frailer individuals, such as nursing home residents, have difficulty performing such programs because of the fatigue [17] or even fear of falling [14]. Thus, other alternatives need to be evaluated with these individuals.

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Table 1
Description of the training protocol.

Weeks	Sessions/wk	Warm up	Number of WBV exercises	Number of WBV repetitions	Frequency (Hz)/amplitude (mm)	Rest period (s)	WBV total repetitions	WBV total session duration (min)
1–2	3	3/30 s/30 s	6	6	30/4	45	48	12.3
3–4	3	3/30 s/30 s	6	8	30/4	45	64	13.9
5–6	3	3/30 s/30 s	6	10	35/4	45	80	15.5
7–8	3	3/30 s/30 s	6	12	35/4	45	96	17.1

Whole-body vibration (WBV) training has become increasingly popular over the past several years as an effective alternative to conventional exercise programs. WBV training minimizes the need for conscious exertion and stress on the musculoskeletal, respiratory and cardiovascular systems in comparison with traditional exercises [18]. In addition, over a short period of time, it can be useful for improving postural control among older adults [19], thereby reducing risk of falls in this population [20]. Subsequently, WBV training can be applied in frailer persons as well as in those that report a previous sedentary status [20]. Therefore, WBV training has been shown to be feasible among older adults living in nursing homes [21]. The same study demonstrated that dynamic exercises upon WBV have been shown to be more effective on some functional outcomes than static exercise.

Unfortunately, few studies have been conducted to test the usefulness of WBV training to reduce the risk of falling (or related factors) among nursing home residents and those that have been conducted have yielded inconsistent results [21–25]. The feasibility and effectiveness of WBV for this purpose have rarely been investigated among those over 80 years [22,24,25]. Moreover, only one of these studies assessed health-related quality of life [22] and, to our knowledge, none of these studies have assessed the effects of this type of therapy on either functional dependence or in lower limb muscle performance (including power) among this population. Therefore, the aim of this study was to determine if 8-weeks of a dynamic WBV exercise program is feasible and effective for nursing home residents aged 80+ years and whether it offers any additional benefits to the usual nursing home care for fall-related risk factors, health-related quality of life and functional dependence among this clinical population.

2. Materials and Methods

2.1. Participants and study design

A randomized controlled trial (ACTRN12613000189729) was conducted. The study was approved by the research ethics committee of the University and conducted in accordance with the Declaration of Helsinki, as revised in Edinburgh, 2008. All participants signed an informed consent form prior to participation in the study. Participants in the study were recruited via health care staff from a nursing home facility. Residents were eligible for the study if they were at least 80 years old and were institutionalized in the nursing home where the study was performed. Potential participants were excluded if they had a pacemaker, knee or hip prosthesis, acute thrombosis or its high risk, acute musculoskeletal inflammation, hernia, cardiac or other systemic disease not well balanced with medical treatment, diabetic neuropathy, or severe vertigo. Ultimately, the medical staff from the nursing home checked the inclusion/exclusion criteria and granted the participant's enrollment in the program. Out of 60 eligible participants, 35 showed initial interest in the study. However, only 29 fulfilled the inclusion/exclusion criteria and were allocated to one of the two study groups using a computer generated random allocation data processing program and a 1:1 ratio (intervention: control). Randomization was undertaken by a member of the research team not directly involved in the recruitment or assessment of patients.

2.2. Experimental protocol

Participants in both the intervention and control groups had access to the usual nursing home care available in public nursing homes in the south of Spain (i.e., physiotherapy including 1 h/week of therapeutic massage and heat therapy and 4 h per week of mobility and stretching exercise, occupational therapy—mainly designed to train the memory, and nursing care). Participants in the control group were further asked to not change their lifestyle. Participants in the intervention group participated in an 8-week WBV-based program consisting of three sessions per week with at least one day between sessions. Description of the WBV intervention is provided in Table 1. Each exercise session was performed on a vertical platform (YV20RS 700, BH, Spain) with a frequency of 30 Hz for the first month and 35 Hz for the last month. Peak-to-peak displacement of 4 mm was maintained during the entire program. For warm-up, participants adopted an isometric squat position flexing the knees about 80° for 30 s. This exercise was repeated three times. After that, participants were asked to perform six exercises (step up and down, lunge, squat, calf raises, left and right pivot in a front and lateral positions) with slow movements at a rate of 3 s for both concentric and eccentric phases. The repetitions in each exercise were gradually increased every two weeks starting from 6 and reaching 12 repetitions with a rest period of 45 s for the entire program. All participants in the intervention group received a training session on the exercise program consisting of an explanation and trial of the different exercises which comprised the training protocol. Each training session was supervised by one of the researchers of the study and the physiotherapist of the nursing home.

2.3. Outcome measures

The outcomes measures were assessed before the randomization and after the end of 8-week WBV intervention. All outcome measures were performed in the nursing home.

Socio-demographic variables (i.e., age and gender) as well as clinical predictor variables (i.e., years since home nursing care and number of daily drugs) were recorded. Weight, height, and waist and hip circumference were measured to calculate body-mass index (BMI; kg/m^2) and waist to hip ratio. Body-fat percentage was also estimated using an impedance analyzer (Omron BF-306, Omron Healthcare Europe BV, Hoofddorp, The Netherlands) according to the manufacturer's instructions.

Functional mobility was assessed using the Time Up and Go (TUG) test [26]. The score of this test has been previously used as an important outcome among nursing home residents [22,27], and even has been proposed as an indicator of fall risk in community-dwelling older adults [28]. Participants had to stand up from a standard chair, walk 2.44 meters to and around a cone, and then return to the chair in the shortest possible time. The best time of two trials (1-min rest period between each trial) was recorded.

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This test was assessed at baseline and at the 2, 4, 6 and 8-week follow-up.

Muscle performance was assessed using the 30-s Chair Sit to Stand (30-s CSTS) test [29]. This test has been previously used for nursing home residents [30]. Participants were instructed to perform the task which started and finished in a seated position. Participants were allowed a practice trial before the beginning of the test. The number of times within 30 s that the participant could raise to a full stand from a seated position as fast as possible, with their back straight and feet flat on the floor without pushing off using their arms, was counted. The maximum speed of each repetition as well as the average speed was recorded with a Linear Encoder (Model TF-100, T-Force System Ergotech, Murcia, Spain) and the peak force was recorded using a Kistler force platform, type 9281A (Kistler Instruments AG, Winterthur, Switzerland). The peak power during the test could then be calculated.

Postural stability was measured using a Kistler force platform, type 9281A (Kistler Instruments AG, Winterthur, Switzerland) by recording the anterior–posterior (AP) and medial–lateral (ML) center of pressure (COP) excursions while in a quite standing posture. Sway ellipse area (cm^2) was calculated 3 times each with increasing postural difficulty: (i) standing on the force platform with the eyes open, (ii) standing on the force platform with the eyes open (cognitive task) and (iii) standing on the force platform with the eyes closed. For each condition, three trials were performed. Each trial lasted for 30 s and was followed by a rest period of 1 min. In this case, only the final 20 s were analyzed [31]. The cognitive task was counting backwards as fast and as accurately as possible by 3 s whilst performing the standing task, beginning with a randomly selected number from a range of 100–200. Data were sampled at 1000 Hz and transformed to obtain COP values.

The Barthel Index (BI) of ADL [32] was used to measure performance in activities of daily living (ADL) of the participants. The Barthel Index of ADL is comprised of 10 items (bathing, grooming, feeding, dressing, bowels, bladder, toilet uses, stairs, transfer and mobility) that evaluate a person's ability to perform activities of daily living. Total scores were calculated by summing the individual item scores. Scores were weighted and ranged from 0 (dependence) to 100 (independence). For analysis purposes, those participants scoring 100 were considered to be independent.

The EuroQol-5D (EQ-5D) [33] was used to assess health-related quality of life (HRQoL). The EQ-5D includes five dimensions (mobility, personal care, usual activities, pain/discomfort and anxiety/depression), each of which has three levels (no problems, some problems, or extreme problems/unable to) with answers ranging from 1 to 3. For analysis purposes, these dimensions were grouped into problems and no problems. The juxtaposition of the levels for these five dimensions correlates to a five-digit number, which reflect 243 possible health status values. These health status values can be converted to a health functional index or a 'utility', using time-trade off values (EuroQol utility: 1 = full functional quality of life, 0 = death). The EQ-5D-3L also includes a vertical 20-cm Visual Analogue Scale (VAS) which is used by participants to rate their own health between 0 (worst imaginable health state) and 100 (best imaginable health state), thereby providing an overall numerical estimate of their HRQoL [34].

2.4. Statistical analysis

Intent to treat and per-protocol analyses were performed using SPSS version 17.0 (SPSS Inc., Chicago, IL, USA). The significance level was set at $p < 0.05$ for all analyses. The distribution of the data was examined using the Shapiro Wilk test. After non-normal distribution of the data was confirmed, between-group comparisons at baseline were performed using Mann–Whitney *U* test for continuous variables or chi square analysis and between-groups comparisons after treatment were performed using Mann–Whitney *U* test or chi square analysis. Wilcoxon test was used to assess the intra-group pre (baseline) to post (8-week follow up) differences of the different outcomes of the study. Effect sizes and probability of superiority were calculated and interpreted according to previously published guidelines [35]. Friedman test was used to compare the TUG test score and 30-s CSTS across the 8-week treatment in the intervention group and Wilcoxon test was used to assess the differences between the different follow-up points in the in the same group.

3. Results

Twenty-nine nursing home residents were finally randomized into one of the two groups (Fig. 1). None of the participants in the intervention group reported any adverse health effects during the treatment. In the intervention group, 73% (11 out of 15) of all participants completed at least 80% of the sessions offered in the program and were included in the per protocol analysis. In the control group, 78% were assessed at baseline and during an 8-week follow-up and were also included in the per protocol analysis. Intent-to-treat analysis was performed with the complete randomized sample. When follow-up data were not available, the last value carried forward method (i.e., take into account the last observation of the analysis) was used to impute for the missed data. In the intervention group, 25% of follow-up data were imputed. In the rest of the cases, the real observation was used as data. In the control group, 100% (3 out of 3) of follow-up data were imputed. Participants in the intervention group reported no adverse health events during the program period.

The baseline characteristics of the study participants were compared (Table 2). No statistically significant differences were observed between participants in the two groups of the study. Intent to treat analysis depicted similar results.

Mann–Whitney *U* test depicted a statistically significant effect of the treatment (i.e., WBV vs. usual care) at 8-week follow-up on several lower limb performance outcomes assessed including mobility [TUG test ($p =< 0.001$)] and 30-s CSTS number of times ($p = 0.006$) (Table 3). We also detected a pre to post improvement (i.e., greater scores) in the intervention group regarding the 30-s CSTS peak power (Table 3). However, we did not detect any differences for any of the postural stability outcome measures assessed ($p > 0.05$). HRQoL [$\text{EQ-5D}_{\text{mobility}}$ ($p < 0.001$), $\text{EQ-5D}_{\text{utility}}$ ($p < 0.001$) and $\text{EQ-5D}_{\text{VAS}}$ ($p = 0.014$) and performance in ADL [Barthel index ($p = 0.003$) and the number of independent participants ($p < 0.001$)] improved (increased) in the intervention group as compared to the control group (Table 4). Intent to treat analysis depicted similar results.

TUG test scores improved (decreased) across the five follow-up assessments ($p = 0.001$). However, only statistical significant differences were detected between the scores at baseline and 4 weeks ($p = 0.018$), 6 weeks ($p = 0.021$) and 8 weeks ($p = 0.010$); between 2 weeks and 8 weeks ($p = 0.013$); between 4 weeks and 8 weeks ($p = 0.017$) and between 6 weeks and 8 weeks ($p = 0.012$) (Fig. 2). Similarly, the 30-s CSTS number of times improved (increased) across the five follow-up assessments ($p < 0.001$). In this case, statistical significant differences were only detected between the scores at baseline and 2 weeks ($p = 0.005$), 4 weeks ($p = 0.003$), 6 weeks ($p = 0.005$) and 8 weeks ($p = 0.007$) (Fig. 2). Intent to treat analysis depicted similar results.

4. Discussion

Falls are one of the leading causes of mortality [2] and morbidity [3] among institutionalized older adults. In this study, we

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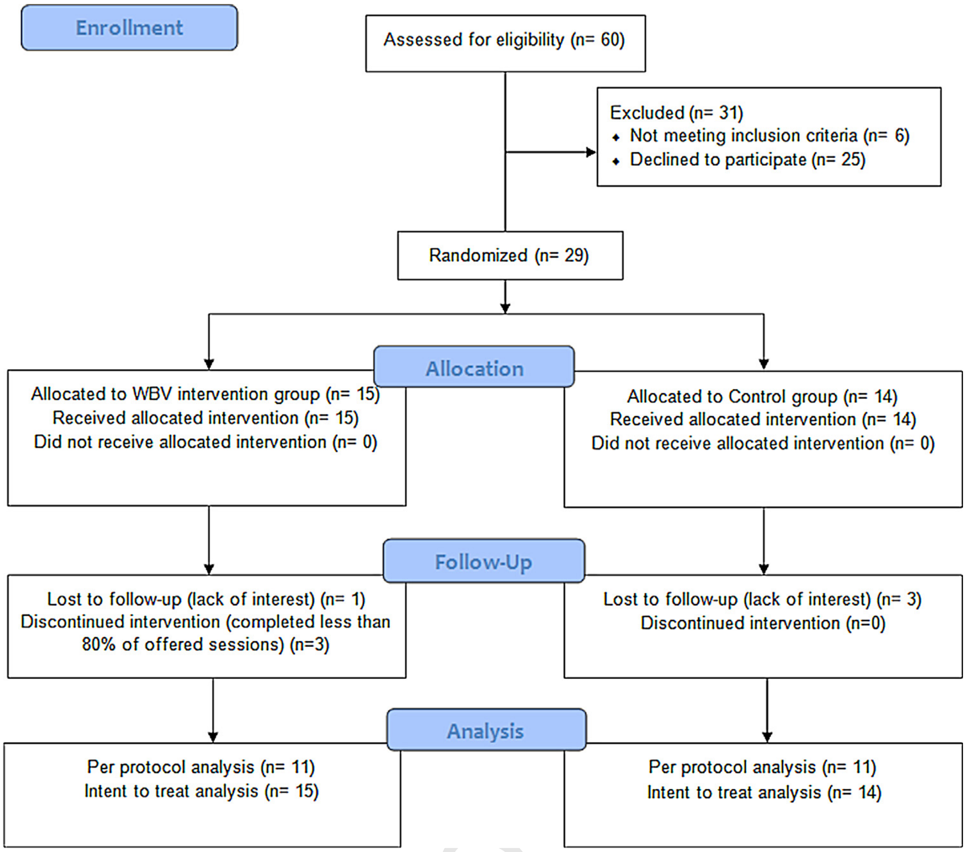

Fig. 1. Flow diagram of the participants in the study.

Table 2
Demographic and clinical characteristics of study participants.

Variables	Per protocol analysis			Intent to treat analysis		
	Control group ($n = 11$)	WBV group ($n = 11$)	*p*	Control group ($n = 15$)	WBV group ($n = 14$)	*p*
Socio-economic variables						
Age (years)	85.5 (6.7)	84.0 (3.0)	0.595[a]	86.0 (7.5)	84.0 (3.0)	0.523[a]
Gender (% females)	81.8	72.7	0.611[b]	85.7	80.0	0.684[b]
Body composition						
BMI (kg/m^2)	29.2 (7.2)	26.0 (3.4)	0.056[a]	28.5 (7.7)	26.8 (3.4)	0.169[a]
WHR	0.89 (0.1)	0.91 (0.1)	0.974[a]	0.90 (0.1)	0.90 (0.09)	0.861[a]
Body fat (%)	42.8 (14.0)	40.6 (11.8)	0.725[a]	42.7 (12.3)	43.9 (11.25)	0.520[a]
Clinical variables						
Years institutionalizing	4.2 (6.8)	2.0 (3.0)	0.104[a]	3.2 (5.6)	3.0 (2.6)	0.518[a]
Number of daily drugs	8.0 (6.0)	5.0 (3.0)	0.113[a]	7.5 (4.5)	5.0 (4.0)	0.148[a]

Values are median (IQR) unless otherwise indicated; BMI: Body Mass Index; WHR: waist to hip ratio; *p*: *p* value from Mann–Whitney *U* [a] or x^2 test [b].

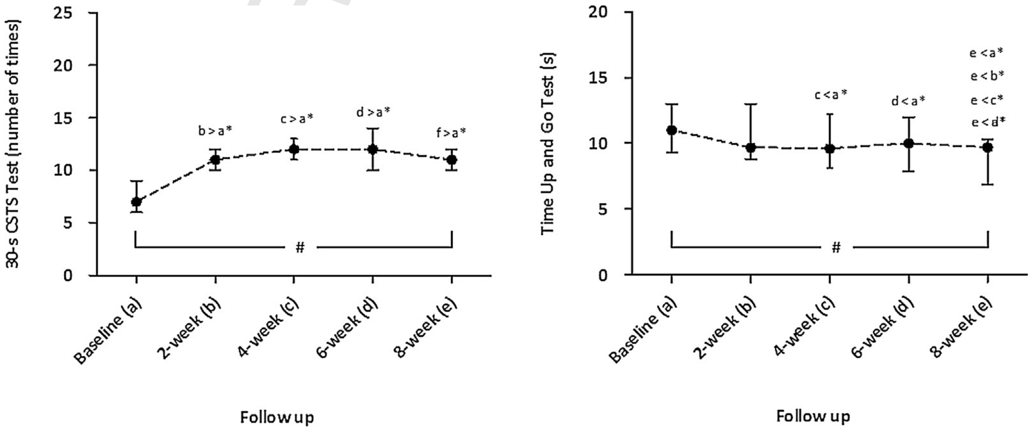

Fig. 2. Median changes (IQR) in 30-s Chair Sit to Stand test score (left) and Time Up and Go test score (right) over the 8-wk treatment in the participants that followed the whole body vibration intervention. * Denotes statistical significant differences.

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Table 3
Lower limb performance outcomes.

Outcome measures	Per protocol analysis							
	Baseline		p	Post-intervention		p	Effect size	PS
	Control group ($n = 11$)	Intervention group ($n = 11$)		Control group ($n = 11$)	Intervention group ($n = 11$)			
Time “Up and Go” Test (s)	14.25 (6.25)	11.00 (4.30)	0.231	15.70 (6.08)	$9.70\ (3.40)^*$	<0.001	0.766	96
30-s CSTS (number of times)	7.00 (2.00)	7.00 (3.00)	0.920	7.00 (3.00)	$11.00\ (2.00)^*$	<0.001	0.776	96
30-s CSTS V_{max} (m/s)	0.46 (0.26)	0.54 (0.35)	0.341	0.49 (0.20)	.056 (0.17)	0.082	0.371	71
30-s CSTS V_{med} (m/s)	0.41 (0.23)	0.48 (0.31)	0.412	0.41 (0.16)	0.43 (0.22)	0.375	0.189	61
30-s CSTS strength (N)	787.93 (321.27)	644.24 (185.16)	0.491	802.02 (209.82)	750.38 (278.69)	0.450	0.161	61
30-s CSTS power (W)	399.48 (257.77)	373.29 (284.14)	0.922	414.01 (205.21)	$419.55\ (260.16)^*$	0.412	0.175	61
Area (cm^2): opened eyes	2.43 (0.90)	1.39 (2.88)	0.200	2.35 (3.56)	1.83 (2.15)	0.178	0.287	66
Area (cm^2): closed eyes	3.53 (2.89)	1.71 (2.99)	0.250	3.52 (3.62)	1.89 (4.03)	0.309	0.217	61
Area (cm^2): cognitive interference	2.24 (1.91)	1.76 (6.01)	0.622	1.98 (1.72)	2.39 (0.99)	0.308	0.217	61

Intent to treat analysis

Baseline		P	Post-intervention		p	Effect size	PS
Control group ($n = 15$)	Intervention group ($n = 14$)		Control group ($n = 15$)	Intervention group ($n = 14$)			
14.15 (7.67)	11.40 (4.90)	0.329	15.70 (6.27)	$9.90\ (4.80)^*$	0.002	0.575	84
7.00 (3.00)	7.00 (4.00)	0.642	7.00 (3.00)	$10.00\ (2.00)^*$	0.006	0.515	80
0.46 (0.21)	0.49 (0.26)	0.485	0.46 (0.18)	0.54 (0.26)	0.198	0.239	64
0.38 (0.19)	0.39 (0.28)	0.383	0.35 (0.16)	0.39 (0.27)	0.407	0.152	58
683.60 (580.96)	734.96 (185.16)	0.760	770.26 (485.88)	750.38 (266.31)	1.000	0.02	0
297.18 (285.46)	344.15 (259.71)	0.600	304.00 (256.55)	$346.82\ (279.40)^*$	0.159	0.170	61
2.43 (1.50)	1.39 (4.66)	0.222	2.45 (3.85)	1.83 (2.13)	0.206	0.235	64
3.64 (4.87)	2.37 (2.84)	0.206	3.88 (7.18)	2.28 (4.36)	0.315	0.186	27
2.73 (2.89)	1.77 (4.44)	0.485	2.00 (3.17)	2.39 (1.52)	0.694	0.073	53

Values are median (IQR); Control group: group that had access to usual care; Intervention group: group that had access to the WBV intervention and usual care; CSTS: chair sit to stand test; p; p value from Mann–Whitney U; * $p < 0.05$ (intra group differences following Wilcoxon test); PS: probability of superiority.

Table 4
Health-related quality of life and activities of daily living outcomes.

Outcome measures	Per protocol analysis							
	Baseline		$p^{a\ or\ b}$	Post-intervention		$p^{a\ or\ b}$	Effect size	PS
	Control group ($n = 11$)	Intervention group ($n = 11$)		Control group ($n = 11$)	Intervention group ($n = 11$)			
EQ-5D								
EQ-5D$_{mobility}$, *problems* (%)	63.60	36.40	0.201^b	90.90	0.00	$<0.001^b$	0.913	–
EQ-5D$_{self\text{-}care}$, *problems* (%)	18.20	9.10	0.534^b	27.30	9.10	0.269^b	0.235	–
EQ-5D$_{daily\ life\ activities}$, *problems* (%)	27.30	0.00	0.062^b	27.30	0.00	0.062^b	0.397	–
EQ-5D$_{pain/discomfort}$, *problems* (%)	72.70	90.90	0.269^b	72.70	54.50	0.375^b	0.188	–
EQ-5D$_{anxiety}$, *problems* (%)	27.30	9.10	0.269^b	27.30	0.00	0.062^b	0.397	–
EQ-5D$_{utility}$	0.78 (0.15)	0.88 (0.10)	0.215^a	0.78 (0.07)	$0.89\ (0.12)^*$	$<0.001^a$	−0.774	96
EQ-5D$_{VAS}$	70.00 (45.00)	80.00 (35.00)	0.763^a	70.00 (20.00)	$90.00\ (20.00)^*$	0.014^a	−0.524	80
Barthel index								
Total	85.00 (30.00)	95.00 (10.00)	0.069^a	85.00 (20.00)	100.00 (5.00)	0.003^a	−0.640	89
Independent, *yes* (%)	27.3	45.5	0.455^b	0.00	63.6	$<0.001^b$	0.683	–

Intent to treat analysis

Baseline		$p^{a\ or\ b}$	Post-intervention		$p^{a\ or\ b}$	Effect size	PS
Control Group ($n = 15$)	Intervention Group ($n = 14$)		Control group ($n = 15$)	Intervention group ($n = 14$)			
71.4	46.7	0.176^b	92.9	20.0	$<0.001^b$	0.732	–
14.3	13.3	0.941^b	21.4	13.3	0.564^b	0.107	–
28.6	6.7	0.119^b	35.7	6.7	0.054^b	0.358	–
78.6	80.0	0.924^b	78.6	46.7	0.077^b	0.328	–
21.4	6.7	0.249^b	21.4	0.0	0.058^b	0.351	–
0.78 (0.16)	0.87 (0.10)	0.111^a	0.76 (0.07)	$0.88\ (0.13)^*$	$<0.001^a$	−0.689	91
77.5 (45.75)	80.00 (40.00)	0.860^a	80.00 (24.5)	$90.00\ (25.00)^*$	0.131^a	−0.280	66
85.00 (26.25)	95.00 (10.00)	0.247^a	85.00 (20.00)	100.00 (5.00)	0.006^a	−0.515	80
35.7	46.7	0.833^b	14.3	66.7	0.004^b	0.531	–

Values are median (IQR) unless otherwise stated; Control group: group that had access to usual care; Intervention group: group that had access to the WBV intervention and usual care; CSTS: Chair Sit to Stand Test; Independent: Barthel index = 100; p^a: p value from Mann–Whitney U; p^b: p value from x^2 test; * $p < 0.05$ (intra group differences following Wilcoxon test); PS: probability of superiority.

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investigated the feasibility and effectiveness of WBV therapy in nursing home residents over the age of 80 years. Of interest in this study is the fact that fall-related risk factors, performance in daily life activities and health-related quality of life outcomes were included and assessed in the same group of participants so that more certain conclusions might be achieved. The main findings in the current study were the enhancements in fall risk-related factors, performance of the daily life activities and health-related quality of life in institutionalized octogenarians after 8-weeks of WBV therapy. Hence, the results of this study are promising and of value to people working in nursing home facilities.

One of the novelties of this study was to test the effects of WBV on lower limb muscle performance (i.e., peak power, peak velocity and strength) during a test that simulates a real daily life task (i.e., sit to stand test). To the best of our knowledge, this is the first study analyzing the effects of a WBV therapy on the lower limb muscle performance outcomes using a functional test among institutionalized older adults. After the program, participants in the intervention group increased their skeletal muscle power. This result is of importance because it has been previously reported that skeletal muscle power decreases before strength with advancing age [36] and also, skeletal muscle power seems to be more related to functionality than muscle strength in older adults [37]. Wilcoxon test derived effect size (not reported in tables) was $r = 0.57$ for power which is considered large. Therefore, even though our participants did not improve lower limb strength, the TUG test score improved at 8-week follow-up. This is in accordance with previous RCTs testing the effects of WBV among nursing home residents [22,24]. It has been previously hypothesized that in response to the vibration stimulus (tonic vibratory reflex), more motor units are activated leading to a better neuromuscular response [38]. This hypothesis may help, at least in part, to explain the power output increases observed in the current study [39] and the subsequent TUG test score improvement [40].

The TUG test and the 30-s CSTS test (number of times) were assessed at baseline, 2, 4, 6 and 8-week follow-up. Interestingly, although there was a trend toward the improvement across the different assessments points in both tests (i.e., we found statistical significant differences between baseline and the 8-week treatment), we failed to find any significant difference between the last points of assessment. This was especially true in the case of the 30-s CSTS test where only significant differences were detected between the first assessment point (i.e., baseline) and the rest of the assessments points (i.e., 2,4,6 and 8 weeks) but no differences were detected between these last assessment points. Similarly, the TUG score improved between the first assessment point and the rest of the assessment points and slightly did so (but still significantly) between the second point of assessment and the 6- and 8-week assessment. Also, the TUG score improved between the 6-week and final assessment. This may suggest that a high dose of WBV should better enhance the lower limb muscle performance and mobility. However, considering that we designed the exercise to be safe for the patients, we decided to start in the lower range (30 Hz) and progressed to 35 Hz for the last 4-week period with slight variation in time application of the bouts every 2 weeks. Future studies should test how less conservative doses (e.g. higher frequencies) of WBV affect the outcomes assessed in the current study among the studied population. Nevertheless, after treatment effect sizes for both TUG and 30-s CSTS test (number of times) ($r = 0.76$ and $r = 0.77$, respectively) were considered large, with a probability of superiority of 96% [35]. That means that the probability of success at improving the performance in the TUG test of those participants allocated in the intervention group as compared to those participants in the control condition is 96%.

On the other hand, the results of the postural stability test showed that WBV did not have a significant effect on static balance. This could reflect the aforementioned effects of a conservative dose of WBV. Also, the fact that the nature of the exercise program performed on the vibration device was dynamic exercise can support the lack of improvement in statics tests, thus, supporting the improvement in dynamic tests (TUG test). Another, more comprehensive possible reason is that balance is controlled by a combination of sensory, neuromuscular and biomechanical factors [41]. Although WBV can improve biomechanical factors like muscle strength, power, and flexibility, which may result in a positive effect on the dynamic performance (as reflected by the improvements in the lower limb muscle performance and the improvements seen in the TUG score in the current study), it may not have the same effect on sensory factors, especially for older adults over 80 years who normally have a significant decline of the sensory-motor functions. Another plausible explanation for the lack of positive findings regarding postural stability could be the type of vibration used in this study (i.e., vertical stimulation) as other studies on other clinical populations have found positive effects on postural stability using reciprocal stimulation [14,42,43].

Unsurprisingly, participants in the intervention group reported a better performance in their activities of daily living after the 8-week treatment. This could reflect the improvement in their dynamic balance and in their lower limb muscle performance, thus leading to more freedom in their daily life activities routine and preventing disability [40]. Consequently, participants in the study reported improvements in their health-related quality of life, mainly in the mobility dimension and the anxiety/depression dimension of the EQ-5D questionnaire. This could reflect the aforementioned performance in daily life activities, thereby reducing the anxiety/depression levels among the participants in the study [44]. The only study analyzing the effects of WBV among nursing home residents obtained similar results using the SF-36 questionnaire [22]. The effect sizes calculated in the current study range from medium to large for these before commented variables. Thus, our results strengthen the idea that appropriate WBV can prevent and even improve the decline of health-related quality of life with aging [45]

Some limitations need to be acknowledged. The small sample size could limit the generalization of the results. Despite this, this study was carried out as a pilot trial to determine the feasibility of the program and to determine the direction of future, large trials. Due to the small sample size it was not possible to determine the optimal dose-response of the WBV, thus this question still remains unknown. Another shortcoming is that our participants wear their own shoes so a potential damping of the vibration could be noticed. Also, the comparison of this kind of therapy with other successful ones, such as multi-component exercise interventions [40], is required. We did not record the number of falls in each group but the results showed in the current study might indicate a reduction in risk of falling. One might think that the performed exercise on the vibration platform could be considered low intensity resistance training or that WBV dose applied was also low. However, these aspects support the fact that we designed the exercise to be safe for and tolerable by the patients. The lack of a third group performing the same program of exercise on the same machine but without vibration does not allow for more certain conclusions. However, another previously published study comparing the effects of dynamic exercise with and without vibration on function among institutionalized older adults has yield some promise results [21]. Future studies might consider including some outcomes regarding satisfaction with treatment. Further cost-effectiveness analysis is warranted to enhance the decision-making process of policy makers on the implementation of this type of intervention in nursing home settings. This research line can clearly be heightened by a multi-centric approach involving a large sample size allowing us to answer all of these remaining

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questions. This could allow for the development of more specific WBV interventions designed for specific subgroups with different frailty levels.

5. Conclusion

The application of an 8-wk WBV-based intervention in a nursing home setting is feasible and effective to reduce fall risk factors, improve performance in activities of daily living and increase health-related quality of life in nursing home residents over the age of 80 years. In practice, these findings could operate as a model for nursing home practitioners to implement WBV as an exercise-based management intervention for residents in nursing homes.

Q4 Contributors

Q5 J.P.C and B.P.C designed the study and directed its implementation, including quality assurance and control. R.A.R and Y.Z helped supervise the field activities and designed the study's analytic strategy. F.A.B helped conduct the literature review and prepare the introduction, Materials and Methods sections on the text. M.E.R. prepared the discussion and helped in stat analysis. All authors approved the final version of the manuscript.

Competing interest

The authors declare no conflict of interest.

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