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Original Article

Balance Exercise Circuit for fall prevention in older adults: a randomized controlled crossover trial

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Abstract

Objectives: This study aimed to assess the immediate and short-term effects of the Balance Exercise Circuit (BEC) on muscle strength, postural balance, and quality of life, with the aim of preventing falls in older adults. **Methods**: Twenty-two volunteers participated in this randomized controlled crossover study. Group A performed BEC training in the initial 3 months and received no intervention in the following 3 months. Group B received no intervention during the first 3 months and then participated in BEC training for the next 3 months. In addition, participants were followed for an additional 3 months. Muscle strength, postural balance, functional mobility, and quality of life were assessed, respectively, using an isokinetic dynamometer, force platform, TUG test, and the WHOQOL. **Results**: After 3 months of training, Group A presented improved balance and rate of force development (RFD), while Group B presented improvements in RFD, TUG performance, and WHOQOL physical and psychological domains. Regarding the short-term effects, the participants maintained the training effects in WHOQOL balance, RFD, and the social domain. In addition, the number of falls decreased during follow-up. **Conclusion**: The BEC intervention improved muscle strength, postural balance, and quality of life in older adults, in addition to reducing the risk of falls. **Trial registration**: Brazilian Registry of Clinical Trials (ReBEC) - RBR-5nvrwm.

Keywords: Aging, Circuit-based exercise, Muscle strength, Postural Balance, Quality of life

Introduction

Falls in older age are a major public health problem due to their high prevalence, significant impact on health and quality of life, and high cost[1-5]. Impairments in balance and lower limb muscle strength are intrinsic factors for an increased risk of falls in older adults[6-8]. This is because, during the aging process, it is natural for there to be a decrease in muscle strength, with strength declines being detected in the abductors, hip adductors, and knee extensors. Evidence shows that older adults use the primary motor muscles in their daily activities at a higher intensity than the leg stabilizers, which may perhaps lead to weak support during gait and in the bipedal position, with a particular need for strength training of lower limb muscles with emphasis on knee extensors and lower limb stabilizers[9,10]. In addition, strong evidence supports that specific exercise can reduce the risk and rate of falls in older adults[1,3,11-14]. Thus, exercise programs including moderate to high balance difficulties have the greatest impact on falls[12,13,15].

Therefore, we believe that the Balance Exercise Circuit (BEC) could be an effective program for the prevention of falls,

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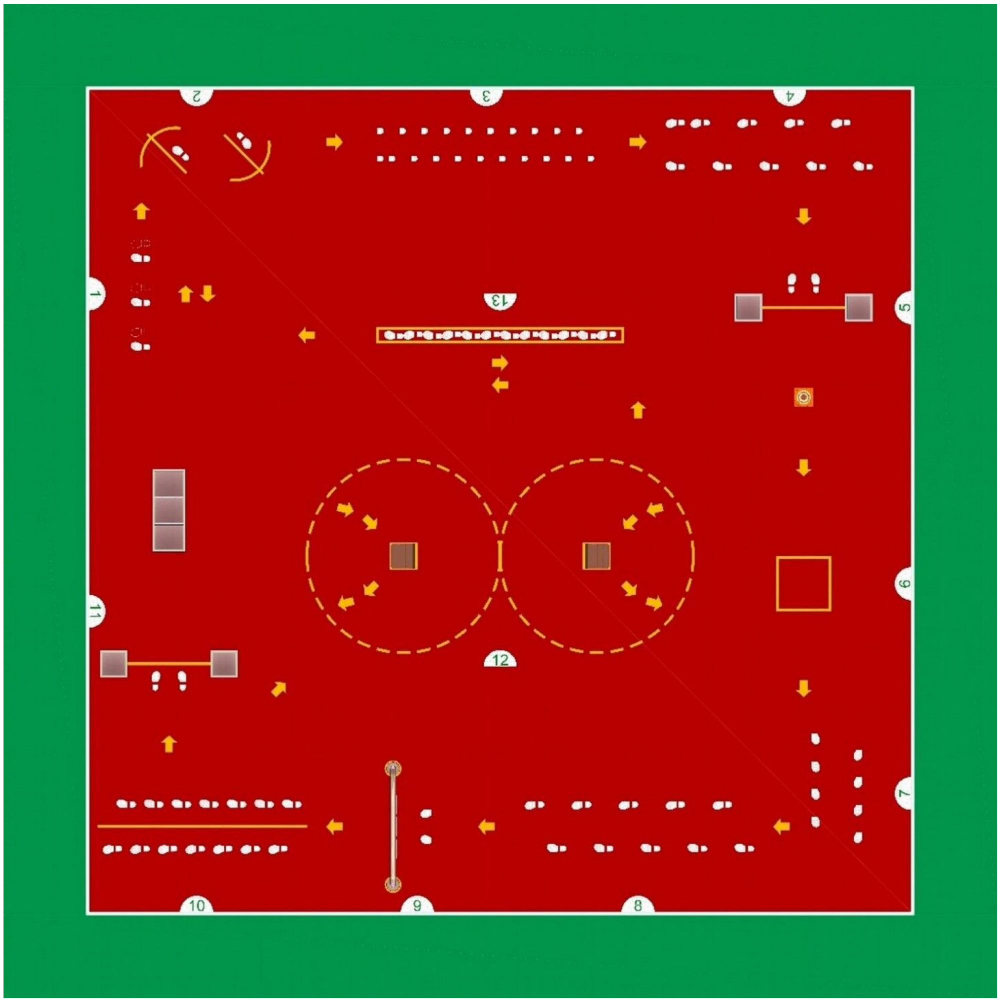

Figure 1. Balance Exercise Circuit.

as it includes multimodal exercises that simulate activities of daily living, designed to provide a progressive challenge to balance and lower limb strength through a combination of sensory stimuli, force, and balance. In addition, the BEC increased muscle strength, balance, and functional mobility in women aged 60+ years[4], requires relatively low supervision and material costs, and contains a structured manual that provides practical information in terms of training volume, (i.e., type, frequency, duration), to facilitate the replication of the intervention for potential widespread implementation.

Recent studies evaluating the impact of multimodal and multisensory training programs have focused on the immediate intervention effects[16-18], with few examinations of the long-term impact on important health outcomes[19-22]. Furthermore, a systematic review that included 94 randomized clinical trials and concluded that certain types of exercise, such as gait, balance, coordination, and functional training, as well as other three-dimensional exercise programs, are moderately effective in improving balance in people aged 60+ years[23-25], did not consider the short-term effects of these programs. In addition, recent systematic reviews of fall prevention interventions with short and long-term follow-ups[19-22] do not allow a comparative analysis of the BEC because they include interventions, populations, and evaluation tools with characteristics different from the protocol proposed in this study. Thus, further evidence is needed on the short and long-term impact (e.g., detrained period) on fall risk factors[26-28].

Complementarily, the practice of physical exercise is positively associated with the health-related quality of life of older adults, especially in the dimensions related to physical functions. Thus, this relationship could also occur with activities of daily living, in such a way that the higher the level of physical fitness, the greater the ability to perform

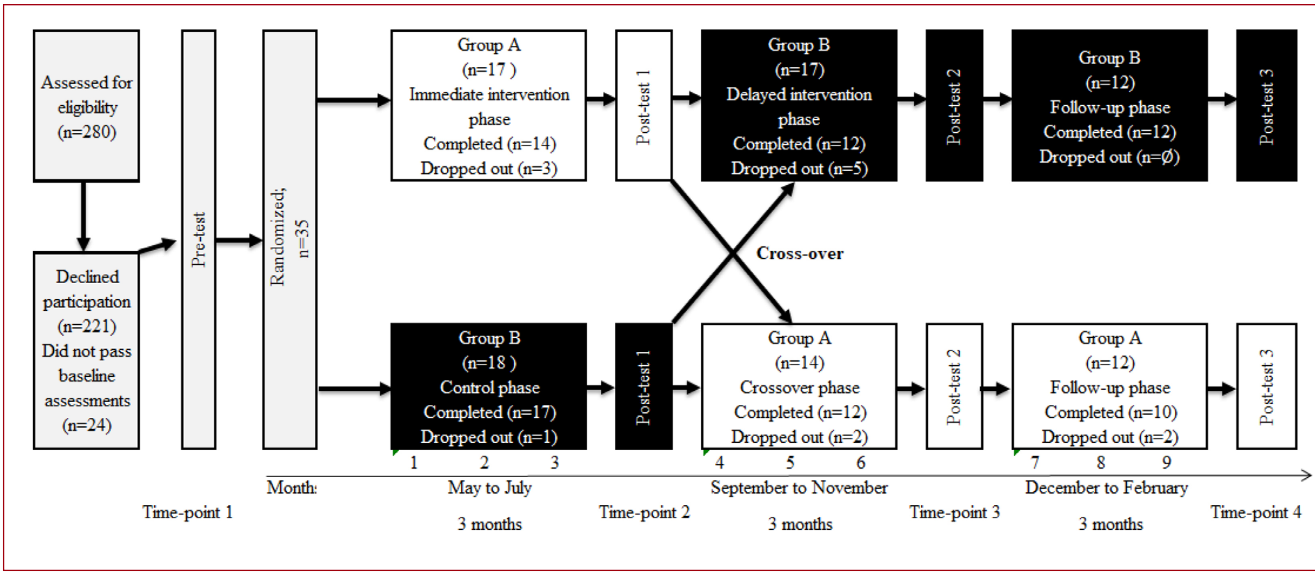

Figure 2. Flow of participants through the trial.

daily tasks, and, consequently, the better the quality of life[29]. However, most studies on these relationships involved cross-sectional designs or did not simultaneously analyze short or long-term outcomes without exercise practice. Therefore, monitoring how long physical exercises continue to have an effect even after interrupting the practice could be essential to provide better guidance and a warning about the harmful effects on quality of life of not adhering to continuous physical exercise programs.

Therefore, the current study aimed to assess the immediate and short-term effects of the BEC on muscle strength, postural balance, and quality of life, with the aim of preventing falls in older adults.

Materials and methods

Although the crossover study design is not common in balance interventions for older adults, we strategically adopted this method so that all participants acted as their own control, since both groups participated in the control and the proposed intervention. Therefore, the study was designed as a randomized controlled crossover trial with a six-month duration, including blind evaluation of the results and follow-up for an additional period of 3-months.

Initially, randomization to choose the initial arm of the study (intervention or control) was performed using a computerized program (http://www.randomization.com), through the random assignment method of 1 of 2 groups. The resulting assignments were placed in opaque envelopes and distributed to the participants after all baseline evaluations.

All outcome assessments were carried out at the strength training laboratory and the human movement analysis laboratory of the Faculty of Physical Education, University of Brasilia. The intervention with the experimental group (BEC) was carried out in an external court of the Olympic Center at the same university, as shown in Figure 1, and the control group was guided through lectures in an amphitheater located in the university.

The study was conducted in four phases (time points): 1) enrolment and baseline assessment, where the participants were randomized into an immediate training intervention group (Group A) and a delayed intervention group (Group B); 2) the immediate intervention phase, where Group A underwent training for 3 months and Group B served as a control group; 3) the crossover and delayed intervention phase, where participants in Group B received the same training intervention for 3 months as Group A received in phase 2, and Group A served as a control group; and 4) additional 3-month follow up without intervention (Figure 2). Outcome assessments occurred at baseline and at the end of the second, third, and fourth time points.

Sample

Participants were conveniently recruited through advertisements on television, newspapers, and presentations in the local community. This recruitment resulted in 280 individuals who contacted us to participate in the study, however, 221 gave-up participating before the initial interview (the major reasons were the length of the study, binding periods, lack of interest, or spouse illness), and another 24 individuals did not pass the baseline assessment. Therefore, thirty-five individuals (Group A=17; Group B=18)

Class	Contents	Speaker	Training
01	A look at aging	Juliana Nunes de Almeida Costa	Physical Education Professional, and Ph.D. in Health Sciences
02	Elza and Fred (Film)	Lucy de Oliveira Gomes	Doctor and Ph.D. in Physiology
03	Faith as a health factor	Fernando Rebouças	Priest
04	Most suitable exercises: when and how to do them	Juliana Nunes de Almeida Costa	Physical Education Professional, and Ph.D. in Health Sciences
05	Osteoporosis: how to prevent it	Helenice Alves Teixeira Gonçalves	Rheumatologist
06	Knowing osteoarthritis	Jamille Nascimento Carneiro	Rheumatologist and master in Health Sciences

Table 1. Themes and speakers for the educational classes (control group).

	Group A (n=10)	Group B (n=12)	*p value*
Age (year), mean (SE)	65.80 (1.20)	65.83 (1.19)	0.985
Body Mass Index (kg/mÇ), mean (SE)	26.80 (0.90)	28.00 (1.91)	0.601
Falls in the previous year	6 (40.0)	6 (50.0)	0.485
Chronic Diseases			
Diabetes	2 (22.2)	3 (25.0)	0.594
Hypertension	5 (55.6)	6 (50.0)	0.665
Depression	2 (22.2)	2 (16.7)	0.632
Labyrinthitis	5 (55.6)	3 (25.0)	0.221
Urinary incontinence	2 (22.2)	1 (8.3)	0.429
Insomnia	2 (22.2)	0 (0.0)	0.195
Osteoporosis	1 (11.1)	3 (25.0)	0.368
Anxiety	5 (55.6)	5 (41.7)	0.515
Neuronal disease	0 (0.0)	0 (0.0)	-
Arthritis	2 (20.0)	3 (25.0)	0.594
Number of Medications			
Up to 2	3 (30.0)	3 (25.0)	0.583
3 or 4	7 (70.0)	9 (75.0)	

SE - standard error.

Table 2. Baseline characteristics of subjects randomized to immediate intervention (Group A) and delayed intervention groups (Group B).

were eligible and randomized. However, for reasons beyond our control (e.g., family disease), only 22 participants (Group A=10; Group B=12) concluded the study (Figure 2).

To be eligible, participants were required to be aged 60 years or older, living in the community, able to walk independently without an assistive device, be able to hear and communicate verbally, and understand the trial procedures. Participants were excluded if they reported acute medical diseases in the previous 3 months, pre-existing neurological diseases such as Parkinson's disease, dementia, or stroke, if they had arthritis, vision impairment, or a cardiovascular disease that impaired walking, or if they were unable to walk without assistance whether due to an orthopedic problem affecting walking, dementia, or severe cognitive impairment.

Training Program

Participants allocated to the experimental group took part in the BEC for 50 min, two times per week, for a total of 3 months. Each BEC session comprised 10 minutes of warm-up and stretching, 30 minutes of exercise circuit involving progressive balance exercises, including time for a short break to drink water, and the last 10 minutes for cool-down, as described in Table 2 of the study by Avelar et al.[4]. The participants exercised in pairs at each station for 2 min (1 min for each participant of the pair), and a whistle was blown after every minute to indicate respectively the pair to change who was exercising and the need to move on to the next exercise station. The progression of exercises occurred every 3 weeks and was closely supervised by an exercise specialist to ensure safety, especially in the first week in which the progression was introduced. Progressions were as follows: (1) exercises performed with eyes open, (2) exercises performed with eyes closed, (3) exercises performed with obstacles and eyes open, and (4) exercises performed with obstacles and eyes closed. Progressions were applied on an individual basis, with instructors judging whether or not participants were ready to attempt the more difficult activities of the next progression[4]. Note that verbal encouragement and feedback were also offered by the trainers.

Participants allocated to the control group attended educational lectures, for 60 min, two times per month for a total of 3 months. Each session comprised health lectures, including topics such as the impact of dizziness on the quality of life in older adults (Table 1). In addition, participants were instructed to maintain their usual level of physical activity and were contacted by telephone twice a month to foster an ongoing engagement with the study. It is important to note that the participants who performed the intervention in phase 2 were advised and supervised via telephone and during the face-to-face meetings not to perform the exercises they learned, only to attend the educational lectures and wait for the moment to start the exercises again (after the fourth time point).

Outcome assessments

All measurements were carried out by a trained and experienced technician and the equipment was calibrated daily according to the manufacturer's specifications. It is important to note that the outcome measures were assessed by the same investigator throughout the study.

Primary Outcomes

Muscle strength

Dominant knee extensor peak torque (PT) and rate of force development (RFD) were assessed using an isokinetic dynamometer (Biodex System 3, Medical Systems, NY, USA). In the first assessment, the equipment set-up for each participant was recorded to ensure consistent conditions in re-assessment measurements. The protocol adopted a warmup involving two sub-maximal sets (set 1: 10 repetitions at 210°/s; set 2: 6 repetitions at 120°/s) and the testing, which consisted of two sets of one maximal contraction at 60°/s, two sets of four maximal contractions at 60°/s, and two sets of four maximal contractions at 180°/s, with 60 seconds rest between sets[30]. The participants were asked to perform the movement with their maximal strength while verbal encouragement was offered.

Data were collected using Biodex software, analyzed in MATLAB R2010a software, filtered using a Butterworth filter of 10 Hz. The calculation of RFD was performed according to time intervals (0-30, 0-50, 0-100, 0- 200, 0-300 ms) and PT (0-PT - Nm)[31,32]. Note that the onset of muscle contraction was defined as the time point at which the moment curve exceeded baseline by >7 Nm[33]. The highest PT for each speed was recorded for analyses.

Postural balance

Static balance was evaluated using an AccuSway Plus force platform (AMTI Inc.) that measures displacements of the center of pressure (CoP). The force platform signals were sampled at 100 Hz and data were filtered using a fourth order Butterworth filter with a cutoff frequency of 10 Hz. The software Balance Clinic (AMTI Inc.) was used for signal recording[34]. The reliability coefficient was $r \geq 0.75$[35]. Environmental conditions during testing were kept consistent, with no visual or auditory disturbances. To standardize participant stance position, the platform was marked with a 2 cm wide tape to indicate the desired positioning of the feet. Participants were asked to keep their sight fixed on a mark on the wall positioned 1.5 m away from the platform and 1.5 m above floor level and to breathe normally. Participants were barefoot and were instructed to stand for 30 seconds on the force platform, with arms relaxed and minimal body sway. The protocol consisted of three 30-second attempts with open base and high-density foam under two different conditions tested in random order: eyes open (EO) and eyes closed (EC). Each condition was randomized to minimize learning effects, and the participants were able to rest between trials. The CoPml range is a strong single predictor of falling risk, and the CoPam range is associated with the risk of serious injury following fall events.

Functional performance

The Timed Up and Go (TUG) test is a clinical performance-based measure of mobility, lower extremity function, and fall risk. The time taken to complete the test is strongly correlated to the level of functional mobility[36] and is suitable for the assessment of healthy older adults[37]. The TUG was conducted using a chair with arms and a seat height of 46 cm placed on a flat surface with cones marking the 3 m turning point. Participants were instructed as follows; on the word 'go', get up and walk as quickly as you can to the mark, turn around, and then walk back and sit down[38,39].

Secondary Outcome

Quality of life

To assess the quality of life, participants completed a validated Portuguese version of the WHOQOL-BREF. This

	Group A (n=10)			Group B (n=12)			A x B Post 1
	Baseline (Mean±SE)	Post 1 Intervention (Mean±SE)	d'	Baseline (Mean±SE)	Post 1 Educational Classes (Mean±SE)	d'	d'
Postural Balance							
EO CoPvel (cm/s)	3.42±0.48	2.56±0.39	-0.727	2.90±0.18	2.63±0.22	-0.429	-0.095
EO CoPap (cm)	4.72±0.37	3.83±0.55	-0.736	4.13±0.25	4±0.33	-0.146	-0.159
EO CoPml (cm)	4.02±0.35	3.46±0.30	-0.625	3.59±0.20	3.26±0.32	-0.419**	0.266
EC CoPvel (cm/s)	4.98±0.37	4.43±0.55	-0.463	5.69±0.40	4.84±0.44	-0.643	-0.337
EC CoPap (cm)	7.48±0.48	5.99±0.59	-1.054*	7.22±0.34	6.72±0.50	-0.383	-0.529
EC CoPml (cm)	5.71±0.42	5.45±0.43	-0.231	5.69±0.43	5.04±0.55	-0.424	0.324
Muscle strength							
Peak Torque 180° (N.m)	56.69±7.14	69.38±8.7	0.604	65.81±7.2	65.13±9.31	-0.027	0.186
RFD 30 180º (N.m.s-¹)	755.55±143.22	999.37±172.38	0.582	792.96±78.52	927.52±153.29	0.397	0.182
RFD 50 180º (N.m.s⁻¹)	450.49±80.69	795.5±162.98	1.114**	535.85±64.02	739.84±110.63	0.793	0.169
RFD 100 180º (N.m.s⁻¹)	268.87±58.61	374.77±83.56	0.569	331.3±51.34	369.4±68.26	0.213	0.029
RFD 200 180º (N.m.s⁻¹)	206.22±34.63	280.63±47.81	0.688	255.35±35.98	286.34±55.97	0.227	-0.045
RFD 300 180º (N.m.s⁻¹)	160.85±23.22	200.49±25.47	0.608	189.42±24.47	191.38±38.84	0.021	0.114
RFDP 180º (N.m.s⁻¹)	286.90±78.75	281.36±62.71	-0.028	279.17±53.65	395.74±124.50	0.452	-0.487
Functional performance							
Timed Up and Go (s)	5.99±0.31	5.95±0.17	-0.059	5.90±0.18	6.03±0.19	0.205	-0.145
Quality of life							
Physical	57.86±3.00	60.00±3.72	0.202	60.86±2.49	64.39±3.03	0.369	-0.394
Psychological	61.58±3.86	63.75±3.93	0.176	62.15±3.57	68.06±2.92	0.525	-0.382
Social Relationships	62.50±7.27	65.00±3.24	0.150	68.94±5.52	73.61±4.08	0.288	-0.706
Environment	70.32±5.09	65±5.27	-0.324	69.27±5.41	72.92±3.59	0.234	-0.544

**- Significant difference p<0.01; ** Significant difference p<0.05; d'-Cohens' d; SE - sample error; EO - Open base with eyes open on high density foam; EC - Open base with eyes closed on high density foam; CoP - Oscillation of center of pressure; vel - mean speed; ap - anteroposterior; aml - mediolateral; RFD - Rate of force development; RFDP - Rate of force development peak; s - seconds; cm - centimeter; m - meters; N - Newtons.*

Table 3. Outcomes for subjects who completed the second time point and between-group differences.

self-report questionnaire explores six domains of quality of life: environment (8 items), physical (7 items), psychological (6 items), social relationships (3 items), and overall QoL (2 items). Domain values were transformed into a range between 0 and 100.

Falls

A fall was defined as "unintentionally coming to the ground or some lower level, not as a consequence of a sudden onset of paralysis, epileptic seizure, or external force"[40]. Participants were asked to report any falls sustained during the study in a fall diary and to hand in this diary at each time point[41-43]. The participants were reminded about the diary weekly in the training session, or by telephone. The Falls Efficacy Scale - International Among Elderly Brazilians (FES-I-Brazil)[44] was used to estimate the risk of falls.

Ethical Approval

All methods and procedures were approved by the Ethics Committee on Research with Humans (protocol: 56891516.6.0000.0030) at the University of Brasilia and the trial protocol was registered with the Brazilian Registry of Clinical Trials (RBR-5nvrwm). Prior to participation, all subjects received a complete explanation of the purpose, risks, benefits, and procedures of the investigation, and provided written informed consent.

	Group A (n=10)			Group B (n=12)			A x B Post 2
	Post 1 Intervention (Mean±SE)	Post 2 Educational Classes (Mean±SE)	d'	Post 1 Educational Classes (Mean±SE)	Post 2 Intervention (Mean±SE)	d'	d'
Postural Balance							
EO CoPvel (cm/s)	2.56±0.39	2.38±0.75	-0.220	2.63±0.22	2.6±0.76	-0.035	-0.296
EO CoPap (cm)	3.83±0.55	3.56±1.1	-0.236	4±0.33	3.71±0.99	-0.300	-0.152
EO CoPml (cm)	3.46±0.3	3.16±0.74	-0.432	3.26±0.32	3.25±0.82	-0.008	-0.111
EC CoPvel (cm/s)	4.43±0.55	4.37±1.1	-0.047	4.84±0.44	5.6±1.17	0.622	-1.078
EC CoPap (cm)	5.99±0.59	6.09±0.88	0.094	6.72±0.5	7.06±0.84	0.302	-1.123
EC CoPml (cm)	5.45±0.43	4.93±1.11	-0.506	5.04±0.55	5.89±1.78	0.508	-0.666
Muscle strength							
Peak Torque 180° (N.m)	69.38±8.7	71.6±14.71	0.130	65.13±9.31	67.74±30.6	0.092	0.170
RFD 30 180º ($N.m.s^{-1}$)	999.37±172.38	1066.67±434.54	0.164	927.52±153.29	970.17±348.01	0.113	0.247
RFD 50 180º ($N.m.s^{-1}$)	795.5±162.98	713.06±200.77	-0.292	739.84±110.63	799.06±185.17	0.248	-0.446
RFD 100 180º ($N.m.s^{-1}$)	374.77±83.56	386.68±70.76	0.092	369.4±68.26	421.94±182.09	0.290**	-0.279
RFD 200 180º ($N.m.s^{-1}$)	280.63±47.81	280.79±78.31	0.002	286.34±55.97	279.35±135.4	-0.049	0.013
RFD 300 180º ($N.m.s^{-1}$)	200.49±25.47	199.23±49.14	-0.024	191.38±38.84	193.83±94.2	0.025	0.075
RFDP 180º ($N.m.s^{-1}$)	281.36±62.71	216.85±72.41	-0.607	395.74±124.5	553.65±458.86	0.401	-1.268
Functional performance							
Timed Up and Go (s)	5.95±0.17	5.8±0.45	-0.296	6.03±0.19	5.76±0.59	-0.4386*	0.083
Quality of life							
Physical	60.00±3.72	69.29±13.7	0.729	64.39±3.03	79.54±11.19	1.399*	-0.824
Psychological	63.75±3.93	65.83±12.7	0.166	68.06±2.92	81.97±8.01	1.536*	-1.558*
Social Relationships	65±3.24	60±13.49	-0.421	73.61±4.08	74.24±15.12	0.043	-0.995**
Environment	65±5.27	65.14±9.67	0.010	72.92±3.59	77.52±7.92	0.452	-1.408*

** - Significant difference p<0,01; ** Significant difference p<0,05; d' - Cohens' d; SE - sample error; EO - Open base with eyes open on high density foam; EC - Open base with eyes closed on high density foam; CoP - Oscillation of center of pressure; vel - mean speed; ap - anteroposterior; aml - mediolateral; RFD - Rate of force development; RFDP - Rate of force development peak; s - seconds; cm - centimeter; m - meters; N - Newtons.*

Table 4. Outcomes for subjects who completed the third time point (crossover phase) and between-group differences.

Statistical analysis

The sample size calculation was performed considering the explanatory power of the statistical tests based on the observation of mean effects, giving an initial result of n=30. However, the sample loss exceeded the increase in sample size (n=5). Thus, for all tests, post hoc analyses were performed to verify the adequacy of the effects found and the size of the final sample (n=22). Chi-square and independent t-tests were used for baseline comparisons of categorical and scalar measurements, respectively. As no differences were found between the groups, covariates were not adopted. For the comparison between the moments of the intervention, two-way ANOVA for repeated measures was used with the intercept of the group variable. In addition, the effect sizes (ES) were calculated according to Cohen's d (d') specifications[45]. Data were analyzed using SPSS v.18.0 for Windows (Chicago, IL, USA). A p-value ≤ of 0.05 was considered statistically significant for all analyses.

Results

Table 2 shows the characteristics of the groups, demonstrating that there are no significant differences between the groups in the initial evaluations.

Primary Outcome

The effects of the intervention on outcome measures at the second moment are presented in Table 3. Immediately

	Overall (n=22)		
	Baseline (Mean±SE)	Follow Up (Mean±SE)	d'
Postural Balance			
EO CoPvel (cm/s)	3.14±0.24	2.47±0.21	-0.452
EO CoPap (cm)	4.4±0.22	3.75±0.22	-0.464
EO CoPml (cm)	3.79±0.20	3.35±0.27	-0.324*
EC CoPvel (cm/s)	5.37±0.28	4.64±0.42	-0.366*
EC CoPap (cm)	7.33±0.28	6.3±0.43	-0.520*
EC CoPml (cm)	5.7±0.29	4.79±0.3	-0.487
Muscle strength			
Peak Torque 180° (N.m)	61.66±5.07	64.46±7.25	0.078
RFD 30 180° ($N.m.s^{-1}$)	775.96±75.99	1248.26±147.1	0.787
RFD 50 180° ($N.m.s^{-1}$)	497.05±50.25	762.57±68.21	0.761*
RFD 100 180° ($N.m.s^{-1}$)	302.92±38.32	371.95±44.2	0.273
RFD 200 180° ($N.m.s^{-1}$)	233.02±25.14	276.59±40.14	0.236**
RFD 300 180° ($N.m.s^{-1}$)	176.43±16.91	181.86±24.77	0.045
RFDP 180° ($N.m.s^{-1}$)	282.68±45.07	511.83±167.79	0.468
Functional performance			
Timed Up and Go (s)	5.94±0.17	5.62±0.11	-0.318
Quality of life			
Physical	59.5±1.91	69.67±3.96	0.579
Psychological	61.89±2.56	71.23±2.68	0.523**
Social Relationships	65.87±4.45	64.47±3.18	-0.051
Environment	69.75±3.66	66.78±3.77	-0.117

** - Significant difference p<0,01; ** Significant difference p<0,05; d' - Cohens' d; SE - sample error; EO - Open base with eyes open on high density foam; CE - Open base with eyes closed on high density foam; CoP - Oscillation of center of pressure; vel - mean speed; ap - anteroposterior; aml - mediolateral; RFD - Rate of force development; RFDP - Rate of force development peak; s - seconds; cm - centimeter; m - meters; N - Newtons.*

Table 5. The short-term effects of the BEC in all 22 participants.

after the intervention, Group A showed significant improvements in eyes closed balance (CE), anteroposterior oscillation (d'-1.054, p<0.01), and RFD with a velocity of 50 m/s (d' 1.114, p<0.05). In the same period, Group B, which did not have an intervention, showed only significant improvement in eyes open balance (EO) in the mediolateral oscillation (d'-0.419, p<0.05).

The results of the third moment (crossover) are presented in Table 4. After the crossover, Group A did not show significant improvement in any of the variables, however, even without physical training and participating only in educational lectures, this group did not demonstrate significant losses. In the same period, Group B showed significant improvements in mobility measured by the TUG (d'-0.4386, p<0.01), the physical (d' 1.3999, p<0.01) and psychological (d' 1.536, p<0.01) domains of quality of life, and in the RFD with a speed of 100 m/s (d' 0.290; p<0.05).

As the short-term effects of the BEC were similar, and without statistical difference between the groups, these effects were grouped and are summarized in Table 5. During the follow-up period, the 22 participants who completed the study showed significant improvements in the social domain of quality of life (d' 0.523; p<0.05), the CoPml eyes open scale (d'-0.324; p<0.01); CoPvel (d'-0.366; p<0.01), the eyes closed CoPvel (d'-0.366; p<0.01) and CoPap (d'-0.520; p<0.01), and the RFD, with significant improvement in the long run at the speed of 50 m/s (d' 0.761; p<0.01) and 200 m/s (d' 0.236; p<0.05).

Secondary Outcome

Table 3 shows no significant changes in quality of life at the second time point or differences between groups. However, at the third crossover moment, Group A did not show significant improvement in any of the variables, unlike

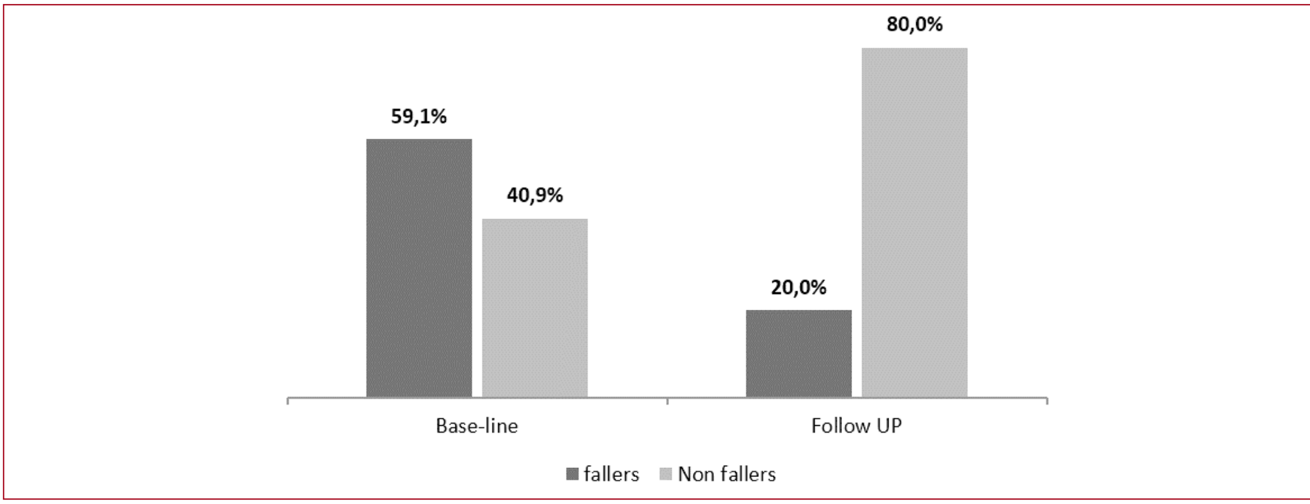

Figure 3. Number of older adults who frequently fell.

Group B, which presented significant improvements in the physical (d' 1.3999, p<0.01) and psychological (d' 1.536, p<0.01) domains of quality of life, and in RFD with a speed of 100 m/s (d' 0.290; p<0.05), as shown in Table 4.

Finally, according to the reports collected during the study, there was a significant reduction in the number of older adults who fell frequently (59.1% to 20%, p<0.01), as shown in Figure 3.

Adverse events

There were no adverse events associated with BEC participation and the progression was well tolerated by all participants.

Discussion

The primary aim of this study was to assess the immediate and short-term effects of the BEC on muscle strength, postural balance, and quality of life, with the aim of preventing falls in older adults. The most interesting finding was the improvement in several fall-related outcome measures after 12 weeks of follow-up intervention in groups A and B. These results imply that the intervention had a sufficient duration and intensity for effects to be observed, not only immediate effects but also a short-term improvement in postural control.

There is a consensus in the literature that multimodal and multisensory exercises, such as the BEC, are effective in improving physical abilities such as strength and balance[1,12,46-48]. Characterized by the integration capacity of the sensorimotor system, the BEC helps to promote better postural control[3,4,14,49]. The present study demonstrated that in addition to the immediate improvement, the participants maintained the gains obtained for at least 3 months. This study was also the first to verify a short-term effect; although we are unable to state that there were no more falls in the older adults after the intervention, the number of episodes suffered reduced.

Although studies recommend a minimum of 6 months follow-up of falls[12,50], the time of 3 months was enough to observe maintenance of the gain in physical functions that are risk factors for falls. The following variables presented alteration during the intervention and maintenance of the gain after 3 months of follow up; balance, in the eyes open oscillation protocols lateral mean (d'-0.324), closed eyes velocity of the CoP (d'-0.366), anteroposterior oscillation (d'-0.520), RFD at velocity 50 m/s (d' 0,761) and 200 m/s (d' 0,236), and, finally, the quality of life in the psychological domain (d' 0,523).

The immediate effects from the training intervention in our study showed statistical improvements in static balance (GA, d'-1,054), in a more challenging situation than the one proposed in the Avelar protocol[4], where the results found were similar (d' 1,007) to the immediate intervention phase. Another aspect of great importance in the present work for the assessment of balance was the adoption of different positions for activities of daily living during the intervention period, such as bathing, dressing, personal hygiene (e.g., use of the bathroom), transference, sphincter continence, and eating alone. In addition, there are also postures used in instrumental activities (related to tasks necessary for home care) and advanced activities (productive, recreational, and social activities), which require the use of static and dynamic balance.

When evaluating the oscillation variables (CoP) with eyes closed, the proprioceptive system, together with the vestibular, act in an integrative way with muscles, requiring high attention from the recessed sensory systems, since the visual loss in this population directly affects the CoP[4,35,51,52]. Thus, specific balance training with simulations of daily life activities can slow down and reduce the area of CoP movement, especially under more demanding balance test conditions[52,53] as performed during BEC progression in the stations of static and dynamic activity, where specific stimuli were provided to the remaining systems.

Considering the muscular system, for recovery of balance, maximal muscle strength usually is required in less than 200 m/s[33]. Therefore, decreasing the time to reach maximal contraction becomes a determining factor in the reduction of risk factors for falls in older adults. The meta-analysis of Guizelini et. al.[54] showed that training for 4 to 16 weeks is effective for improving RFD. However, the correlation between maximal muscle strength and RFD becomes smaller with decreasing RFD time[55]. Thus, the statistically significant improvement in RFD at rates of 50 m/s ($p<0.01$) and 200 m/s ($p<0.05$) after the BEC is highly significant to the ability to decrease the time to produce rapid muscle contraction to avoid a fall event.

Therefore, the significant findings on strength in the present study, through the RFD, showing the improvement in the production of rapid strength (GA, 1,114; GB, 0.290) although similar to those found by the researchers in the Avelar study[4], are more consistent since there was randomization of volunteers, a key factor to guarantee the quality of investigation in the studied sample. Therefore, there appears to be a need to replicate the study, with greater methodological accuracy, to verify the effects of the BEC, not only to verify the behavior of the variables that help in reducing the risk factors for falls in the short-term but also three months after the training.

An important effect of the program that remained at follow-up was an improvement in overall quality of life. This component involves greater satisfaction in the areas considered important to people's lives. Quality of life is considered a key goal in both individual and social welfare, especially in older adults[56].

The B group presented improvements in the physical (d' 1,399) and psychological (d'-1,155) domains immediately after the intervention, which was not observed for the A group. However, an improvement in quality of life in the psychological domain was observed (as assessed by the WHOQOL) in both groups in the follow-up period, suggesting that the improvements in physical performance in both groups led to improvements in the global functions of daily life.

This study has several limitations. One limitation was the impracticality of experimental blinding of the participants. Another possible limitation lies in the fact that the baseline history of falls was based on self-report[57,58], in contrast to the prospective data collection. In addition, the final sample size was smaller than recruited and calculated (n=30), so must be considered as a limitation. However, to minimize errors in the planning, execution, and data analysis phases of the study, a multidisciplinary team of evaluators systematically supervised all actions.

In summary, this trial contributed to the possible validation of the BEC exercise protocol, demonstrating its short-term effects for older adults. Physiotherapists and other health professionals could use this viable and validated exercise routine, whose effects on balance and knee extensor strength (intrinsic risk factors for falls) have been scientifically assessed. Finally, the results of the present study may help in the development of theories and models that explain the effects of the BEC, especially in older adults. We stress the importance of further studies and interventions using the BEC, if possible, with a larger population of older adults.

Conclusion

Besides improving muscle strength, postural balance, and quality of life in older adults, the BEC reduces the number of falls. Additionally, the benefits of exercise on physical function are maintained for at least 3-months without training. Thus, the BEC could represent a suitable intervention for wider implementation in society.

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