Can a Whole-Body Vibration Program Potentialize the Benefits of a Psychomotor Intervention Program in Community-Dwelling Older Adults At Risk of Falling? A Randomized Controlled Trial

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Abstract

Background

To evaluate the effects of two interactive cognitive-motor programs in processing speed, lower-body strength, and body composition in community dwellings at risk of falling.

Methods

Forty-eight community dwellings (75.0 ± 5.4 years) completed this randomized controlled trial, were allocated into three groups: 1) experimental group 1 (EG1: psychomotor intervention program); 2) experimental group 2 (EG2: combined program [psychomotor intervention program + whole-body vibration]); and 3) control group (kept their daily life routines). Participants were assessed at baseline, at post-24-week intervention, and after a 12-week no-intervention follow-up.

Results

Significant improvements were induced by EGs programs in processing speed, lower-body strength, and bone mass ($p < 0.05$). The treatment effect was similar in both EGs in processing speed and lower-body strength, and higher in bone mineral content and density within EG2. The number of falls decreased by 44.2% in EG1 and 63% in EG2 ($p < 0.05$). After the follow-up, improvements in processing speed were maintained, particularly in EG2, but were reversed in lower-body strength in both EGs, as were in bone mineral content and density, particularly within EG2 ($p < 0.05$).

Conclusions

Both interactive cognitive-motor programs were accepted and well tolerated by the participants, inducing similar improvements in cognitive and physical functions and decreased the fall rate. Additionally, the combined program led to additional benefits in bone mass. This evidenced that both programs were effective for fall and injury prevention.

Trial registration:

ClinicalTrials.gov Identifier: NCT03446352, registered on 26/02/2018.

Background

Falls are common in older adults and are responsible for a significant cause of mortality or fall-related injuries such as fractures, leading to reduced mobility and independence [1]. Given the increasing aging population, the occurrence of falls and healthcare-associated costs are projected to rise [1, 2].

The aging process can lead to changes in some modifiable risk factors for falls as a decrease in cognitive performance, particularly a slower processing speed, and in physical function as a loss of muscle strength; these impairments can enhance the risk of falling, especially in previous fallers [3, 4]. Also, it is widely accepted that body composition changes, particularly a reduced muscle mass in the lower limbs and loss of bone mineral density (BMD), are major indicators of falls or fall-related fractures [5, 6]. Whereby it is essential to promote specific interventions to prevent the negative consequences of falls.

It is well established in the literature that single (e.g.: exercise alone as resistance training) or different combinations of interventions (e.g.: exercise alongside with Vitamin D supplementation, or balance plus strength training) are effective in reducing fall risks and may prevent falls in community dwellings [2, 7, 8]. However, the intervention type, frequency, duration, participants' mean adherence or participants' satisfaction level may influence the intervention effectiveness and should be investigated. Recent studies have shown an association between long-term exercise (at least 24-weeks, three times per week at a moderate intensity) and a reduction in the number of falls or fall-related fractures in community-dwelling older people [1, 9].

Exercise training improves not only physical function but also leads to enhancements in cognitive function as processing speed [10, 11]. The connectivity between physical activity/exercise and cognitive function is well established, and the potential mechanisms supporting the protective effects of exercise on cognitive abilities are described in the literature [12]. According to the previous study, this relationship can lead to hippocampal changes promoting neurogenesis and synaptogenesis processes through neuroplasticity. Concomitantly, positive effects of cognitive-based interventions (e.g.: computerized cognitive training) on physical performance have been reported, leading to significant improvements on risk factors for falls as mobility, balance, and gait impairments [13, 14]. However, an interactive cognitive-motor (ICM) intervention, promoting simultaneous cognitive and motor stimulation, may present better results on cognition and physical function, particularly on risk factors for falls, and should be preferred compared to a single intervention [15, 16].

In this way, a psychomotor intervention program directed at older adults may present promising results for cognitive and physical function [17–19], and can be considered an ICM intervention. Psychomotor therapy uses movement and corporality as the main resources to optimize physical, cognitive, affective, and perceptual skills through physical activity and functional body movements [17]. However, given that a psychomotor intervention traditionally does not reach great intensities or perform an impact training, it is not expected to promote great benefits in body composition factors. Also, the potential effects of this therapy to reduce the risk of falls should be further explored, given the lack of studies. By other hand, a whole-body vibration (WBV) training by mechanical stimulation/oscillation can compensate a psychomotor intervention. The WBV promotes muscle contractions and could lead to improvements in physical function performance, particularly on muscle strength, a critical risk factor for falls [5, 20]. WBV can also improve some aspects of cognition [21]; nonetheless, little are known about the WBV effects in older adults' processing speed. Moreover, it is expected that WBV may improve bone mass and reduce the incidence of falls, and thus minimize the risk of fracture in case of fall [5].

Given the potential benefits of both interventions, a combined intervention could emerge as an effective and novelty intervention to reduce the risk factors for falls or fall-related fractures. To the authors' knowledge, the effects of this combined intervention for fall prevention in older adults have never been studied. Also, few ICM programs have included a no-intervention follow-up [22, 23], remaining unclear the maintenance of the potential positive effects in cognitive and physical functions and body composition, over time. Thus, the purpose of this randomized controlled trial (RCT) was to evaluate the effects of two ICM programs in processing speed, lower-body strength, and body composition in community dwellings at risk of falling.

Methods

Study design and participants

This 24-week RCT, with a single-blinded (participants) design, was performed between March 2018 and January 2019. The study included three groups: 1) experimental group 1 (EG1), which performed a psychomotor intervention program; 2) experimental group 2 (EG2), which underwent a combined program (psychomotor intervention program + WBV); and 3) control group (CG), in which participants were asked to keep their daily life routines. Participants were evaluated at baseline (m1), after 24 weeks of intervention (m2), and after a 12-week no-intervention follow-up (m3). Participants allocated in the CG were invited to integrate a fall prevention program after the follow-up evaluations. This RCT was performed according to CONSORT criteria (http://www.consort-statement.org) and registered at ClinicalTrials.gov (NCT03446352) on 26/02/2018.

The sample size was calculated using the online G*Power software, considering an effect size = 0.25, alpha = 0.05 and statistical power of 95%. Hence, a minimum sample size of 45 participants was determined (15 participants for each group) to identify significant changes. To cover an expectable dropout rate, the number of participants was increased. Thus, 61 community-dwelling Portuguese older adults were enrolled in response to verbal communication and leaflets placed in community settings as senior associations, recreation centers, and city hall.

Inclusion criteria required: a) males or females aged 65 years or more; b) score of ≥ 18 points (moderate or high physical functioning) in the Composite Physical Function scale [24]; and c) a history of fall (≥ 1 fall) preceding six months or scoring 25 points and bellow (high risk of falling) on the Fullerton Advanced Balance scale [25]. Exclusion criteria were as follows: a) scoring ≤ 22 points (cognitive decline) in the Mini-Mental State Examination (MMSE) [26]; b) dependent mobility; c) musculoskeletal (diagnosis of osteoporosis [T-score of -2.5 or below]; recent lower limb fracture; knee or hip prostheses), cardiovascular (pacemaker), and neurological (epilepsy) conditions that could compromise participants' well-being [27]; and d) participation in a regular exercise program over the last six months [28].

Fifty-six volunteers (47 women and nine men) met the inclusion criteria, and 5 participants were excluded, as described in Figure 1. Then, participants were randomly assigned according to simple randomization procedures with sequential numbers (1:1:1 ratio), which was performed by an investigator with no clinical involvement in the trial. The online “Random Team Generator” (https://www.randomlists.com/team-generator) was used and participants were allocated into three groups: EG1 (n = 18), EG2 (n = 19), and CG (n = 19).

Written informed consent was given by all the participants. Ethical approval for the study was provided by the institutional research ethics committee in the areas of human health and well-being (reference number 16012), following the guidelines of the Declaration of Helsinki.

Procedures

The same trained rater, who graduated in rehabilitation sciences, conducted the participants' assessments individually. Cognitive tests and questionnaires filling out were performed in a room with minimal noise and a comfortable temperature. Physical function and body composition variables assessment were undertaken in appropriate laboratories. Before each cognitive and physical assessment, participants were instructed with a verbal explanation, following by a practice trial. Furthermore, a demonstration was performed by the rater in the 30-s Chair Stand Test (30CST). The data collection took place at the university laboratories.

Outcome measures

Primary outcome measures

Processing speed was assessed by the Trail Making Test (TMT) parts A and B, according to the instructions proposed by Cavaco et al. [29]. The time to complete each task was recorded (s), as the number of errors.

Lower-body strength and muscle resistance were measured by the 30CST, in accordance with the methodology proposed by Jones, Rikli and Beam [30]. The number of full and corrected stands in 30 s was recorded. Furthermore, maximal strength of the knee extensors and flexors (60º/s) assessment was performed by an isokinetic dynamometer (Biodex System 3, Biodex Corp., Shirley, NY, USA), which was established as a reliable assessment device in community-dwelling older adults [31]. After a practice trial, one test trial including a set of three concentric repetitions was performed. The highest peak torque value (N·m) reached in the test was recorded for further analysis.

Body composition was assessed by dual-energy X-ray absorptiometry (DXA - Hologic QDR, Hologic, Inc., Bedford, MA, USA), which is considered a reliable, accurate, and safe imaging modality to measure changes in body composition and bone [6]. This assessment involved fat mass (%), lean body mass (kg), total bone mineral content [BMC] (g), total BMD (g/cm^2), T-score (n), and Z-score (n). Daily quality assurance was performed through a Hologic Spine Phantom.

Fall occurrence was assessed by a questionnaire based on an interview that comprises information about the date of each fall and the circumstances surrounding it (e.g., fall-related injuries, type, and location of fall). This oral interview was conducted as double-check for false-positive or false-negative responses. A fall was defined "*as an event which results in a person coming to rest inadvertently on the ground or floor or other lower level"* [32]. The self-reported number of falls was collected at baseline (retrospective falls over the previous six months) and at post-intervention (prospective falls over the six intervention months).

Secondary outcome measures

To assess the exercise intensity was used the Borg Rating of Perceived Exertion (RPE) scale, based on the effort levels: 6 points (very, very light) to 20 points (very, very hard) [33]. Participant's satisfaction level was assessed by using the Caregiver Treatment Satisfaction questionnaire, which ranged between 1 point (extremely dissatisfied) and 5 points (extremely satisfied) [34]. Sociodemographic characteristics (age, sex, and educational level) were collected using a questionnaire. The cognitive state was assessed by the Portuguese version of the MMSE [26]. Standing height (m) and body mass (kg) were measured by means of a stadiometer (Seca 206, Hamburg, Germany) and an electronic scale (Seca 760, Hamburg, Germany), respectively; and body mass index (kg/m^2) was calculated. To assess the physical independence was used the Composite Physical Function scale, which includes an ample range of functional abilities [24]; this 12-item self-report scale could range between 0 (worst) and 24 (best) points, and participants were categorized as "low functioning" (score: < 18), "moderate functioning" (score: 18 to 23), or "high functioning" (score: 24). Participant's habitual physical activity was measured using the short version of the International Physical Activity Questionnaire (IPAQ), by means of the metabolic equivalent of task ([MET]-min/week), recording the time (min/day), the frequency (days/week), and MET intensity (i.e.: walking: 3.3 MET; moderate: 4.0 MET; or vigorous: 8.0 MET). Physical activity was computed as the sum of metabolic expenditure spent on the three types of activity, each one calculated as time x frequency x MET intensity [35].

Interactive cognitive-motor programs

Both programs were performed three times per week (75 minutes/session), on alternate days, with up to 10 participants in each class. All supervised sessions were delivered by the same specialist, who has a master's degree in rehabilitation sciences.

Adaptative, specific, and progressive (i.e., intensity-difficulty gradually increasing; static to dynamic exercises) cognitive and motor tasks were performed over the intervention period. The progression of the physical exercises followed the American College of Sports Medicine recommendations (i.e., initial stage: 2 sets of 8 repetitions; final stage: 3 sets of 15 repetitions) [36]. Physical exercises were executed using participant's bodyweight or affordable equipment like fitballs, resistance bands, rubber mats or unstable surfaces. A moderate exercise intensity at the Borg RPE scale was a target in both programs.

Psychomotor intervention program

This program included the main principles of a psychomotor intervention directed for older people (e.g., body-mediated activities as body scheme awareness) and was focused on ICM stimulation. Each class started with a 5-min beginning ritual, followed by a 10-min warm-up. This phase involved join rotation (from neck to ankle) and a quickly dual-task activity for a neurophysiological activation (e.g., stand up and sit down from the chair or point body parts according to arithmetic tasks). The main phase (50 min) consisted of different interactive activities (sensory/neuromotor exercises) that promote simultaneous cognitive and motor stimulation on alternate periods of approximately 15 minutes (i.e., the first 15 minutes comprised activities with greater cognitive demand, followed by 15 minutes with greater motor demand). The previous phase included neurocognitive activities (e.g., processing speed: nominate different animals/flowers based on relevant stimulus, as quickly as possible), motor activities (e.g., posture muscle and lower limbs exercises: dorsi-plantar flexion as standing on toes; knee extension/flexion as bodyweight squats), and dual-task paradigms (e.g., fitball wall squads simultaneous to a regressive countdown by three from 30 or while reciting their phone number backwards). At the 5-min cool-down phase, stretching exercises or relaxation methods using massage balls for body awareness development were performed. Last, at the 5-min finishing ritual, participants were asked to record their exercise intensity (RPE scale) and satisfaction levels (Caregiver Treatment Satisfaction questionnaire).

Combined exercise program

As a complement to the psychomotor intervention program, participants in the combined exercise program were instructed to individually perform a WBV program (initial stage: 3 min; final stage: 6 min) on a side-alternating vibration device (Galileo® Med35). Participants were asked to stand up on the platform without shoes while holding the handlebar with a knee-bending (~30º of knee flexion) and a trunk erect position to prevent musculoskeletal injuries. The exercise volume was also increased gradually during the 24-weeks intervention (exercise time: 45-60 s; number of series: 4-6; and frequency: 12.6-15 Hz). An amplitude of 3 mm and a 1-min seated rest between series were always performed.

Statistical analysis

All statistical analyses were conducted using the SPSS software package (version 24.0, IBM SPSS Inc.). According to the Shapiro-Wilk and the Levene tests results, ANOVA repeated measures assumptions were not met. Thus, non-parametric statistics were performed. Friedman test was used for within-group comparisons, and the Kruskal-Wallis test was used for between-group comparisons. Pairwise post hoc tests were also carried out when significant differences were found. Last, the Wilcoxon test was performed to compare falls paired data between the baseline and the post-intervention (i.e.: number of falls).

Data were presented as mean ± standard deviation or frequencies (%). The variation value was calculated between the baseline, post-intervention, and follow-up evaluations as Δ: $moment_x$ - $moment_{x-1}$. The respective delta percentage was also computed by the formula as follows: (Δ%: [($moment_x$ - $moment_{x-1}$)/$moment_{x-1}$] × 100).

Effect size (ES) was determined for the within-group and between-group comparisons in accordance with the guidelines for non-parametric tests [37]. To quantify the practical meaningfulness of the treatment effect, the ES was computed as r = (Z/ √N) and classified based on Cohen's thresholds (small: 0.10; medium: 0.30; and large: 0.50) [38].

In all analyses, a *p*-value of < 0.05 was considered significant statistically.

Results

Overall, 48 participants out of the 56 who were initially randomized completed the present study. Dropouts (dropout rate: 14.3%) were similarly distributed between groups, and participants who dropped out presented equally characteristics compared to participants who finished the ICM programs (75 sessions each). Mean adherence was identical in both EGs (EG1: 82.3% vs. EG2: 84.3%) as well the exercise intensity (EG1: 12.9 ± 0.4 vs. EG2: 13.2 ± 0.3), or the satisfaction level (EG1: 4.98 ± 0.3 vs. EG2: 4.99 ± 0.1). No adverse event from intervention programs was reported.

Table 1 summarizes participants' general characteristics at baseline, and no significant between-group differences were observed.

Table 1
General characteristics of the participants at baseline

Characteristics	**Prevalence or mean ± SD**	***p*-value**
Age (years)		
EG1	74.3 ± 5.4	0.750
EG2	74.7 ± 5.5	
CG	75.9 ± 5.7	
Sex, female (%)		
EG1	14 (87.5)	0.571
EG2	15 (93.8)	
CG	13 (81.3)	
Educational level (years)		
EG1	6.0 ± 2.6	0.992
EG2	6.1 ± 3.4	
CG	7.0 ± 5.1	
MMSE (points)		
EG1	27.7 ± 1.7	0.421
EG2	28.2 ± 1.7	
CG	28.4 ± 1.7	
BMI (kg/m^2)		
EG1	29.1 ± 3.0	0.601
EG2	28.6 ± 4.3	
CG	28.0 ± 4.8	
CPF (points)		
EG1	21.5 ± 2.7	0.579
EG2	20.8 ± 2.2	
CG	21.4 ± 2.9	

SD standard deviation, *EG1* experimental group 1 [psychomotor intervention program] (n = 16), *EG2* experimental group 2 [psychomotor intervention program + WBV] (n = 16), *GC* control group (n = 16), *MMSE* Mini-Mental State Examination, *BMI* Body Mass Index, *CPF* Composite Physical Function, *IPAQ* International Physical Activity Questionnaire, Significant differences within groups, $p < 0.05$.

Characteristics	Prevalence or mean ± SD	*p*-value
IPAQ (MET-min/week)		
EG1	927.0 ± 557.9	0.803
EG2	953.4 ± 638.5	
CG	791.7 ± 482.2	
Number of falls within the last six months (n)		
EG1	1.13 ± 0.8	0.978
EG2	1.19 ± 1.0	
CG	1.13 ± 0.3	

SD standard deviation, *EG1* experimental group 1 [psychomotor intervention program] (n = 16), *EG2* experimental group 2 [psychomotor intervention program + WBV] (n = 16), *GC* control group (n = 16), *MMSE* Mini-Mental State Examination, *BMI* Body Mass Index, *CPF* Composite Physical Function, *IPAQ* International Physical Activity Questionnaire, Significant differences within groups, $p < 0.05$.

Likewise, no significant differences between groups were found at baseline regarding cognitive function, physical function, and body composition variables.

Concerning cognitive function (Table 2), namely the processing speed variables, significant within-group changes between the baseline and the post-intervention were observed in both EGs, particularly in the “TMT-A time” (Δ_{m2-m1}% EG1: -20.8%, $p = 0.011$; Δ_{m2-m1}% EG2: -24.0%, $p = 0.008$) and “TMT-B time” (Δ_{m2-m1}% EG1: -23.1%, $p < 0.001$; Δ_{m2-m1}% EG2: -22.9%, $p < 0.001$). The previous values described showed a better performance after the 24-weeks intervention by decreasing the time to complete the tasks. These improvements remained evident in both EGs between the baseline and the 12-weeks follow-up evaluations, in the same variables “TMT-A time” (Δ_{m3-m1}% EG2: -20.0%, $p = 0.014$) and “TMT-B time” (Δ_{m3-m1}% EG1: -19.6%, $p = 0.001$; Δ_{m3-m1}% EG2: -17.0%, $p = 0.040$). The correspondent effect sizes (r) were large between the baseline and the post-intervention periods in both EGs (EG1: 0.55 to 0.62; EG2: 0.51 to 0.58), while between baseline and the follow-up were large in EG1 (0.61), and medium in EG2 (0.43 to 0.45).

Table 2
Impact of the interactive cognitive-motor programs in processing speed variables

		Baseline (A) (Mean ± SD)	Post-intervention (B) (Mean ± SD)	Follow-up (C) (Mean ± SD)	*p*-value	Pairwise Comparison
Processing speed						
TMT-A time (s)						
	EG1	91.3 ± 31.6	72.3 ± 27.8	85.1 ± 35.5	0.010	A > B
	EG2	85.2 ± 36.4	64.7 ± 29.3	68.2 ± 31.1	0.003	A > B, C
	CG	80.4 ± 39.8	73.3 ± 34.6	72.1 ± 30.8	0.305	–
TMT-A errors (n)						
	EG1	0.6 ± 1.1	0.3 ± 0.6	0.5 ± 1.0	0.438	–
	EG2	0.4 ± 0.5	0.3 ± 0.6	0.3 ± 0.6	0.368	–
	CG	0.4 ± 0.6	0.3 ± 0.6	0.4 ± 0.7	0.595	–
TMT-B time (s)						
	EG1	254.9 ± 70.9	196.0 ± 81.2	204.9 ± 81.6	< 0.001	A > B, C
	EG2	224.0 ± 87.1	172.7 ± 76.9	186.0 ± 89.1	< 0.001	A > B, C
	CG	202.5 ± 80.1	200.1 ± 83.1	187.8 ± 75.7	0.105	–
TMT-B errors (n)						
	EG1	2.1 ± 1.4	1.4 ± 1.2	2.0 ± 1.4	0.109	–
	EG2	1.6 ± 1.3	0.9 ± 1.1	1.3 ± 1.3	0.217	–
	CG	1.9 ± 1.3	1.4 ± 1.0	1.8 ± 1.2	0.234	–

SD standard deviation, *TMT* Trail Making Test, *EG1* experimental group 1 [psychomotor intervention program] (n = 16), *EG2* experimental group 2 [psychomotor intervention program + WBV] (n = 16), *CG* control group (n = 16), > significant differences within groups, $p < 0.05$.

Table 3 displays the analyses within and between groups for physical function concerning lower-body strength variables. Within-group comparisons between the baseline and post-intervention evaluations detected significant improvements in both EGs, in the variable “30CST” ($\Delta\%_{m2-m1}$EG1: 45.2%, $p < 0.001$; $\Delta_{m2-m1}\%$ EG2: 42.9%, $p < 0.001$), representing an increase in the number repetitions. However, these improvements at the post-intervention were not maintained at the follow-up evaluation, with a considerable performance decrease in both EGs ($\Delta_{m3-m2}\%$ EG1: -21.4%, $p = 0.001$; $\Delta_{m3-m2}\%$ EG2: -21.6%, $p = 0.008$). Additionally, significant differences among groups were also found at the post-intervention in this variable, between the EG1 and the CG, as the participants in the EG1 achieved ~6 more repetitions than the GC ($p < 0.001$), as well as between the EG2 and the CG, in which participants in EG2 executed ~5 more repetitions than the CG ($p = 0.004$). The within-group ES was large from baseline to post-intervention in EG1 (0.62) and EG2 (0.60), remaining large between the post-intervention and the follow-up (EG1: 0.63; EG2: 0.58). Concerning the ES between groups, it was also large between EG1 and the CG (0.69) and between EG2 and the CG (0.56). In what concerns to the maximal strength of the knee extensors and flexors variables, despite descriptive analysis suggest an increase of 8.9% at post-intervention in the variable “Isokinetic peak torque (extension 60º)” in EG2, significant differences were only detected between the baseline and the follow-up evaluations in EG1 and CG. In fact, a significant decrease between baseline and the follow-up was observed in the variable “Isokinetic peak torque (extension 60º)”, in EG1 ($\Delta_{m3-m1}\%$: -8.6%, $p = 0.008$, r = 0.31) and CG ($\Delta_{m3-m1}\%$: -9.2%, $p = 0.008$, r = 0.41), and in the variable “Isokinetic peak torque (flexion 60º)”, in CG ($\Delta_{m3-m1}\%$: -12.9%, $p = 0.040$, r = 0.51).

Table 3

Impact of the interactive cognitive-motor programs in physical function variables

		Baseline (A) (Mean ± SD)	Post-intervention (B) (Mean ± SD)	Follow-up (C) (Mean ± SD)	p-value	Pairwise Comparison
Lower-body strength						
30CST (n)						
	EG1	12.4 ± 3.2	18.1 ± 3.1 [a]	14.2 ± 2.3	< 0.001	B > A, C
	EG2	11.9 ± 3.5	17.1 ± 4.2 [b]	13.4 ± 3.5	< 0.001	B > A, C
	CG	13.2 ± 3.3	12.3 ± 3.2	12.0 ± 3.3	0.325	–
Isokinetic peak torque (extension 60°) (N·m)						
	EG1	82.3 ± 26.3	82.3 ± 25.6	75.3 ± 23.6	0.008	A > C
	EG2	71.2 ± 27.8	77.5 ± 21.0	75.6 ± 25.6	0.144	–
	CG	75.6 ± 24.9	71.7 ± 22.9	68.7 ± 19.7	0.010	A > C
Isokinetic peak torque (flexion 60°) (N·m)						
	EG1	42.5 ± 13.7	45.0 ± 14.2	43.3 ± 16.5	0.646	–
	EG2	40.3 ± 10.3	40.8 ± 9.5	39.9 ± 10.5	0.829	–
	CG	43.7 ± 14.7	38.7 ± 12.3	38.0 ± 11.3	0.022	A > C

SD standard deviation, *30CST* 30-s Chair Stand Test, *EG1* experimental group 1 [psychomotor intervention program] (n = 16), *EG2* experimental group 2 [psychomotor intervention program + WBV] (n = 16), *CG* control group (n = 16), > significant differences within groups, $p < 0.05$, [a] significant differences between EG1 and CG, $p < 0.05$, [b] significant differences between EG2 and CG, $p < 0.05$.

Table 4 presents the findings of our study regarding the body composition variables. Comparisons within-groups evidenced significant improvements from baseline to post-intervention evaluations only in the EGs, specially in EG2, in the variables “Total BMC” (Δ_{m2-m1}% EG2: 11.4%, $p < 0.001$), “Total BMD”

(Δ_{m2-m1}% EG1: 2.1%, $p = 0.040$; Δ_{m2-m1}% EG2: 7.1%, $p < 0.001$), "T-score" (Δ_{m2-m1}% EG2: 46.0%, $p < 0.001$) and "Z-score" (Δ_{m2-m1}% EG2: 243%, $p < 0.001$). These results were not seen at the follow-up evaluation, in which the EG2 demonstrated a significant decrease trend in the previous variables, namely "Total BMC" (Δ_{m3-m2}%: -6.9%, $p = 0.002$), "Total BMD" (Δ_{m3-m2}%: -5.0%, $p = 0.001$), "T-score" (Δ_{m3-m2}%: -72.2%, $p = 0.001$), and "Z-score" (Δ_{m3-m2}%: -53.2%, $p = 0.008$). The respective effect sizes from baseline to post-intervention were medium (0.32), in EG1, and large (0.56 to 0.59), in EG2, whereas between post-intervention and the follow-up were large (0.57 to 0.62).

Table 4
Impact of the interactive cognitive-motor programs in body composition variables

		Baseline (A) (Mean ± SD)	Post-intervention (B) (Mean ± SD)	Follow-up (C) (Mean ± SD)	*p*-value	Pairwise Comparison
Body composition						
Fat mass (%)						
	EG1	39.3 ± 4.7	39.8 ± 5.1	39.0 ± 4.9	0.185	–
	EG2	41.1 ± 6.1	40.6 ± 6.2	41.0 ± 6.3	0.269	–
	CG	38.8 ± 6.9	38.7 ± 6.4	38.4 ± 6.7	0.570	–
Lean body mass (kg)						
	EG1	41.1 ± 7.1	40.9 ± 7.3	41.5 ± 7.3	0.368	–
	EG2	38.6 ± 5.6	38.6 ± 5.7	38.7 ± 5.9	0.829	–
	CG	40.2 ± 7.3	40.3 ± 7.7	40.3 ± 7.6	0.829	–
Total BMC (g)						
	EG1	1923.4 ± 313.0	2024.9 ± 402.0	1934.3 ± 271.6	0.047	–
	EG2	1705.9 ± 322.3	1901.0 ± 392.8	1770.3 ± 404.6	< 0.001	B > A, C
	CG	1992.8 ± 443.0	1997.1 ± 485.0	2026.1 ± 461.7	0.939	–
Total BMD (g/cm^2)						
	EG1	1.050 ± 0.098	1.072 ± 0.097	1.045 ± 0.091	0.022	B > A
	EG2	0.974 ± 0.112	1.043 ± 0.124	0.990 ± 0.133	< 0.001	B > A, C
	CG	1.091 ± 0.141	1.084 ± 0.156	1.093 ± 0.146	0.570	–

SD standard deviation, *EG1* experimental group 1 [psychomotor intervention program] (n = 16), *EG2* experimental group 2 [psychomotor intervention program + WBV] (n = 16), *CG* control group (n = 16), *BMC* bone mineral content, *BMD* bone mineral density, *>* significant differences within groups, $p < 0.05$, *** these variables included a different number of participants per group due to limitations of reference population in DXA for gender and age in T-score (EG1: n = 14; EG2: n = 15; CG: n = 13) and Z-score (EG1: n = 13; EG2: n = 15; CG: n = 12).

		Baseline (A) (Mean ± SD)	Post-intervention (B) (Mean ± SD)	Follow-up (C) (Mean ± SD)	*p*-value	Pairwise Comparison
T-score (n)*						
	EG1	-0.6 ± 1.2	-0.4 ± 1.1	-0.7 ± 1.1	0.062	–
	EG2	-1.6 ±1.2	-0.9 ± 1.2	-1.5 ± 1.3	< 0.001	B > A, C
	CG	-0.6 ± 1.5	-0.7 ± 1.6	-0.5 ± 1.6	0.225	–
Z-score (n)*						
	EG1	1.3 ± 1.1	1.5 ± 1.0	1.3 ± 0.9	0.101	–
	EG2	0.3 ± 1.3	1.1 ± 1.3	0.5 ± 1.4	< 0.001	B > A, C
	CG	1.4 ± 1.3	1.4 ± 1.4	1.5 ± 1.4	0.192	–

SD standard deviation, *EG1* experimental group 1 [psychomotor intervention program] (n = 16), *EG2* experimental group 2 [psychomotor intervention program + WBV] (n = 16), *CG* control group (n = 16), *BMC* bone mineral content, *BMD* bone mineral density, *>* significant differences within groups, $p < 0.05$, *** these variables included a different number of participants per group due to limitations of reference population in DXA for gender and age in T-score (EG1: n = 14; EG2: n = 15; CG: n = 13) and Z-score (EG1: n = 13; EG2: n = 15; CG: n = 12).

In what concerns the fall occurrence, within-group comparisons from baseline to post-intervention periods showed a reduction in the number of falls by 44.2%, in EG1, and by 63%, in EG2 (EG1: 1.13 ± 0.8 vs. 0.63 ± 0.7, $p = 0.021$; EG2: 1.19 ± 1.0 vs. 0.44 ± 0.7, $p = 0.007$), while the CG presented similar results and remained unchanged (1.13 ± 0.3 vs. 1.06 ± 1.0, $p = 0.763$).

Discussion

The purpose of this study was to evaluate the effects of two ICM programs in processing speed, lower-body strength, and body composition in community dwellings at risk of falling. This is the first study that evaluated the effects of a psychomotor intervention combined with WBV training, and only the second study that investigated the effects of a psychomotor intervention as a fall prevention program [18]. Overall, the present study results evidenced that both programs were accepted and well tolerated by participants. They were effective for fall and injury prevention. Considering both programs effectiveness on the risk factors for falls, our findings indicate that either EG1 or EG2 was beneficial by inducing similar improvements in cognitive function (processing speed) and physical function (lower-body strength). The improvements on these risk factors were clinically relevant as they were all a large ES. Furthermore, despite an increase on BMD within EG1, the EG2, which combined the psychomotor intervention and the

WBV training, led to additional benefits on more bone mass variables, namely on BMD, BMC, T-Score, and Z-score, with a large ES in all these variables. Highlighting both programs' beneficial effects, the number of falls in both EGs decreased after the 24-week intervention. Moreover, the benefits induced by the programs were maintained in the cognitive risk factors for falls after their cessation. In fact, after the no-intervention 12-week follow-up, the enhancements in the processing speed were unchanged, particularly in the EG2. However, there were relevant physical risk factors for falls whose benefits induced by the intervention programs were lost. Namely, the lower-body strength, in which the improvement induced by the intervention programs was reversed. Likewise, the enhancements in bone mass induced by the programs, which is important to prevent fall-related injuries such as fractures, were not maintained, particularly in the EG2.

Concerning the adherence rate and tolerability, few ICM studies were carried out over 24-weeks, three times per week, in community dwellings. In this line, compared to our EGs, the 24-week study of Boa Sorte Silva et al. [23] showed a lower mean adherence (83.3% vs. 70%), and higher values to reach the exercise intensity in the original Borg RPE scale (13.1 vs. 15-17). The prediction of compensatory sessions in case of health problems may be an effective strategy in reducing absenteeism.

Regarding the processing speed of our study participants, both EGs showed significant improvements at the post-intervention, with slightly higher effect sizes in EG1, whereby the WBV training did not lead to additional benefits. Our results are consistent and superior to other ICM programs in community dwellings. After 24 weeks of an ICM intervention (resistance/balance training + computerized cognitive training), the participants (74.5 ± 3.8 years) of the study of Sipila et al. [39] performed the TMT-A and TMT-B tests in less than 3.4% and 8.3% of the time, respectively; compared to the present study, our EGs executed the TMT-A and TMT-B at least 19% in less time. The specificity of the computerized cognitive training initially supervised and after some sessions individually and unsupervised may be a factor to explain these differences. An unsupervised ICM intervention (exergames under different postural conditions) was also carried out in the 16-week study of Schoene et al. [16], and no significant improvements were observed in participants (82.0 ± 7.0 years) performance in the TMT-A (37.1 ± 19.2 vs. 32.8 ± 12.2 s) and TMT-B variables (110.9 ± 60.0 vs. 107.7 ± 47.7 s). Finally, the 12-week study of Desjardins-Crépeau et al. [11] focused on an interactive program (stretching and toning exercises + dual-task training program) significantly improved the processing speed by 15.3% in the TMT-A test, whereby no significant differences in the TMT-B variable were detected. Likewise, the previous study has been supervised, and participants (73.2 + 6.3 years) also performed computerized cognitive training. Despite the preceding studies have shown significant improvements in several domains of executive function, it appears that supervised ICM interventions, like our programs, without resorting to computerized cognitive training can lead to additional improvements in information processing. Moreover, the diversity of group exercises proposed present in our programs, as dual-task paradigms, targeting the enhancement of specific cognitive domains and brain regions as the prefrontal cortex could help explain our study results. In this way, it is recommended that fall prevention programs should have these characteristics. Thus, these findings must be interpreted with caution. Considering the effects of the programs' cessation, the processing speed improvement induced by both programs was maintained at the follow-up evaluation, especially within EG2. These findings are in line with other studies. In the study of Blasco-Lafarga and colleagues [22], after 14 weeks of detraining, the executive function results showed a slight decrease. Whereby cognitive function losses seem to be less sensitive to a detraining period. This is important because cognitive improvements, particularly in processing speed, directedly reduces the risk of falls and can attenuate decline physical function over ten years [4].

With respect to physical function, namely in lower-body strength, both programs induced similar improvements. This is an unexpected finding because the WBV training has been referred to as an effective program for improving muscle strength, alone or combined with other programs [20]. Therefore, it would be expected that an intervention that combines WBV and a psychomotor intervention, that was also included strength stimulation, would obtain additional benefits in terms of muscle strength than the psychomotor intervention alone. At the post-intervention, both EGs significantly increase the number of repetitions performed in the “30CST” (EG1: 45.2%; EG2: 42.9%), with similar effect sizes. These results support the findings in previous studies, as Desjardins-Crépeau et al. [11] study, in which only the mixed aerobic and resistance training combined with cognitive training led to an increase superior to 45% in the number of repetitions. Also, compared to the 12-week study of Hsien-Te Peng and colleagues [40], our EGs achieve a more accentuated increase in the number of repetitions than their ICM EG that improved 10.1% (21.8 ± 6.9 vs. 24.0 ± 6.4). For the maximal strength of the knee extensors and flexors, despite an increase of 8.9% in the variable “Isokinetic peak torque (extension 60º)”, within EG2, it was not significant. However, these results are in accordance with other ICM studies that presented an increase of 10.9% at the knee extension force after 12 months of intervention [39]. The fact that both programs included majority resistance strength exercises could help to explain these results. Therefore, these results recommend that the ICM programs designed for fall prevention should include resistance strength exercises. However, for enhancements in maximal strength, both programs should be more focused on muscle strength and power exercises, possibly through plate-loaded machines, and the sessions' intensity level at the RPE scale should target values between 13 to 15 [39]. Nevertheless, the specificity of a psychomotor intervention, mainly oriented to corporeality and self-awareness, does not incorporate and reach these high intensities on a session. After the 12-week follow-up, improvements induced by both programs in lower-body strength, particularly in the “30CST” variable, were reversed. These findings are similar to those from Blasco-Lafarga et al. study [22], which developed an ICM program (strength + cardiovascular exercises under dual-task paradigms). These authors pointed out that the effects of detraining were more marked in muscle strength than in other physical function outcomes, being muscle strength the physical function capability with more sensitivity to an intervention program and the respective detraining. Also, the previous study evidenced a higher sensitivity at the second detraining moment, showing a decrease in the number of repetitions at the “30CST” (-15.7%), whereas, in the present study, this decrease was superior to -21%, in both EGs. Considering our intervention programs' specificity, the results highlight the need for detraining periods to be less than 12 weeks, which are in line with recommendations of Blasco-Lafarga and colleagues' study [22]. Another recommendation is implementing a home-based program including strength exercises, while the psychomotor intervention is not restarted.

In what refers to body composition, compared to the psychomotor intervention program, the combined intervention not only induced improvements on BMD, but also in BMC, T-Score, and Z-score, with a larger ES in all variables. Thus, these improvements within EG2 were more visible at an osteogenic level than muscular strength and muscle mass levels, as described above, which could positively influence fracture risk. The vibration exposure could lead to a more effective stimulation of bone formation, increasing the BMD and BMC. Furthermore, these results suggest that adding only ~5 minutes per session of WBV training in a psychomotor intervention can lead to additional benefits. Given the lack of ICM studies focused on body composition changes, the comparison of our study with other studies is limited. Contrary to the present study, the 24-week study of Marín-Cascales and colleagues [41] found a significant decrease in total fat mass, either in the WBV group or the multicomponent program group (aerobic and drop jumps exercises), in postmenopausal women. These authors also found no changes in total lean mass and BMD in both groups. The findings of the previous study as regards total lean mass are consistent with our study findings. In fact, the best method to improve muscle mass or lean body mass is still unclear, and future investigations are needed since muscle weakness increases the risk of falling [5, 20]. Also, it is interesting the observation that our psychomotor intervention with low material effort also achieved significant improvements on BMD. Thus, our psychomotor intervention can also be recommended as an effective therapy to minimize bone loss. Concerning the improvements in BMC, our study evidenced superior improvements than the multicomponent 24-month program of Englund and colleagues [42]. In the previous study, their EG, which includes strengthening, aerobic, balance, and coordination exercises, increase 3.5% BMC, while our EG1 and EG2 increase 5.3% and 11.4%, respectively, despite only the EG2 presented significant improvements. Therefore, our EG2 could positively influence the prevention of bone demineralization. At the follow-up these improvements were reversed, especially in EG2, suggesting the importance of a non-cessation WBV training in body composition; these results were followed by the normative data comparisons of the T-score and Z-score variations, in which lower mean scores represent an inferior bone density.

Lastly, a significant reduction in fall occurrence was observed in both EGs at the post-intervention, especially within EG2, which showed a lower number of falls. Despite the WBV training low frequency (15 Hz) used within EG2 to ensure a safe intervention, the mechanical stimulation and higher muscle activation provided by the WBV could lead to a larger protective effect of the combined program for falls. The psychomotor intervention for fall prevention of Freiberger and colleagues [18] reported the fall occurrence over the previous six months at baseline and during the 12-month follow-up, and no significant differences were observed. Likewise, few ICM programs include the number of falls as the main outcome. The 16-week study of Gschwind et al. [43], which include a virtual-reality intervention program, showed a decrease in the incidence of falls in EG (-68.0%). However, alongside the specificity of a virtual-reality intervention, the retrospective falls of the previous study were collected over the previous 12 months at baseline, whereby comparisons to our study should be interpreted with caution. One of the first studies to directly evaluate the effects of WBV training on falls also showed a significant decrease in falls rate only in the combined 18-month program (multicomponent physical training + WBV). However, these results are difficult to compare to our study given the long-term intervention, exclusively postmenopausal women participants, and the higher frequency used (25–35 Hz) on the WBV [44].

Recommendations for future studies should include more psychomotor measures potentially linked with falls as a body scheme or knowledge of body parts impairments. Furthermore, physiological assessments as the collection of the brain-derived neurotrophic factor levels or an electroencephalogram to evaluate more precisely the effects of a psychomotor intervention on brain neuroplasticity can also be incorporated. Regarding the strengths of the present study, we highlight the RCT design that includes a follow-up and the intervention length. Our study also has some limitations. First, this study followed a single-blinded design. Second, the dropout rate (14.3%) was high; however, it was lower than other interactive cognitive-motor fall prevention programs [16], and the sample size remained were sufficient to detect significant changes, according to the G*Power software. Third, participants were not randomly assigned by gender (i.e.: first females, second males). Fourth, nutritional supplementation as vitamin D intake was not controlled, which could allow a more efficiently calcium absorption potentializing the impact of both programs in bone mass; however, the impact of vitamin D supplementation on BMD in older adults is still inconclusive [45]. Lastly, despite the predominance of female participants in our study, it was under the results presented in other studies [1]. However, despite the limitations and as mentioned above, this study was carried out with a sample size with sufficient power to allow the generalization of the results to the target population, whereby is recommended the implementation of a psychomotor intervention program as a fall prevention program.

Conclusions

Our results suggest that both interactive cognitive-motor programs were accepted and were well tolerated by participants. They were effective for fall and injury prevention in community dwellings at risk of falling. Either the psychomotor intervention program or the combined program showed to induce improvements on the risk factors for falls, enhancing the processing speed and the lower-body strength, with similar treatment effects. The combined program evidenced additional benefits in bone mass, particularly in BMC, BMD, T-Score, and Z-score. The combined program's clinical relevance/treatment effect was larger concerning these factors determining the risk of fracture. Both EGs, particularly EG2 induced a significant reduction in fall occurrence. The improvements induced by both programs in processing speed remained after the 12-week no-intervention follow-up, particularly in EG2. However, lower-body strength and bone mass improvements were reversed in both EGs and in EG2, respectively, after the detraining period. These findings highlight the benefits of a psychomotor intervention program as a fall prevention program. Moreover, evidence the advantage of replacing ~5 minutes of WBV training in a psychomotor intervention, particularly due to its protective effect on bone and fall-related fractures.

Abbreviations

BMD: Bone mineral density; ICM: Interactive cognitive-motor; WBV: Whole-body vibration; RCT: Randomized controlled trial; EG1: Experimental group 1; EG2: Experimental group 2; CG: Control group;

MMSE: Mini-Mental State Examination; 30CST: 30-s Chair Stand Test; TMT: Trail Making Test; DXA: Dual-energy X-ray absorptiometry; BMC: Bone mineral content; RPE: Borg Rating of Perceived Exertion; IPAQ: International Physical Activity Questionnaire; MET: Metabolic equivalent of task; SPSS: Statistical Package for the Social Sciences; ES: Effect size.

Declarations

Ethics approval and consent to participate

Written informed consent was given by all the participants. Ethical approval for the study was provided by the University of Évora Ethics Committee - Health and Well-Being (reference number 16012), following the guidelines of the Declaration of Helsinki.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Competing interests

The authors have declared that no competing interests exist.

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Authors' contributions

Conception, design, analysis and interpretation of data, write - original draft: HR. Conception, design, analysis and interpretation of data, write - review, supervision, funding acquisition: CP. Conception, design, analysis and interpretation of data, write - review, supervision: JB, JC, and AR. All authors read and approved the final manuscript.

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Figures

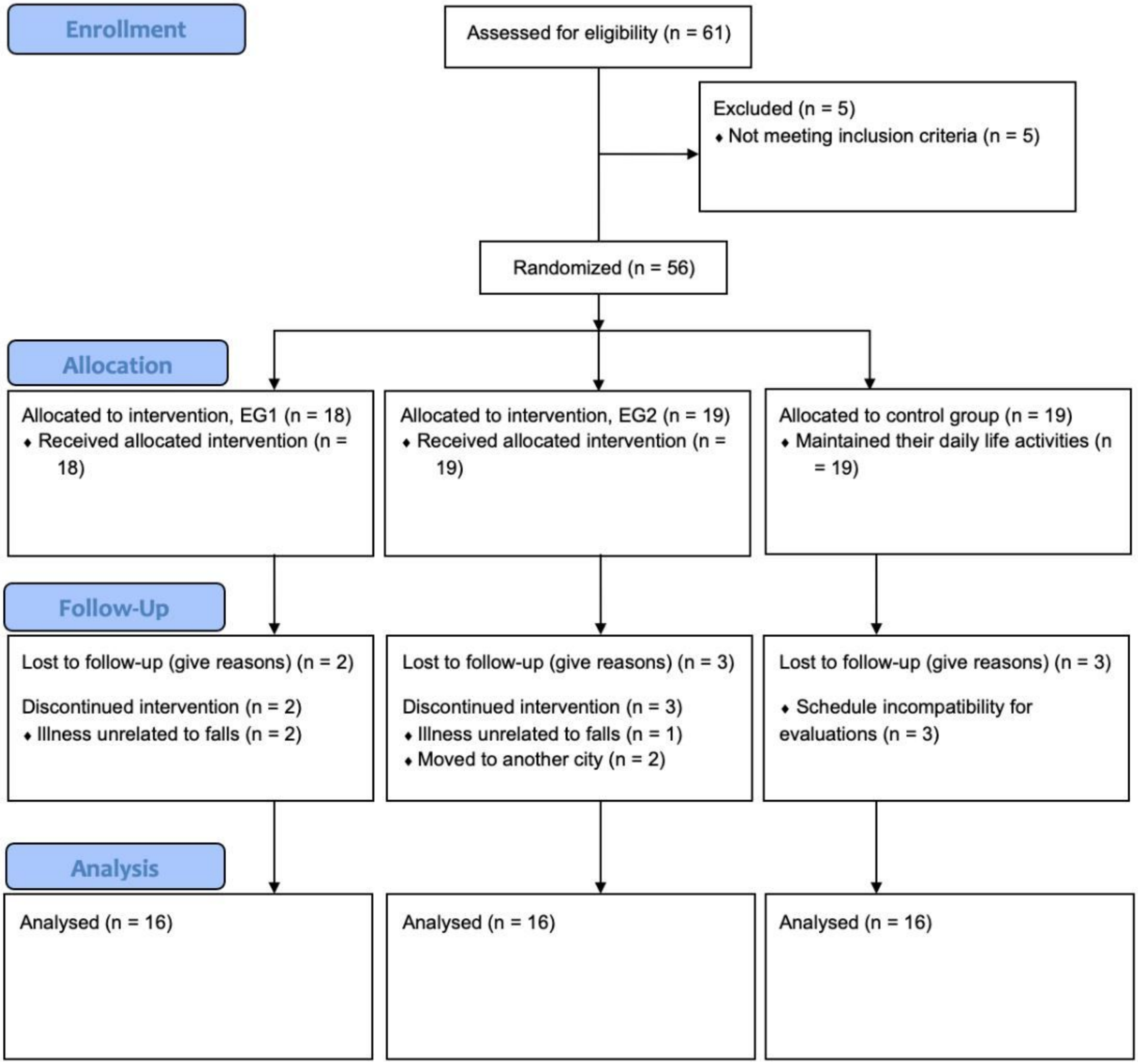

Figure 1

Flow diagram of the study participants