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ORIGINAL ARTICLE

The effects of a multicomponent intervention program on clinical outcomes associated with falls in healthy older adults

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Abstract

Background Multicomponent intervention programs have been shown to be effective in reducing risk factors associated with falls, but the primary target population of these interventions is often low-functioning older adults.

Aims The purpose of this study was to investigate the effectiveness of a multicomponent intervention program focusing on balance and muscle strength for independently functioning community-dwelling older adults.

Methods Fifty-three independently functioning older adults, aged 80.09 ± 6.62 years, participated in a group exercise class (conducted 2 times/week for 8 weeks) emphasizing balance. Outcome measures were balance performance using the Fullerton Advanced Balance (FAB) scale and muscle strength using the Senior Fitness Test (SFT).

Results The intervention improved balance ($P < 0.001$), and older adults who were classified as having high fall risks based on the FAB scores at pre-testing improved more than older adults who were classified as having low fall risks ($P = 0.017$). As a result, 22 participants transitioned from a high fall risk group at pre-testing to a low fall risk group at post-testing ($P < 0.001$). The intervention also enhanced both upper and lower muscle extremity strength based on SFT results ($P < 0.001$) regardless of participants' classification of fall risk status.

Conclusions and discussion The multicomponent intervention conducted two times per week for 8 weeks was effective in improving balance and enhancing muscle strength of independently functioning older adults. The results underscore the importance of providing fall prevention interventions to healthy older adults, a population often not a target of balance interventions.

Keywords Balance · Strength · Balance intervention · Community-dwelling older adults

Introduction

One out of three adults over 65 years of age living in the community experiences at least one fall each year [1]. Falls are the leading cause of fatal and nonfatal injuries and financial burden among Americans aged 65 and older [2]. Hospitalization from fall-related injuries accounts for 77% of all hospitalizations from injuries [3]. In the United States, the direct medical costs due to fall injuries were $31 billion in 2015 [4].

Successful balance control depends on the integration of three systems: the sensory system which collects information about the position of the body in space, the central nervous system that processes the sensory information, and the motor system that sends signals for appropriate movement execution. With aging, accumulated deficits in these systems contribute to falls [5]. Gait and balance impairment [6–8] and decreased muscle strength,

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especially in the lower extremities, increase the risk for falls [9, 10]. Furthermore, decreased movement speed and decreased force control with aging make it difficult to recover balance after tripping [11]. Given the potential negative physical and financial consequences of falls, it is important to provide an intervention to decrease the likelihood of falling before the balance impairments reach a critical level and falling becomes inevitable [12].

Intervention programs to reduce fall risks are divided into either providing single interventions (e.g., exercise) or providing multiple modes of interventions (e.g., exercise and education). The multi-modes interventions are further divided into individually tailored multifactorial interventions and group tailored multicomponent interventions [13]. An umbrella review of meta analyses by Stubbs et al. [14] concluded that single intervention and individually tailored multifactorial intervention programs were effective in reducing both the rate of falls and the number of individuals classified as fallers with varying levels of balance impairment. Because multiple factors contribute to falls, the American Geriatrics Society and British Geriatrics Society recommend either multifactorial or multicomponent interventions [15]. Noticing that the effectiveness of multicomponent interventions has not been extensively reviewed, Goodwin et al. [16] performed a meta analysis of 15 multicomponent intervention studies and concluded that multicomponent interventions are effective in reducing rate of falls and the number of people who fall. Fall prevention efforts, however, often target people who are already at high risk of falling (e.g., nursing home residents, older adults with musculo-skeletal or neurological impairments) [16]. Only 5 of the 15 multicomponent intervention studies reviewed by Goodwin et al. [16] involved older adults who were not considered to be at high risk for falls. Furthermore, the American Geriatrics Society and British Geriatrics Society recommend community-dwelling older people who have a past history of two or more falls, who have experienced a recent acute fall, or who have difficulty with walking and balance should be considered for participation in an intervention to reduce their fall risks [15]. The same guideline suggests that older adults who do not report falling in the past 12 months, need only be periodically reassessed. However, some studies have emphasized the importance of early intervention for maintenance of unimpaired balance [17–19]. For example, Muir et al. [20] found that a significant percentage of community-dwelling older adults who did not report recent falls experienced falls during the next 12 months. They concluded that balance impairment (defined as obtaining a Berg Balance Scale score of less than 50 out of 54) was a contributing factor for future falls. They also found that, for relatively high-functioning older adults who did not report an incident of falling, lower extremity weakness and impaired balance each uniquely contributed to an individual's moving from being classified as a non-faller to being classified as a faller. Thus, it is important to study the effectiveness of a multicomponent intervention program focused on balance and muscle strength for independently functioning community-dwelling older adults.

The current study investigated the effectiveness of an 8-week multicomponent balance training program on reducing fall risks by improving balance and muscle strength in independently functioning, community-dwelling older adults. The Fullerton Advanced Balance (FAB) scores at baseline were used to classify the participants as either with high fall risks or with low fall risks. We hypothesized that the multicomponent balance training program would (a) improve balance and muscle strength and (b) individuals classified as having high fall risks would experience more improvement than individuals classified as having low fall risks, resulting in a significant number of older adults with high fall risks at pre-testing being classified as having low fall risks at post-testing.

Methods

Participants

Fifty-three older adults (9 males and 44 females) participated in the study through the "Balance and Fall Prevention" class offered at a large urban University and a local senior housing community (Fig. 1). Participation in the Program was advertised through the quarterly newsletter of the university-associated Lifelong Learning Institute. Newsletters were distributed to 1600 members and placed in local senior centers and libraries. Participation in the research arm of the class was voluntary. Included participants were 65 years of age or older, able to stand unassisted for 45 min, able to follow verbal commands, independent in feeding, bathing, dressing, toileting, and transfers. Participants were excluded if they reported any medical condition that affected their cognition, balance, or walking. Six out of fifty-three participants were eliminated from the analysis: Five participants missed 3 or more classes (2 due to illness and 3 due to lost interest), and one participant missed post-testing due to traveling (Fig. 1). The age of the 47 participants who completed the intervention ranged from 65 to 91 years of age ($M = 80.09$, $SD = 6.62$). The majority of the participants were Caucasian. The Institutional Review Board of the University approved the study, and all participants signed an informed consent prior to joining the study.

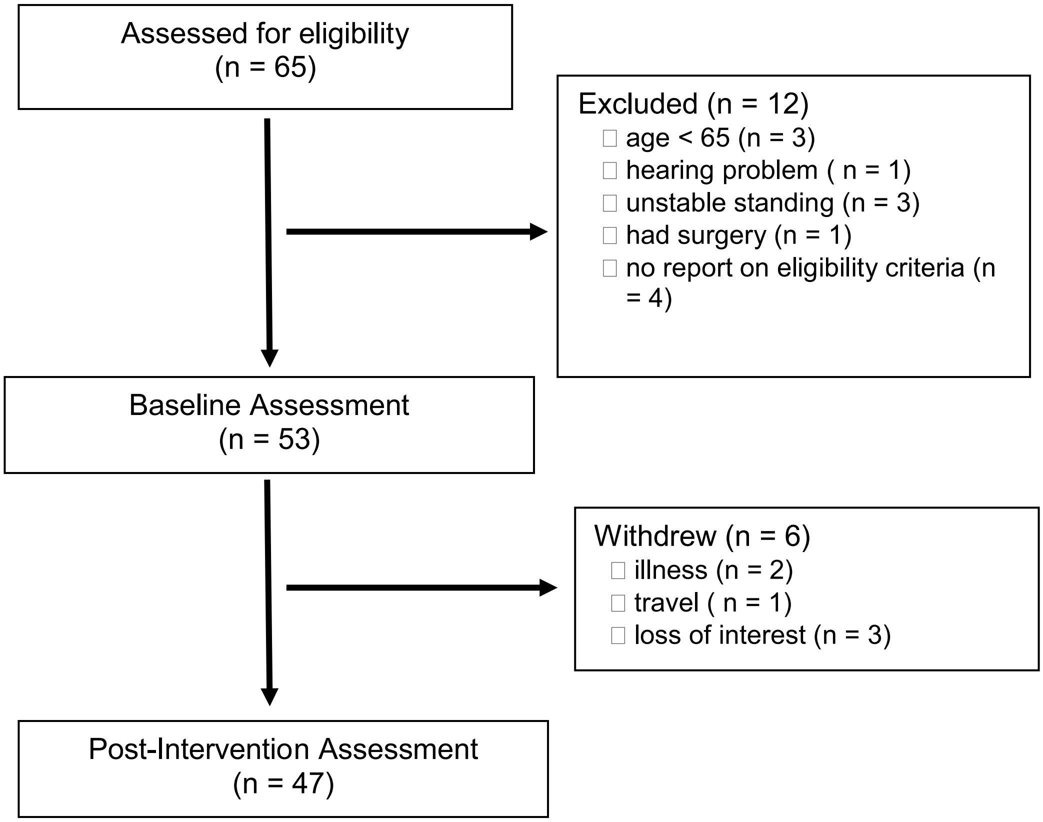

Fig. 1 Participants' flow chart

Procedures

During pre-testing, participants completed a health, activity, and demographic questionnaire providing information that was used to confirm eligibility of the subjects to participate in the study. In addition, we obtained blood pressure, dichotomous fall history (whether or not the participants fell in the past 12 months), exercise frequency (how often they exercised per week), and fall worry score (using a scale ranging from 1 = not worried to 7 = extremely worried). The following three outcome measures were recorded at pre- and post-intervention.

Fullerton Advanced Balance (FAB) scale

The FAB scale was used to assess participants' balance. The score at pre-testing determined each participant's designation as an older adult with high fall risks or an older adult with low fall risks [21]. FAB is known to be appropriate for assessing balance of independently functioning community-dwelling older adults, and is considered a useful tool for identifying subtle changes in various components affecting balance abilities [22]. The scale consists of ten items assessing both static and dynamic balance. Each item is scored using a 5-point scale (0 = not able to perform/needs assistance, 4 = able to perform independently) with a maximum score of 40 points. FAB scores are cross-sectionally associated with faller status as determined from a self-reported fall history such that older adults with FAB scores of 25 or lower are more likely to have a history of two or more falls in the past 6 months [23] or in the past 12 months [22]. A cut-off score of 25 was found to provide the sensitivity of 74.6% and specificity of 52.6% in distinguishing people without a history of falls in the past 12 months from people with a history of two or more falls in the past 12 months among independently functioning older adults [22]. Another study found that a cut-off score of 22 produced the sensitivity of 85% and specificity of 65% in predicting faller status [23]. A recent prospective study found that FAB scores have a sensitivity of 68% in predicting whether people with idiopathic Parkinson Disease will have one or more falls over the next 6 months [24]. The FAB scale has good test–retest reliability ($r = 0.96$), inter-rater reliability ($r = 0.94$–0.97), and convergent validity established using the Berg Balance Scale ($r = 0.75$) [21].

Senior fitness measures

Physical strength was assessed using three measures of the Senior Fitness Test [25]: the number of arm curls in 30 s (arm curl), the number of chair stands in 30 s (chair stand), and the number of in-place steps in 2 min (2-min step). The arm curls and chair stands assess general upper and lower extremity strength and the 2-min step assesses endurance. Although our program does not include an endurance intervention, we included the 2-min step test as an outcome measure to gauge the extent of indirect improvement in endurance that might have occurred as a result of improvement in balance and muscle strength. All measures were assessed once at pre- and post-test. Test–retest reliability for SFT items ranged from 0.80 to 0.98; content validity was established through the literature review and expert opinion; criterion validity ranged from 0.73 to 0.81; and construct validity was demonstrated by superior performance of older adults who were regular exercisers compared to those who were non-exercisers [25].

Intervention

The intervention was a 60-min group exercise class, conducted at an on-campus fitness center twice a week for 8 weeks and one educational session on fall prevention presented halfway through the intervention. A certified balance instructor conducted the exercise class. A licensed physical therapist designed the exercises and supervised the class. Graduate physical therapy students ensured that each participant correctly performed the exercises at a challenging level for that participant. Each student supervised two participants.

Weekly progression of the exercise intervention is presented in Appendix. The warm-up for the class included postural awareness, trunk stabilization, and variable walking activities with arm movement. Participants changed walking direction and speed, made abrupt stops, and performed head turns in response to music. Balance and multisensory training, designed to be progressively more difficult over time, included dynamic weight shifts, toe tapping, tandem walking, and walking in different directions. Sensory challenges during all exercises included eyes open and eyes closed, standing and walking on foam and head movement, as well as reading while walking.

Upper and lower extremity strength exercises were performed from both seated and standing positions using elastic resistance as well as standing against the wall for closed chain exercises. Some participants were able to do the seated exercise sitting on Dyna discs or an exercise ball. The strength of elastic resistance was set for each individual to complete ten repetitions. When a participant was able to complete more than ten repetitions, the participant was given the stronger resistance band. At week 5, exercise intensities were increased from 2 to 3 sets for each exercise.

The class also introduced an activities and games section that included crossing an obstacle course, passing objects in different directions, and kicking balls or balloons in circles or in lines. Head and eye movement training at different speeds and directions was done in the seated positions using popsicle sticks as a focal point.

The education, presented on the 4th week of the program, included instructions on home modifications for safety, proper footwear, the importance of addressing vision problems, proper use of assistive devices, management of medications, and practice on how to get up from the floor after a fall. Participants also received individualized consultation on home safety in response to a completed home safety checklist.

Power analysis

We conducted a priori power analysis using G*POWER [26]. The result showed that the desired total sample size is 34 for an ANOVA with two repeated measures (pre and post) and two groups with a medium effect size (i.e., $F = 0.25$), $\alpha = 0.05$, power = 0.8, and an average correlation for repeated measure = 0.5.

Statistical analysis

Statistical analyses were conducted using IBM SPSS (Armonk, NY) version 23. Fisher's exact test was applied to examine participants' gender distribution, and a MANOVA and follow-up univariate ANOVA analyses were used to examine other demographic and activity characteristics as a function of fall risk status at pre-testing. An exact McNemar's test was applied to compare the frequencies of people who classified with low fall risk and high fall risks at pre- and post-testing. A mixed ANOVA with time (pre vs. post) × group (low fall risks vs. high fall risks) was conducted to investigate the effects of the intervention on the FAB scores. Time was a within-subject variable and group was a between-subject variable. A significant time effect was followed with a paired *t* test for each group. A parallel-mixed MANOVA was conducted to investigate the effects of the intervention on three measures of the SFT. A significant result was followed with a univariate ANOVA on each measure of the SFT. The statistical significance was set at $P < 0.05$ in all analyses.

Results

Balance

Participants were classified based on the FAB scores. People whose FAB score was equal to or less than 25 were classified as having high fall risks and those who scored above 25 were classified as having low fall risks [22]. There were 28 older

Table 1 Demographic and activity characteristics of participants ($n=47$) at pre-testing

	Fall risk status		P
	Low ($n=19$)	High ($n=28$)	
Gender			
Male *(n)*	6	13	0.13
Female *(n)*	3	25	
Age (years)			
Mean	76.11	82.79	< 0.01
SD	5.86	5.76	
Height (cm)			
Mean	167.44	162.74	0.12
SD	12.79	6.11	
Weight (kg)			
Mean	69.43	64.26	0.19
SD	12.08	13.38	
Systolic blood pressure			
Mean	129.95	129.71	0.80
SD	17.19	17.37	
Diastolic blood pressure			
Mean	76.16	71.46	0.09
SD	10.57	12.30	
Past year fall			
Mean	0.5	0.37	0.66
SD	0.51	0.49	
Exercise frequency			
Mean	1.42	1.64	0.49
SD	0.90	1.06	
Fall worry			
Mean	2.53	3.41	0.08
SD	1.87	1.27	

SD standard deviation

adults with high fall risks (M_{FAB} = 20.29, $\mathrm{SD}_{\mathrm{FAB}}$ = 5.09) and 19 older adults with low fall risks (M_{FAB} = 30, $\mathrm{SD}_{\mathrm{FAB}}$ = 3.18) at pre-testing. Table 1 shows demographic characteristics of participants at pre-testing as a function of fall risk status. The results of a MANOVA at pre-testing revealed that there was no significant difference between people with high fall risks and low fall risks in any demographic and activity variables except for age, where people with high fall risks tended to be older than people with low fall risks, as expected. Although there were more females than males in general, the result of the Fisher's exact test showed that males and females were similarly distributed between high and low fall risk groups.

The means and standard deviations of the balance test scores are provided in Table 2. As predicted, the results of a mixed ANOVA showed a significant effect of time, $F_{1,45}$ = 128.25, η^2 = 0.74, $P<0.001$, such that there was an improvement in the FAB scores after the intervention for the combined sample. There was also a significant interaction of time and group, $F_{1,45}$ = 6.15, η^2 = 0.12, $P=0.02$. A follow-up paired sample t test for each group demonstrated that both groups showed a significant improvement in balance from pre-testing to post-testing, but people who classified as having high fall risks showed more improvement, $t_{27}=9.39$, $P<0.001$, than people who classified as having low fall risks, $t_{18}=8.15$, $P<0.001$.

When the participants were re-classified according to their fall risk status after the intervention, significantly more people were classified as having low fall risks than having high fall risks (Table 3) with 41 people with low fall risks (M_{FAB} = 32.27, $\mathrm{SD}_{\mathrm{FAB}}$ = 3.44) and only six people with high fall risks (M_{FAB} = 18.67, $\mathrm{SD}_{\mathrm{FAB}}$ = 4.50). Twenty-two older adults with high fall risks at pre-testing were classified as having low fall risks at post-testing, whereas no one

Table 2 Means (and standard deviations) and paired t tests of Fullerton Advance Balance scores and Univariate Analyses of Senior Fitness Test scores at pre- and post-testing for independently functioning community-dwelling older adults who were classified as low ($n=19$) and high ($n=28$) fall risks at pre-testing

Measures	Fall risk status					
	Low risk			High risk		
	Pre-testing	Post-testing	P	Pre-testing	Post-testing	P
Fullerton Advanced Balance						
Mean	30.00	34.74	< 0.001	20.29	27.69	< 0.001
SD	3.18	2.84		5.09	5.55	
Arm curl						
Mean	13.32	16.16	< 0.001	11.50	14.18	< 0.001
SD	2.43	4.00		3.62	3.66	
Chair stand						
Mean	10.32	12.74	< 0.001	8.36	10.25	< 0.001
SD	1.95	2.98		2.78	4.20	
2-min step						
Mean	76.53	97.47	< 0.001	63.82	78.71	< 0.001
SD	11.67	16.54		20.81	28.52	

SD standard deviation

who classified as having low fall risks at pre-testing was classified as having high fall risks at post-testing. An exact McNemar's test showed that there was a significantly higher proportion of people being classified as having low fall risks after the intervention compared to the baseline proportion, $P<0.001$, showing the effectiveness of the intervention in improving balance.

Senior fitness measures

The means and standard deviations of the senior fitness test scores are also provided in Table 2. As predicted, the results of mixed MANOVA showed a significant main effect of time, Wilks $\lambda=0.39$, $F_{3,43}=22.77$, $\eta^2=0.61$, $P<0.001$, such that there was an improvement in the overall senior fitness test score after the intervention for the combined sample. Univariate analyses showed that the improvement occurred on all three measures of arm curl, chair stand, and 2-min step ($P<0.001$ for all). The interaction of time and group was not significant ($P=0.43$).

Discussion

This study investigated the effects of a multicomponent intervention program conducted two times per week for 8 weeks on reducing fall risks of independently functioning community-dwelling older adults. The intervention included a progressively difficult exercise component as well as an education component provided at the midway of the intervention. Based on the FAB scores at pre-testing, participants were classified as either having low fall risks or having high fall risks. Confirming our hypothesis, the intervention improved balance, and the participants in the high fall risk category improved more than those in the low fall risk category. Our hypothesis on muscle strength was partially confirmed as the intervention improved muscle strength, but both groups improved equally.

This study aimed at evaluating a balance intervention program for relatively healthy older adults using a sensitive measurement tool for assessing balance ability. Although research on the identification of fall risks often focused on older adults with substantial impairment in balance [27], past studies have also demonstrated the prevalence of future falls among high-functioning older adults. For example, Muir et al. [8] found that 43% of the high-functioning community-dwelling older people with no history of recent falls experienced falls within the next 12 months. Another study found that about half of healthy older women with no past history of falls experienced falls within the next 12 months, and about a quarter of all the participants fell more than once [18]. Similar results were obtained in healthy older men as well [20]. These results underscore the importance of providing a fall risk reduction program for older adults who may not be considered at high risk for falls.

Past studies often determined older adults' fall risk based on their fall history during the past 12 months [15]. Because the causes of falls are multifactorial, the past history of falls alone may not accurately reflect the degree of impairment in balance [12]. Given that different tools for assessing balance impairment lead to different results in defining who would be at risk of falling [8, 22], it is important to use the tools that are designed to capture the balance ability of healthy older adults. The FAB scale used in this study includes test items that are more challenging than other balance scales (e.g., Berg Balance Scale) and is useful in detecting the subtle changes in balance abilities of functionally independent older adults [22]. Our intervention improved older adults' FAB scores. Although values for minimal detectable change (MDC) or minimal clinically important difference (MCID) for the FAB scores are not available, it was found that every score increase in FAB is associated with an 8% decrease in the probability of falling [22]. Thus, the average gain of 6 points in the FAB scores in this study implies a significant reduction in the likelihood of falls as a result of the intervention.

This study also found that a multicomponent intervention program was effective in improving older adults' upper and lower body muscle strength and endurance. Studies have shown that a decrease in muscle strength is a risk factor for falls [9, 10], and functional lower extremity weakness and impaired balance independently contribute to moving from non-faller status to faller status [20]. Group exercise programs have been found to be effective in increasing muscle strength [9]. For example, a 12 week regimen of strength training produced a significant improvement in lower limb strength and balance [28]. The results of this study on muscle strength are consistent with those of past studies and emphasize the importance of strength training in decreasing the risk of future falls. While the MDC or MCID values for the SFT performance with healthy older adults are not available, a study found that the MDC values at the 90% confidence intervals in the community-dwelling older adults with cognitive impairment were 2.3 for the arm curl test and 2.0 for the chair stand test [29]. The current study with healthy older adults found improvements of 2.75 for the arm curl test and 2.11 for the chair stand test. Because the

Table 3 Number of older adults with low and high fall risks at pre- and post-testing

Fall risk status	Low risk at post-testing	High risk at post-testing
Low risk at pre-testing	19	0
High risk at pre-testing	22	6

variabilities in performance in these two tests were smaller in our data from healthy older adults than the data from the people with cognitive impairment, we can conclude that the changes in this study exceeded the MDC values, demonstrating clinical importance of our intervention program. Even though our intervention program did not emphasize endurance training, the improvement in the 2-min step test is not surprising considering the variety of walking activities, as well as lower extremity resistance training employed in the exercise intervention.

We also hypothesized that compared to people who were classified as having low fall risks, people who were classified as having high fall risks would show greater improvements after the intervention, because people with low fall risks would have less room for improvement. Our results, however, supported this hypothesis only for balance, but not for muscle strength. Both groups equally improved in muscle strength. This might be related to the novelty of strength training in both groups. These results underscore the importance of an intervention targeting independently functioning older adults. The older adults who did not seem to have an immediate danger of falling still had ample room for further improvement in overall balance. Given that fall-related injuries can lead to admission to a long-term care facility that could cause additional financial burden as well as negative psychological consequence such as depression [30, 31], it is important to provide an early intervention that will allow healthy older adults to continue their independent living without experiencing falls.

This study has some limitations. One limitation is that this study did not have a control group that did not receive intervention and where participants were randomly assigned to either a control group or an intervention group. Instead, we classified older adults as either having low fall risks or having high fall risks using the FAB cut-off score that was determined based on older adults' self-report of past history of falls, not based on fall data obtained through a prospective study [22]. It would be desirable for future studies to employ a randomized controlled trial and also utilize measures for group assignment that have been shown to be predictive of future falling among community-dwelling older adults. In addition, a more comprehensive assessment of fall likelihood could provide an improved classification of balance ability [8]. For example, in studying the effectiveness of a physical therapist-prescribed home exercise intervention on balance, one study applied several balance assessment measures (e.g., the functional reach test, the step test, walking speed, the step quick turn test) to identify older adults with mild balance dysfunction [12]. Another limitation is that this study only measured the clinical outcomes of balance and senior fitness. Other physical measures such as gait characteristics [32], the occurrence of future falls [32], and psychological measures such as fall efficacy [33] would have provided a deeper understanding of the effects of an intervention on reducing fall risks. In addition, the outcome measures were assessed only just before and after the intervention. Follow-up testing would be useful to determine if the participants maintained these improvements. Finally, participants were volunteers from two large senior communities, but the sample size was relatively small ($n = 47$). Despite the small sample size, after the participants were separated into having high fall risks and having low fall risks, there was enough power to detect a significant interaction effect of time and group on balance. Also, there were more females than males, consistent with literature on fall prevention [1] and with the population of older adults from which the sample was derived (68% female, 32% male). Future studies could employ a similar proportion of males and females to investigate potential sex-related effects in fall prevention. This study investigated the effects of an intervention on independently functioning community-dwelling older adults. Given that independently functioning older adults are not necessarily high-functioning older adults [1], future studies could benefit from investigating the effects of interventions aimed at reducing fall risks specifically for high-functioning older adults. In addition, our multicomponent intervention consisted of static and dynamic balance exercises, strengthening exercises, sensory integration (visual, proprioception, and vestibular), and education. Future studies could incorporate other modes of intervention such as vitamin D supplementation or cataract surgery [1] to investigate the effectiveness of a comprehensive multicomponent intervention on the reduction of fall risks.

In conclusion, this study demonstrated the effectiveness of an intervention targeting independently functioning older adults, a group often not a primary target of fall prevention efforts. The intervention improved balance and muscle strength in all participants. People who were classified as having high fall risks based on the FAB scores at pre-testing showed greater improvement in balance compared to those who were classified as having low fall risks.

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Compliance with ethical standards

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

Ethical standards All procedures performed in this project involving human participants were in accordance with the ethical standards of our institutional review board and with the 1964 Helsinki declaration and its later amendments or comparable ethical standard.

Informed consent Informed consent was obtained from all individuals participants included in the study.

Appendix: Weekly progression of the exercise intervention

Activity	Week 1	Week 2 Additions	Week 3 Additions	Week 4 Additions	Week 5 Additions	Week 6 Additions	Week 7 Additions	Week 8 Additions
Warm up (7 min) with music	*Seated*: Proper posture awareness Core muscle contraction Arm and shoulder movement Chest stretch	*Seated*: Sitting on a compliant surface (disc or ball)	*Seated*: Marching while sitting	*Seated*: Head turns with movement	*Seated*: Pass the potato	*Seated*: Balloon volleyball	*Seated*: Balloon volleyball	*Seated*: Balloon volleyball
	Walking: With music, arm movement	*Walking*: High stepping walking	*Walking*: Fast and slow walking Abrupt change of pace	*Walking*: Abrupt change of direction	*Walking*: Tossing a bean bag upward and catching it	*Walking*: Tossing a ball upward and catching it	*Walking*: Tossing a bean bag between two hands	*Walking*: Tossing balls between two hands
Balance and multisensory training (10 min)	Standing weight shifts (all directions, EO, EC) Diagonal weight shift (forward and backward)	Tandem standing Tandem weight shifts (forward and backward)	Toe and heel tapping(all directions) Foot drawing (first name with the right foot, last name with the left foot) Single limb stance	Marching in place with head turns Four corner marching with head turns	Teach how to get on and off foam pad Standing on foam weight shifts (all directions)	Standing on foam (EO, EC)	Standing on foam weight shifts (all directions, EO, EC)	Standing on foam on one foot (EO, EC)
	Semi-tandem weight shifts (all directions, EO, EC)							
Walking activities and games (10 min) with music	Walking on toes Walking on heels	Walk in files (in line one behind the other) Walk in files across the midline	Walk with abrupt stop and change of direction Walking across tossing a bean bag then relay to opposite participant	Walk reading a script Passing a ball (forward, behind and to the side in a circle)	Walk on dense foam Standing volleyball	Wide step walking as if crossing a real water creek Obstacle course (avoiding obstacles and stepping on & off different objects)	Obstacle course (stepping on different surfaces picking objects from floor)	Obstacle course (carrying objects while stepping on different surfaces)
Wall flexibility and strengthening (10 min)	Semi-tandem walk Narrow step walking Alternating narrow and wide step walking				Side walking Walking with head turns Tossing a ball while walking			
	Figure 8 walking Wall squats (10 reps) Heel raises (10 reps) Toe raises (10 reps)				Wall push-up (10 reps) Hamstring stretch (10 reps) Calf stretch (10 reps)			

Activity	Week 1	Week 2 Additions	Week 3 Additions	Week 4 Additions	Week 5 Additions	Week 6 Additions	Week 7 Additions	Week 8 Additions
Seated strengthening (10 min) using resistance bands (10 reps for each set)[a]	Biceps curls Horizontal and diagonal pulls Triceps curls				Leg press Seated hip abduction Point and flex			
Eye/hand coordination (3 min)	Follow a moving target (popsicle stick) with slow eye movement (side to side, up/down and diagonal) with the head stable	Increase the speed of eye movement	Follow eye movement with head movement in the same direction					
Cool down (5 min) breathing instructions with all movements	Arm movements Neck bending Trunk bending and rotation Arm stretches Hamstring and calf stretches Ankle circles							

EO eyes open, *EC* eyes closed

[a]Seated strengthening was increased to 2–3 sets at week 5

References

1. Gillespie LD, Robertson MC, Gillespie WJ et al (2012) Interventions for preventing falls in older people living in the community. Cochrane Database Syst Rev. https://doi.org/10.1002/14651858.CD007146.pub3
2. Bergen G, Stevens MR, Burns ER (2016) Falls and fall injuries among adults aged ≥ 65 years—USA, 2014. MMWR Morb Mortal Wkly Rep 65:993–998. https://doi.org/10.15585/mmwr.mm6537a2
3. Johnson S, Kelly S, Rasali D (2015) Differences in fall injury hospitalization and related survival rates among older adults across age, sex, and areas of residence in Canada. Inj Epidemiol 2:24. https://doi.org/10.1186/s40621-015-0056-1
4. Burns ER, Stevens JA, Lee R (2016) The direct costs of fatal and non-fatal falls among older adults—USA. J Safety Res 58:99–103. https://doi.org/10.1016/j.jsr.2016.05.001
5. Shumway-Cook A, Woolacott MH (2007) Motor contro: translating research into clinical practice, 3rd edn. Lippincott Williams & Wilkins, Baltimore, MD
6. Borowicz A, Zasadzka E, Gaczkowska A et al (2016) Assessing gait and balance impairment in elderly residents of nursing homes. J Phys Ther Sci 28:2486–2490. https://doi.org/10.1589/jpts.28.2486
7. Deandrea S, Lucenteforte E, Bravi F et al (2010) Risk factors for falls in community-dwelling older people: a systematic review and meta-analysis. Epidemiology 21:658–668. https://doi.org/10.1097/EDE.0b013e3181e89905
8. Muir SW, Berg K, Chesworth BM et al (2010) Balance impairment as a risk factor for falls in community-dwelling older adults who are high functioning: a prospective study. Phys Ther 90:338–347. https://doi.org/10.2522/ptj.20090163
9. Granacher U, Zahner L, Gollhofer A (2008) Strength, power, and postural control in seniors: Considerations for functional adaptations and for fall prevention. Eur J Sport Sci 8:325–340. https://doi.org/10.1080/17461390802438763
10. Orr R (2010) Contribution of muscle weakness to postural instability in the elderly. A systematic review. Eur J Phys Rehabil Med 46:183–220
11. Pijnappels M, van der Burg PJ, Reeves ND et al (2008) Identification of elderly fallers by muscle strength measures. Eur J Appl Physiol 102:585–592. https://doi.org/10.1007/s00421-007-0613-6
12. Yang XJ, Hill K, Moore K et al (2012) Effectiveness of a targeted exercise intervention in reversing older people's mild balance dysfunction: a randomized controlled trial. Phys Ther 92:24–37. https://doi.org/10.2522/ptj.20100289
13. Lamb SE, Becker C, Gillespie LD et al (2011) Reporting of complex interventions in clinical trials: development of a taxonomy to classify and describe fall-prevention interventions. Trials 12:125. https://doi.org/10.1186/1745-6215-12-125
14. Stubbs B, Brefka S, Denkinger MD (2015) What works to prevent falls in community-dwelling older adults? Umbrella review of meta-analyses of randomized controlled trials. Phys Ther 95:1095–1110. https://doi.org/10.2522/ptj.20140461
15. Panel on Prevention of Falls in Older Persons, American Geriatrics Soc, British Geriatrics Soc (2011) Summary of

the Updated American Geriatrics Society/British Geriatrics Society clinical practice guideline for prevention of falls in older persons. J Am Geriatr Soc 59:148–157. https://doi.org/10.1111/j.1532-5415.2010.03234.x

16. Goodwin VA, Abbott RA, Whear R et al (2014) Multiple component interventions for preventing falls and fall-related injuries among older people: systematic review and meta-analysis. BMC Geriatr 14:15. https://doi.org/10.1186/1471-2318-14-15
17. de Rekeneire N, Visser M, Peila R et al (2003) Is a fall just a fall: correlates of falling in healthy older persons. The health, aging and body composition study. J Am Geriatr Soc 51:841–846
18. Hill K, Schwarz J, Flicker L et al (1999) Falls among healthy, community-dwelling, older women: a prospective study of frequency, circumstances, consequences and prediction accuracy. Aust Nz J Publ Heal 23:41–48. https://doi.org/10.1111/j.1467-842X.1999.tb01203.x
19. Gouveia BR, Goncalves Jardim H, Martins MM et al (2016) An evaluation of a nurse-led rehabilitation programme (the ProBalance Programme) to improve balance and reduce fall risk of community-dwelling older people: a randomised controlled trial. Int J Nurs Stud 56:1–8. https://doi.org/10.1016/j.ijnurstu.2015.12.004
20. Muir SW, Berg K, Chesworth BM et al (2010) Modifiable risk factors identify people who transition from non-fallers to fallers in community-dwelling older adults: a prospective study. Physiother Can 62:358–367. https://doi.org/10.3138/physio.62.4.358
21. Rose DJ, Lucchese N, Wiersma LD (2006) Development of a multidimensional balance scale for use with functionally independent older adults. Arch Phys Med Rehabil 87:1478–1485. https://doi.org/10.1016/j.apmr.2006.07.263
22. Hernandez D, Rose DJ (2008) Predicting which older adults will or will not fall using the Fullerton Advanced Balance scale. Arch Phys Med Rehabil 89:2309–2315. https://doi.org/10.1016/j.apmr.2008.05.020
23. Jeon YJ, Kim GM (2017) Comparison of the Berg Balance Scale and Fullerton Advanced Balance Scale to predict falls in community-dwelling adults. J Phys Ther Sci 29:232–234. https://doi.org/10.1589/jpts.29.232
24. Schlenstedt C, Brombacher S, Hartwigsen G et al (2016) Comparison of the Fullerton Advanced Balance Scale, mini-BESTest, and Berg balance scale to predict falls in Parkinson disease. Phys Ther 96:494–501. https://doi.org/10.2522/ptj.20150249
25. Rikli RE, Jones CJ (1999) Development and validation of a functional fitness test for community-residing older adults. J Aging Phys Activ 7:129–161
26. Faul F, Erdfelder E, Lang A-G, Buchner A (2007) G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods 39:175–191
27. Faber MJ, Bosscher RJ, Chin APMJ., van Wieringen PC (2006) Effects of exercise programs on falls and mobility in frail and pre-frail older adults: a multicenter randomized controlled trial. Arch Phys Med Rehabil 87:885–896. https://doi.org/10.1016/j.apmr.2006.04.005
28. Lee IH, Park SY (2013) Balance improvement by strength training for the elderly. J Phys Ther Sci 25:1591–1593. https://doi.org/10.1589/jpts.25.1591
29. Hesseberg K, Bentzen H, Bergland A (2015) Reliability of the senior fitness test in community-dwelling older people with cognitive impairment. Physiother Res Int 20:37–44. https://doi.org/10.1002/pri.1594
30. Seitz D, Purandare N, Conn D (2010) Prevalence of psychiatric disorders among older adults in long-term care homes: a systematic review. Int Psychogeriatr 22:1025–1039. https://doi.org/10.1017/S1041610210000608
31. Spillman BC, Lubitz J (2000) The effect of longevity on spending for acute and long-term care. N Engl J Med 342:1409–1415. https://doi.org/10.1056/NEJM200005113421906
32. Paterson K, Hill K, Lythgo N (2011) Stride dynamics, gait variability and prospective falls risk in active community dwelling older women. Gait Posture 33:251–255. https://doi.org/10.1016/j.gaitpost.2010.11.014
33. Moore DS, Ellis R, Kosma M et al (2011) Comparison of the validity of four fall-related psychological measures in a community-based falls risk screening. Res Q Exerc Sport 82:545–554. https://doi.org/10.1080/02701367.2011.10599787