The feasibility of whole body vibration in institutionalised elderly persons and its influence on muscle performance, balance and mobility: a randomised controlled trail.

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Abstract

Background
Fatigue or lack of interest can reduce the feasibility of intensive physical exercise in nursing home residents. Low-volume exercise interventions with similar training effects might be an alternative. The aim of this randomised controlled trail was to investigate the feasibility of Whole Body Vibration (WBV) in institutionalised elderly, and its impact on functional capacity and muscle performance.

Methods
Twenty-four nursing home residents (15 female, 9 male; mean age 77.5±11.0 years) were randomised (stratification for age, gender and ADL-category) to 6 weeks static WBV exercise (WBV+, N=13) or control (only static exercise; N=11). Outcome measures were exercise compliance, timed up-and-go, Tinetti-test, back scratch, chair sit-and-reach, handgrip strength and linear isokinetic leg extension.

Results
At baseline, WBV+ and control groups were similar for all outcome variables. Twenty-one participants completed the program and attended respectively 96% and 86% of the exercise sessions for the WBV+ and control groups. Training-induced changes in timed up-and-go and Tinetti-test were better for WBV+ compared to control ($p=0.029$ and $p=0.002$ respectively). Subjects of the WBV+ group improved on timed up-and-go ($p=0.008$) and maintained baseline Tinetti-scores. In the controls, timed up-and-go remained unchanged and Tinetti-scores worsened ($p=0.004$). Improved leg extension performance was observed in both groups ($p<0.05$) and chair sit-and-reach improved in the WBV+ group ($p<0.05$); without significant difference in changes between both groups.

Conclusions
In nursing home residents with limited functional dependency, six weeks static WBV exercise is feasible, and is beneficial for balance and mobility. The supplementary benefit of WBV on muscle performance compared to classic exercise remains to be explored further.

Background

In old age, muscle weakness due to sarcopenia is responsible for the development of frailty and important disability [1-3]. Especially in institutionalised elderly persons, muscle strength can deteriorate to a point where it becomes critical for independence of transfers and walking.

There is strong evidence that in healthy older persons major gains in muscle strength can be obtained by resistance exercises [4]. Also in frail institutionalised elderly resistance training is feasible [5, 6], and can lead to clinically relevant strength gain and improved mobility [7, 8].

However, intensive resistance training programmes targeting key muscle groups necessary for transfers and walking attain often exercise volumes of 45 minutes or more at submaximal intensity (3 series of 10 repetitions at 70-80% maximal strength). Consequently, fatigue or lack of motivation can reduce its feasibility in frail elderly subjects.

Whole body vibration (WBV) is a new training method using an oscillating platform upon which exercises are performed (e.g., standing, static or dynamic). A small volume of this type of exercises has been reported to lead to significantly improved muscle function in young [9, 10] and healthy elderly persons [11].

The aim of this randomised controlled trial was to investigate the feasibility of WBV in frail institutionalised elderly persons, and its impact on muscle performance and functional capacity.

Methods

Participants

All residents of a nursing home (Van Zanden, Brussels, Belgium; capacity of 102 beds) within dependence categories O, A and B according to the scale of Katz et al. [12] for basic activities of daily living (ADL) were eligible. Exclusion criteria were mainly based on contra-indications for WBV: presence of infectious disease, insulin-dependent diabetes mellitus, endogenous osteosynthethical material, knee or hip prosthesis, pacemaker, epilepsy, musculo-skeletal disorders and cognitive or physical dysfunction interfering with test and training procedures.

At the moment of the study, 98 subjects (74 female and 24 male) resided in the nursing home, among whom 62 were eligible (N=39 and N=23 for category O/A and B respectively). Thirty-Three persons showed no exclusion criteria, among whom 24 gave informed consent to participate in the study (15 female and 9 male, mean age 77.5 ± 11.0 years). All participants were naïve for WBV. The local ethical committee approved the study.

Randomisation

The participants were randomised in two groups, with stratification for age, gender and ADL-category. One group was assigned to 6 weeks static WBV exercise (WBV+, N=13) and another group to the same exercise regimen without WBV (control, N=11). (Table 1)

Intervention

The participants assigned to the WBV+ group performed a 6-week exercise program on a vertical vibration platform (Power-Plate, Badhoevedorp, The Netherlands), which was installed for the study purpose in the rehabilitation room of the nursing home. This device provides a vertical vibration with a frequency of 30-50 Hz and an excursion of 2-5 mm. Exercises were performed three times per week (with a minimum of 1-day rest in between) and consisted in 6 static exercises targeting lower limb muscles. The exercise volume and intensity were progressively increased according to the overload-principle (figure 1, table 2).

Subjects in the control group performed exactly the same exercise program on the vibration platform as the WBV+ group, but without vertical vibration. In fact, the sound of the motor of the vibration platform was reproduced by a tape recorder during each bout of exercise. Hence, all subjects were convinced that the vibration platform was functioning during the exercises and thus were blinded for group assignment.

All participants wore identical adjustable sandals during the exercise.

During the study period all participants continued to attend two-weekly seated gymnastic sessions together with other residents of the nursing home (not participating in the study), which were organised by independent physical therapists who were unaware of the group assignment of the participants. The gymnastic exercises were performed on a chair and targeted social interaction of the residents.

Measurements

Functional performance and linear isokinetic leg press were assessed at baseline and after 6 weeks training. At baseline, height and weight were measured, and body mass index and total body muscle mass were estimated in all participants. The participants' attendance was recorded at each exercise session.

Functional performance

Maximal grip strength of the dominant hand was measured using a Martin vigorimeter device (Elmed, Addison, USA), as described previously [13].

Balance and gait were assessed using the timed up-and-go test [14] and Tinetti-test [15].

Upper limb and lower body flexibility were assessed using the back scratch and chair sit-and-reach test. The back scratch test consists in reaching behind the head with one hand and behind the back with the other hand towards the middle finger of both hands [16]. The score is expressed as the distance (in cm) between both middle fingers. During the chair sit-and-reach test the subject sits on the front edge of a chair and extends one leg straight out in front of the hip, with the foot in dorsal flexion and the heel resting on the floor and reaches as far as possible toward the toes [16]. The result of the test is expressed as the distance (in cm) between the fingers and foot. In both tests the scores were negative when the subject was unable to touch the foot or the middle finger and positive when overlap with foot or middle fingers was possible. Both tests were performed twice with the preferential leg or arms and the best score was registered [17].

Closed chain bilateral leg extension was evaluated using the Aristokin® (Lode, Groningen, The Netherlands), a linear isokinetic multi-joint dynamometer. Power (W), force (N), work (J) and explosivity (N/sec) developed during the movement were measured at 40 and 60 cm per second, as described previously [17]. High single-session reproducibility (ICC 0.85-0.99) and high intra-observer reliability (ICC 0.67-0.94) over a 6-week period are described for this technique [18].

Body composition & anthropometry

The body mass index was calculated as weight (kg) / height (m) ². Total body skeletal muscle mass was estimated as described previously [19] with the formula:

$$\text{Muscle Mass (g)} = \text{Height} \times (0.0553\ CTG^2 + 0.0987\ FG^2 + 0.0331\ CCG^2) - 2445.$$

where height in cm, CTG = thigh circumference corrected for the front thigh skin fold thickness (cm), FG = uncorrected forearm circumference (cm), and CCG = calf circumference corrected for the medial calf skin fold thickness (cm). [20]

Statistical analysis

Statistical analysis was performed using SPSS for Windows (release 12.0). Average values are given ± their standard deviation (SD). Since the number of participants was small and most of the data subsets presented non-normal distribution (Shapiro-Wilk Test $p<0.05$), non-parametric techniques (with exact testing) were used: Wilcoxon Signed Ranks Test and Mann-Whitney U Test for paired and unpaired comparisons respectively. Significance level was set at two-sided $p<0.05$.

Results

At baseline, no significant differences were found between the WBV+ and control groups for any of the observed variables (table 1). Twenty-one of the 24 participants completed the 6-week exercise program and attended respectively 96% and 86% of the exercise sessions for the WBV+ and control groups. Three subjects of the WBV+ group dropped out (figure 2): 1 female presented groin pain after the first exercise sessions and refused to continue the program, 1 female became afraid to go to the rehabilitation room, 1 male developed airway infection during the study and was then excluded.

As can be seen in table 3, changes in performance on timed up-and-go and Tinetti-test were significantly better for the WBV+ compared to the control group ($p=0.029$ and $p=0.002$ respectively). In fact, subjects of the WBV+ group improved significantly on the timed up-and-go test ($p=0.008$), whereas no change was observed in the controls. Balance, as observed by the Tinetti-test, worsened significantly in the controls ($p=0.004$) but remained unchanged in the WBV+ group.

As shown in table 3, significant improvements in leg extension performance were observed in both groups (all $p<0.05$, except for explosivity at 40cm/sec for the control group), and chair sit-and-reach improved significantly in the WBV+ group ($p<0.05$). However, no significant difference in change between both groups was observed.

Discussion

In this study we have investigated the feasibility and benefit of 6 weeks WBV in institutionalised elderly persons. The results of our study indicate that WBV has beneficial effects on balance and mobility in elderly nursing home residents. Indeed, subjects assigned to WBV improved significantly on the timed up-and-go test and maintained their baseline level of balance (as measured by Tinetti-test), contrary to the controls who did not improve in timed up-and-go and who's balance worsened significantly (difference in change between both groups $p=0.029$ and $p=0.002$ for timed up-and-go and Tinetti-test respectively). Our results were in agreement with those from Bruyere et al. [21], who also found significant changes in timed up-and-go and Tinetti-test performance following WBV in institutionalised elderly. However, they used another type of WBV platform (Galileo, Orthometrix Inc., New-York) generating tilting oscillations; contrary to the Power-Plate, which produces vertical vibrations.

After 6 weeks, both groups (WBV+ and control) showed significantly better leg extension performance compared to baseline (except for explosivity at 40cm/sec for the control group, all $p<0.05$). However, differences in change between both groups were not statistically significant. The important improvements of the controls can be explained by the fact that these persons performed exactly the same exercises as the WBV+ group, except that the platform did not vibrate. Probably the low baseline muscle performance level of the participants predetermined the possibility to obtain considerable gains in a short time. These results indicate that frail elderly are highly trainable by means of simple physical exercise (i.e., maintaining weight-bearing positions). Significant benefit of WBV on muscle performance might be obtained after longer or more intensive training programmes. Russo et al. [22] described significantly improved lower limb muscle power in elderly independently living women following 6 months WBV compared to control. However, their study differed from ours since they used a tilting-platform (Galileo) and their control group performed no physical exercise at all. Roelants et al. [11] reported significantly improved knee extensor strength following 24 weeks WBV in community-dwelling elderly women. These improvements were similar to those obtained with traditional weight-lifting strength training. Also in their study the controls did not perform any exercise at all. Moreover, their WBV program consisted in much more intensive exercises (both static and dynamic, including one-legged) with a total training volume going up to 30 minutes. In our study, only bipodal static exercises were performed, with a maximal exercise volume attaining 5 to 6 minutes WBV (10 to 15 minutes including rest periods).

Lower body flexibility (as measured by the chair sit-and-reach test) improved significantly in the WBV+ group ($p<0.05$), but not in the control group. To our knowledge, this is the first paper describing improved flexibility in elderly persons following WBV. The training-induced change in flexibility, however, was not significantly different between WBV and control group.

In our study, 3 subjects in the WBV+ group dropped out, of whom one because of possible adverse side effects (groin pain). This dropout rate corresponds to that reported in other WBV intervention studies [11, 21, 22] and classic intensive weight-lifting exercise [17] involving elderly subjects. The high rate of compliance in our study (96% in the WBV+ group) supports the feasibility of WBV in frail institutionalised elderly. However, we excluded subjects presenting severe levels of dependency or cognitive decline (66% of the nursing home residents at the moment of the study). More adapted exercise programs need to be developed for these categories of frail institutionalised elderly.

Conclusions

Overall we can conclude that 6 weeks static WBV exercises are feasible in elderly nursing home residents with limited functional dependency, and is beneficial for balance and mobility. It is still insufficiently clear whether WBV has supplementary benefit on muscle performance compared to classic exercise in these persons.

Competing interests

None declared.

Authors' contributions

TM and IB conceived the study. TM participated in the coordination of the study, the analysis and the redaction. IB performed the statistical analysis and the redaction, and participated in the coordination of the study, the supervision of the exercise sessions and the measurements. EVH participated in the supervision of the exercise sessions and the measurements. JCL participated in the coordination of the study and the evaluation of the health condition of the participants. All authors read and approved the final manuscript.

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Legends to the figures

Figure 1. 96-year old participant performing static exercise on the vibration platform.

Figure 1A: Deep squat (exercise 3); Figure 1B: Wide stance squat (exercise 4)

Figure 2. Flow of the progress through the phases of the study.

Category O, A and B = ADL-category according to Katz et al. [12], WBV = Whole Body Vibration

Table 1. Participants' characteristics at baseline.

Parameter	**WBV+** (N=13)	**Control** (N=11)
Gender (M/F)	5 / 8	4 / 7
Age (years)	76.6 ± 11.8	78.6 ± 10.4
Weight (kg)	63.5 ± 14.3	63.2 ± 21.1
Height (m)	1.61 ± 0.12	1.63 ± 0.09
BMI (kg/m²)	24.3 ± 3.7	25.2 ± 5.5
Waist-Hip Index	0.92 ± 0.09	0.91 ± 0.11
Whole-body muscle mass (kg)	24.5 ± 6.4	27.1 ± 9.2
Diagnoses (number)	3.2 ± 1.0	2.9 ± 0.8
Medications (number)	5.6 ± 1.7	4.7 ± 1.7
ADL-category [a]		
O/A (number)	10	8
B (number)	3	3
Chair sit-and-reach (cm)	-20.2 ± 6.2	-23.2 ± 9.4
Back scratch (cm)	-23.2 ± 16.0	-15.9 ± 6.9
30-second chair stand (number)	6.3 ± 4.0	8.2 ± 3.1
Tinetti test (score/28)	22.4 ± 5.9	23.1 ± 4.3
Timed get-up-and-go test (seconds)	17.9 ± 9.3	14.8 ± 6.3
Grip strength (KPa)	41.6 ± 19.5	43.3 ± 24.6
Leg extension 40cm/sec		
Work (J)	66.9 ± 74.6	88.5 ± 79.4
Maximal force (N)	270.0 ± 203.8	375.2 ± 253.8
Maximal power (W)	108.0 ± 81.5	150.1 ± 101.5
Maximal Explosivity (N/sec)	2693.1 ± 1698.3	4070.0 ± 2483.0
Leg extension 60cm/sec		
Work (J)	47.1 ± 57.1	68.7 ± 78.6
Maximal force (N)	204.3 ± 197. 0	312.1 ± 281.3
Maximal power (W)	123.4 ± 117.4	187.3 ± 168.7
Maximal Explosivity (N/sec)	3885.0 ± 3291.6	4872.3 ± 3371.6

[a]ADL-category according to Katz et al. [12]. Values represent number or mean ± SD.

Table 2. Progression of WBV exercise program over 6 weeks training.

	Warming-Up	Training				
		Exercise	Volume	Frequency (Hz)	Amplitude (mm)	Rest (sec) [a]
Week 1	Exercise 1 2x 30 sec each leg Amplitude: 2mm Frequency: 30Hz	2	3x 30 sec	35	2	60
		3, 4	1x 30 sec			
Week 2		2	3x 30 sec	35	2	30-60
		3, 4, 5, 6	1x 30 sec			
Week 3		2	3x 45 sec	40	2	30-60
		3, 4, 5, 6	1x 45 sec			
Week 4		2	3x 60 sec	40	2	30-60
		3, 4, 5, 6	1x 60 sec			
Week 5		2	3x 45 sec	40	2	30-60
		3, 4	1x 30 sec	30	5	
		5, 6	1x 45 sec	40	2	
Week 6		2	3x 45 sec	40	2	30-60
		3, 4	2x 30 sec	35	5	
		5, 6	1x 45 sec	40	2	

Exercise 1 = Lunge, Exercise 2 = Squat, Exercise 3 = Deep squat, Exercise 4 = Wide stance squat, Exercise 5 = Calves, Exercise 6 = Calves deep (see www.power-plate.us [23] for detailed description of the exercises). [a] Amount of rest between each series of exercise.

Table 3. Change in functional performance.

Parameter	**WBV+** (N=10)	**Control** (N=11)
Chair sit-and-reach (cm)	**2.9 ± 3.1** [‡]	3.3 ± 7.1
Back scratch (cm)	1.8 ± 5.0	-1.6 ± 5.6
30-second chair stand (number)	1.8 ± 2.6	0.09 ± 2.4
Tinetti test (score/28) *	0.1 ± 0.8	**-1.8 ± 1.5** [§]
Timed get-up-and-go test (seconds) [†]	**-3.3 ± 3.2** [§]	-0.5 ± 2.4
Grip strength (KPa)	1.3 ± 8.9	2.4 ± 4.1
Leg extension 40cm/sec		
Work (J)	**36.9 ± 49.9** [§]	**30.8 ± 35.8** [§]
Maximal force (N)	**146.3 ± 164.6** [‡]	**107.2 ± 128.1** [‡]
Maximal power (W)	**57.6 ± 66.1** [‡]	**42.8 ± 51.2** [‡]
Maximal Explosivity (N/sec)	**2045.0 ± 3674.8** [‡]	1081.8 ± 1934.9
Leg extension 60cm/sec		
Work (J)	**25.5 ± 34.8** [‡]	**19.7 ± 21.4** [§]
Maximal force (N)	**164.5 ± 182.6** [§]	**86.8 ± 74.0** [§]
Maximal power (W)	**97.7 ± 110.6** [§]	**52.0 ± 44.4** [§]
Maximal Explosivity (N/sec)	**2820.0 ± 3308.9** [§†]	**2221.4 ± 2780.1** [‡]

Significant difference in change between WBV+ and control group *$p<0.05$, [†]$p<0.01$.
Significant change after 6 weeks [‡]$p<0.05$, [§]$p \leq 0.01$.

Figure 1

Figure 2

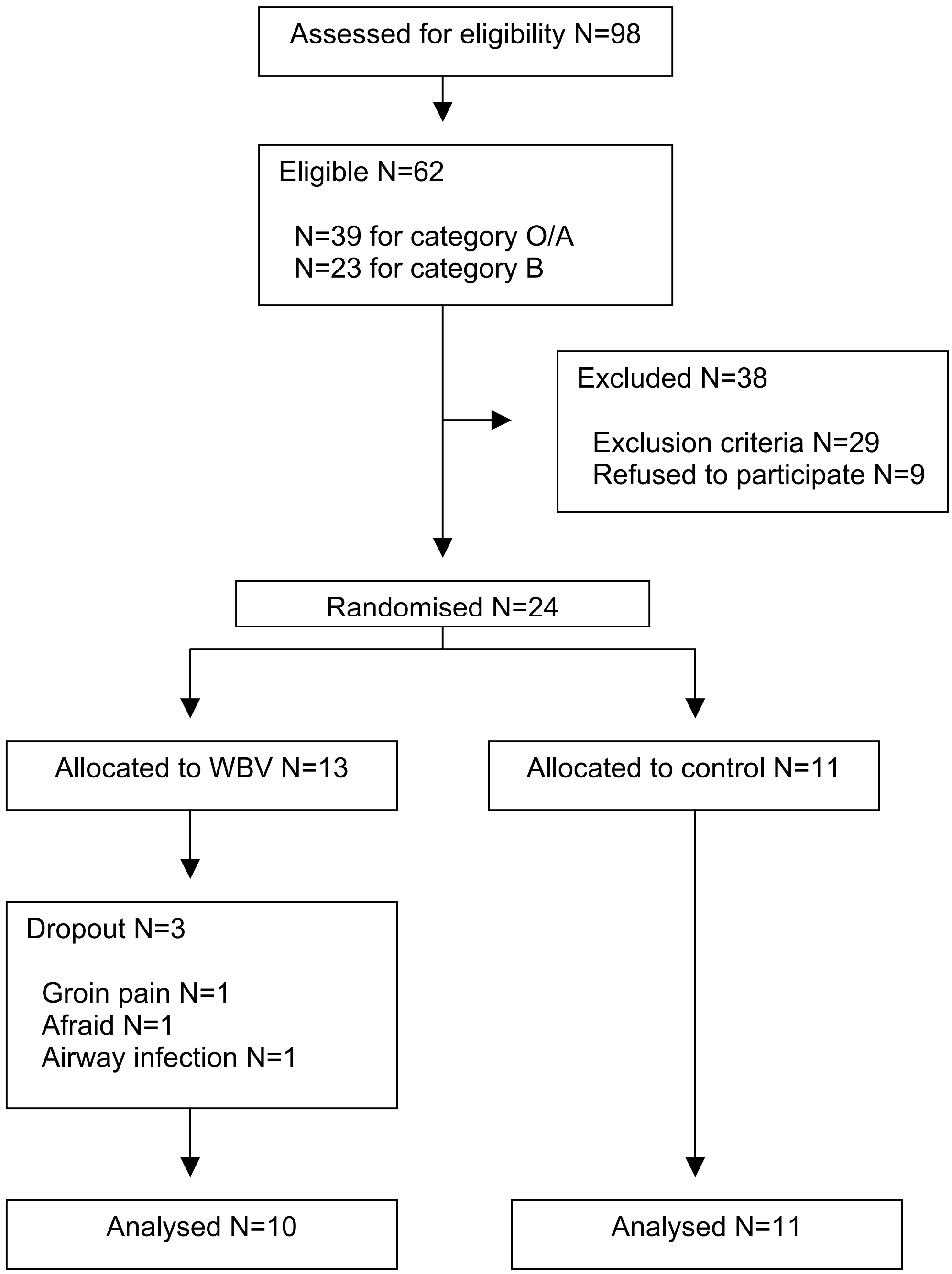
Assessed for eligibility N=98
Eligible N=62
N=39 for category O/A
N=23 for category B
Excluded N=38
Exclusion criteria N=29
Refused to participate N=9
Randomised N=24
Allocated to WBV N=13
Allocated to control N=11
Dropout N=3
Groin pain N=1
Afraid N=1
Airway infection N=1
Analysed N=10
Analysed N=11

Figure 3