Effectiveness of Square Stepping and Weighted Vest Training on Fall Prevention among Ambulatory Community Dwelling Elderly

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KEYWORDS
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ABSTRACT

Background: Falls are a major cause of injuries and dependence among older adults living in the community, and they often result in age-related deficits in balance, strength, and functional mobility. Interventions that address these characteristics are critical for fall prevention. Square Stepping Exercise (SSE) enhances dynamic balance and coordination by using multidirectional stepping patterns, and Weighted Vest Exercise adds resistance to increase muscle strength and bone density. Combining SSE and WVE may provide a more comprehensive approach to reduce fall risk. This study investigates the efficacy of these exercises in increasing balance, strength, and mobility, hence preventing falls among ambulatory elderly. **Method:** This experimental study was conducted on 70 older adults living in the community. Participants were chosen according to specific inclusion criteria and randomly assigned to either an experimental group (n=35) or a control group (n=35). Participants in experimental group performed square stepping exercise along with weighted vest training for duration of 30 minutes per session for 6 weeks. Pre and post-test evaluation were done using Berg balance scale, Time up and go test and Five times sit to stand Test. **Result:** The study results indicated a statistically significant difference in the mean and standard deviation, within the Groups for the outcome measures ($p < 0.0001$). On comparison between the post-test mean value, square stepping exercise group showed more improvement on Balance, Strength and Functional mobility. **Conclusion:** Square stepping exercise along with weighted vest exercise is a simple, home based and effective way on improving balance and strength also preventing falls among elderly population.

Introduction

Older adults are the most vulnerable populations, leading to falls which often resulting in catastrophic consequences such as pain, dependency, and poor quality of life. Accidental falls are the second common cause of unexpected or unintentional mortality worldwide, and are referred to as "Geriatric Giants" [1]. Approximately 646,000 fatal falls occur annually. It's estimated that one in three older adults experience at least one falls each year, with 20% resulting in serious consequences [2]. Falls affect about 65% of women and 44% of men [3]. Research indicates that 40% of older adults over 65 living in the community experience falls annually [4]. Falls can be divided into three stages. The initial stage happens when an event causes the body's

center of gravity to move beyond its base of support. These events can arise from external factors, such as environmental hazards, or internal ones, like muscle weakness, joint instability, or a lack of confidence. In the second stage, the body fails to maintain balance and correct the change in posture, which leads to a fall. This failure is often linked to internal issues, such as loss of sensory function or muscle weakness. The final stage involves the body making contact with the ground or another surface, resulting in force being transferred to various tissues and organs [5].

Falls among elderly arise from a complex interplay of various risk factors, typically grouped into four main categories: biological, behavioral, environmental, and socioeconomic [6]. Key biological factors include impaired sensory-motor functions such as vision, reaction time, balance, strength, and gait, all of which are significant contributors to risk of fall among older adults [7]. Muscle strength declines by approximately 1.5% per year, and this rate increases to as much as 3% annually after the age of 60. Decrease in proprioception can further reduce balance and making older adults more vulnerable to falls [8].

Exercise is widely acknowledged as an effective approach for enhancing functional ability in older adults, lowering numerous fall-related risk factors, and reducing their likelihood of falling. Regular exercise not only improves physical health but also benefits, such as lowering physical inactivity. Numerous studies have shown that strengthening, balance, and aerobic based exercise can considerably prevent falls in older persons, with reductions upto 50% among community dwelling adults. Strength training, plays an important part in preventing the age-related loss in muscle strength [9].

Resistance exercises are shown to be beneficial in maintaining muscular function and are recognized as a critical component of comprehensive fall prevention strategies. Balance exercises have also been widely reported for their ability to reduce fall risk by enhancing stability and coordination, particularly in older adults living isolated [10]. Aside from strength and balance gains, multi-component exercise regimens have been related to a reduction in medically attended falls and a decrease in the overall fall frequency. This emphasizes the value of incorporating a variety of exercises into fall prevention programs for older adults [11].

However, in this study we focus on two specific interventions such as Square Stepping Exercise (SSE) and weighted vest training. Square Stepping Exercise (SSE) involves executing different step patterns in multiple directions on a narrow mat. This exercise aims to improve both proactive and reactive responses, enhancing reaction timing during movement and thus reducing the risk of falls [12]. SSE is especially advantageous for older adults because it activates both agonist and antagonist muscles in the lower limbs, promoting overall leg strength and fitness [13]. Progressive Resistance Training (PRT) using a weighted vest is another home-friendly exercise [14]. To my knowledge, none of studies have focused specifically on the use of SSE and weighted vest training for preventing falls among community dwelling ambulatory elderly. Therefore, the purpose of my study is to explore the effectiveness of these interventions in reducing fall risk by improving functional mobility, balance and strength in this population.

Materials and methods

This experimental study were conducted on 70 older adults at Private medical college and hospital. All participants received an information sheet and were given informed consent, and the purpose, treatment methods and potential benefits were explained prior to intervention according to the Declaration of Helsinki. Participants were chosen according to specific inclusion and exclusion criteria and assigned to the experimental group (n = 35). and Control group (n = 30) (Figure 1).

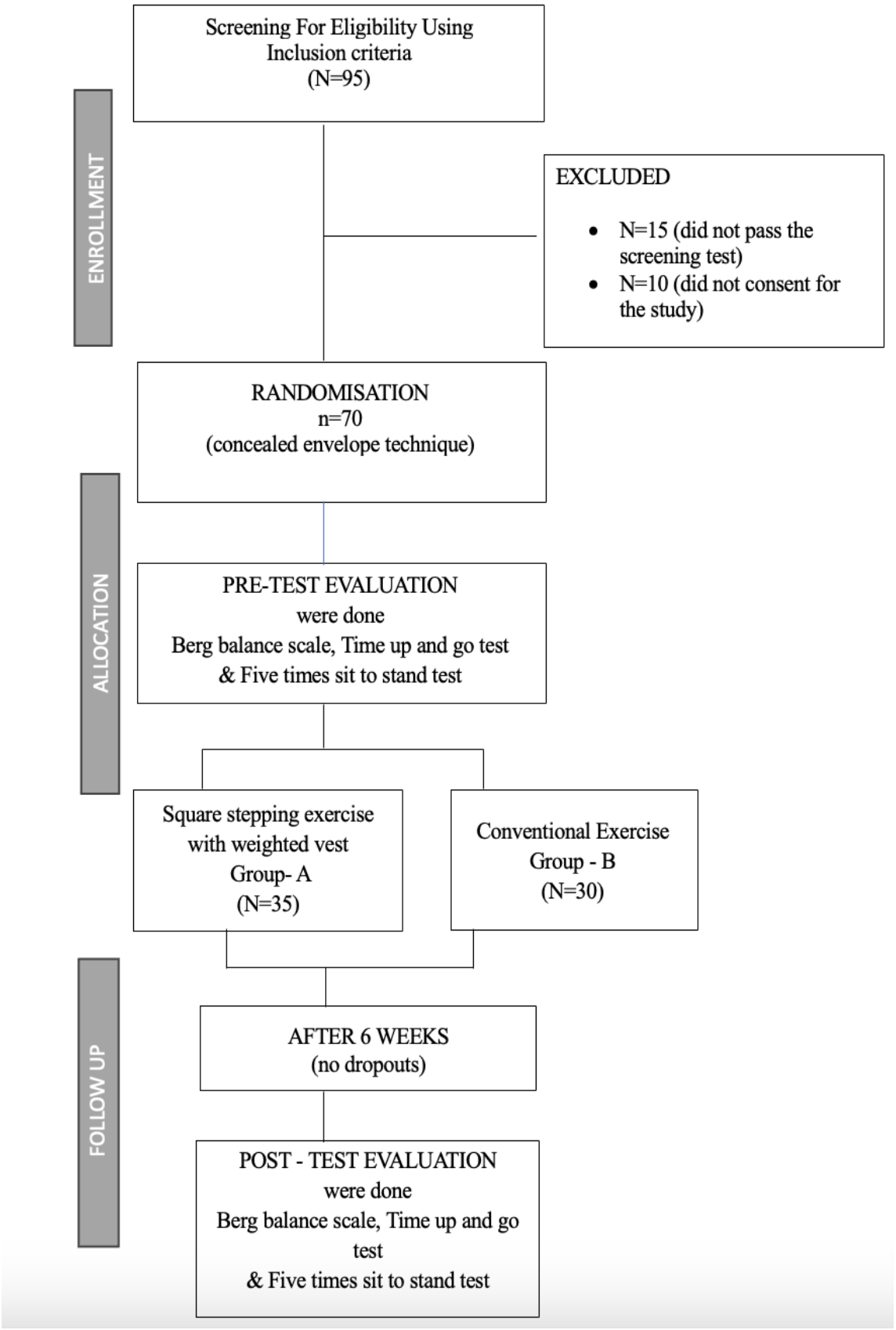

Figure 1: Consort Diagram

Inclusion and exclusion criteria: Community dwelling elderly, both female and male, age group between 65 - 75 years, Berg balance score 30 to 41, independently ambulatory, Previous history of falls includes 2 or more falls within the past 6 months, physically inactive and Mini Mental State Examination greater than 25 were included. Subjects with Neurological conditions, Recent fractures, visual & auditory impairment, unstable cardiac and respiratory condition, Psychiatric issues and not consent to participate were excluded.

Outcome Measures: The Berg Balance Scale (BBS) serves as an effective tool for evaluating balance in older adults with balance function impairments by assessing their performance of functional tasks. This scale includes 14 items rated on a 5-point ordinal scale, where 0 indicates the lowest functional level and 4 represents the highest performance level, leading to a maximum score of 56. The BBS demonstrates excellent intra- and inter-rater reliability, with average reliability coefficients of 0.98 and 0.97, respectively. Additionally, it possesses both content and criterion-related validity [15]. The Timed Up and Go Test (TUG) is a commonly utilized assessment for evaluating functional mobility among the elderly. This test involves the participant standing up, walking 3 meters, turning around, returning to the original position, and sitting back down. The time taken to complete the TUG is strongly linked to the individual's functional mobility; those who take 13 seconds or longer are considered at increased risk for falls. The 5 Times Sit-to-Stand Test (5XSST) assesses functional lower limb strength and fall risk in older adults. The score is determined by how quickly a person can rise from a seated position to standing and back to sitting five times. A shorter completion time indicates better performance. Normative scores for age groups indicate that individuals aged 60-69 should take about 11.4 seconds, those aged 70-79 about 12.6 seconds, and those aged 80-89 approximately 14.8 seconds. The 5XSST exhibits strong intra-rater reliability (ICC range: 0.914-0.933) and test-retest reliability (ICC range: 0.988-0.995) in healthy older adults [16].

Randomization and blinding: Subjects were randomly allocated using a simple random sampling method, concealed envelope technique. The physiotherapist administering the treatments was aware of the group assignments. However, an outcome assessor with expertise in the field, who was blinded to the subject's details, evaluated the results both before and after the interventions. This approach helped to reduce the risk of selection and detection bias in the study.

Intervention: After the baseline evaluation using Berg Balance Scale, TUG and 5XSST subjects randomly allocated into the respective groups, the participants in both the experimental and control groups underwent the following interventions. Each session was lasted for 60 minutes, thrice a week for a duration of 6 weeks.

Group A (Experimental Group): Square stepping exercises are performed for duration of 20 minutes on a thin mat, which is the mat was divided into 40 squares, each measuring 25 cm. Participants were instructed to walk from one end of the mat to the other, following the specified step pattern. The subjects were instructed to walk in four basic and four intermediate patterns (Figure 2).

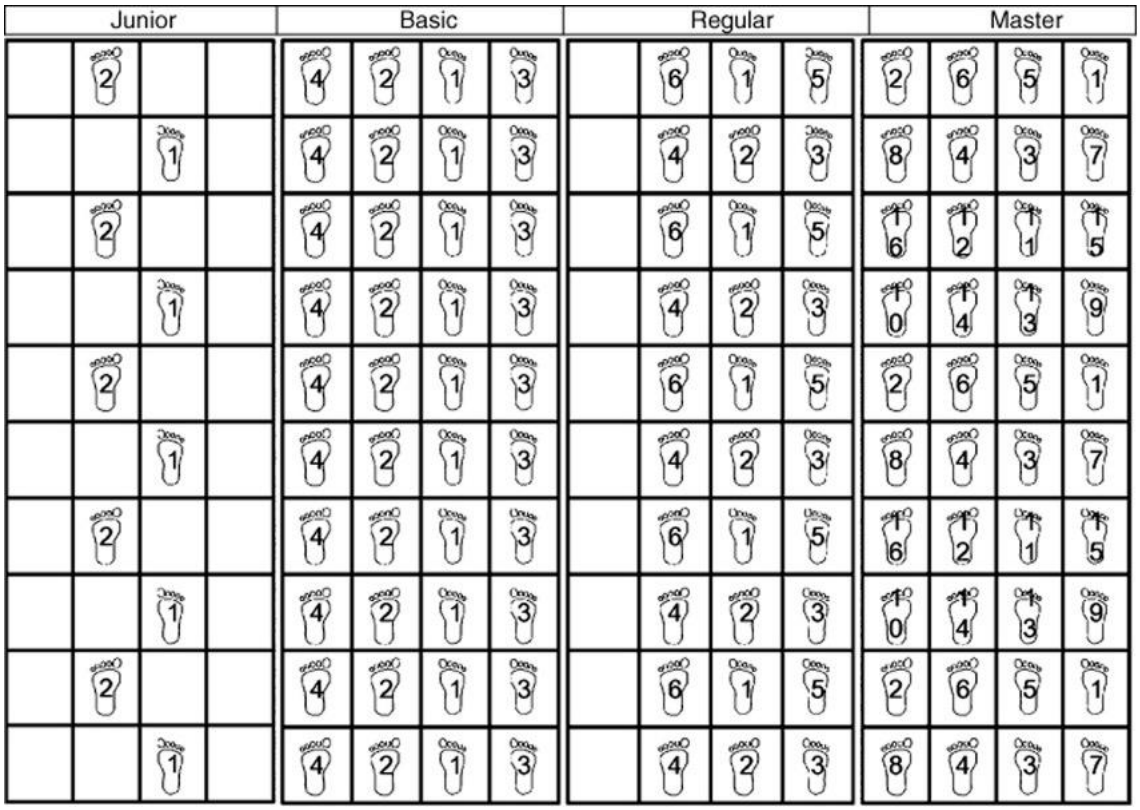

Figure 2: Examples of Junior, Basic, Regular and Master patterns of the Square Stepping Exercise (Shigematsu and Okura) [17].

After becoming comfortable with each of these step patterns, repeating each step pattern 5-10 times and taking 15-20 seconds to accomplish each. Ensure that the individuals can finish the pattern, and then advance to a more complex step pattern.

During each session, subjects wore the weighted vest and performed resistance exercises such as chair raise, forward lunge, lateral lunge, toe raise, knee extension and squats for duration of 10 minutes. Vests were not utilized throughout the first week of training. The initial vest resistance was set at 2% of body weight and gradually raised (by 1 to 2% per week) until 5% of body weight was reached. When the resistance in the vest was increased, and individuals had adjusted to the new resistance, sets and repetitions were increased to the top of the range.

Group B (Control Group): Subjects performed aerobic exercise such as walking for the duration of 20 mins followed by strengthening using dumbbells/ankle weights of 0.5-1 kg for major muscle groups of lower limbs. At the end of the 6 weeks, post-test measures were taken, and there were no dropouts as the different types of exercises kept the participants engaged.

Sample size: The sample size calculation of 70 participants was determined through a power analysis, with Power of 80%, an alpha level of 0.05, which aimed to detect a significant difference in fall prevention outcomes between the groups.

Statistical analysis: The collected data were organized and analyzed using descriptive and inferential statistics. All parameters were evaluated with the Statistical Package for the Social Sciences (SPSS) version 24. A paired t-test was used to identify statistical differences within groups, while an unpaired t-test was employed to assess differences between groups for the outcome measures, including the Berg balance scale, Time up and go Test, and Five Times Sit to Stand Test.

Results

From the statistical analysis, the post intervention Mean ± SD between Group A and Group B for Berg balance scale (Table 1), Time up and go Test (Table 2) and 5 times Sit to Stand test (Table 3) showed that there has been an noticeable increase in the post intervention mean values of Group A when compared to Group B with the high significance of $p<0.0001$ (Figure 3).

Table 1: Comparison of Berg Balance Scale and Mean Difference in Pre and Post Test in the Intra Group (Row) and Inter Groups (Column)

	Pre test Mean (SD)	**Post test Mean (SD)**	**Mean difference (intra)**	**P value**
Group A	44 (1.88)	50.40 (1.40)	6.40	.000***
Group B	43.80 (1.69)	45.93 (1.79)	2.130	.000***
Mean difference (inter)	0.200	4.470	-	-
P value	.763*	.000***	-	-

Table 2: Comparison of Time Up and Go Test and Mean Difference in Pre and Post Test in the Intra Group (Row) and Inter Groups (Column)

	Pre test Mean (SD)	**Post test Mean (SD)**	**Mean difference (intra)**	**P value**
Group A	12.90 (.603)	10.26 (.942)	2.640	.000***
Group B	12.83 (.523)	11.80 (.702)	1.030	.000***
Mean difference (inter)	0.070	1.540	-	-
P value	.749*	.000***	-	-

Table 3: Comparison of 5*Sit To Stand Test and Mean Difference In Pre and Post Test in the Intra Group (Row) and Inter Groups (Column)

	Pre test Mean (SD)	**Post test Mean (SD)**	**Mean difference (intra)**	**P value**
Group A	12.70 (.941)	10.36 (.480)	2.340	.000***
Group B	12.66 (.794)	11.23 (1.09)	1.430	.000***
Mean difference (inter)	0.040	0.870	-	-
P value	.917*	.000***	-	-

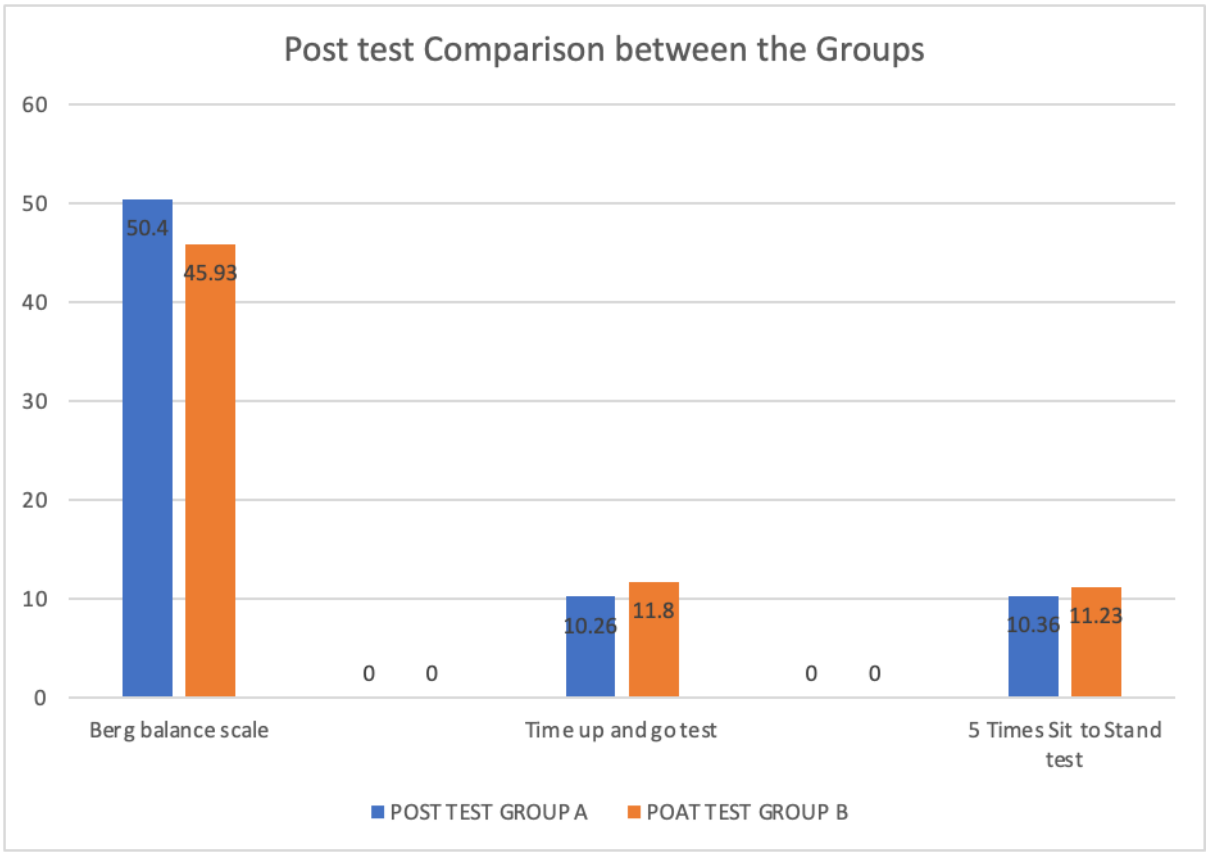

Figure 3: Post Test Comparison of Berg Balance Scale, Time Up and Go Test and Five Times Sit To Stand Test

Discussion

The current study aimed to evaluate the effectiveness of square stepping exercises combined with weighted vest exercises for fall prevention in ambulatory older adults living in the community. While various balance and strength training interventions have been implemented to reduce the risk of falls in the elderly, the present study concentrates on the most effective home based exercise programme for fall prevention by improving modifiable risk factors of fall such as balance, strength and to improve functional mobility. Subjects who performed square stepping exercise with weighted vest exercise showed reduced risk of falling. This study supports our finding. Tomohiro Okura et al. (2008) discovered that square stepping exercises (SSE) are equally effective as strength and balance training in improving lower-extremity functional fitness. Additionally, SSE can be recommended for older adults due to its affordability and efficacy. Ryosuke Shigematsu et al. (2006) reported that the SSE program improved lower-extremity functional fitness, a significant risk factor for falls among the elderly. Further research is needed to determine whether this program can effectively reduce the incidence of falls in this population [18]. Shaw et al. (1998) stated in a study that strengthening exercises employing body weight and general exercises have shown sufficient intensity to enhance lower limb strength and reduce accidental falls among elderly. [14]

A randomized controlled trial on weighted vest exercises for community dwelling older adults revealed that wearing a weighted vest weighing around 10% of one's body weight improved strength, sit-to-stand performance, and aerobic fitness compared to doing the exercise alone [19,20]. The added weight increases muscle activation, particularly in the lower extremities and core, leading to improved muscle strength and endurance. This resistance also stimulates bone remodeling, promoting increased bone density, which is essential for preventing osteoporosis and fractures [21]. The extra load challenges postural control, requiring constant adjustments to maintain balance, thereby enhancing proprioception and stability. Cardiovascular demand rises as the body works harder to perform tasks with the vest, improving endurance and energy expenditure [22].

These physiological benefits, combined with strengthened tendons and ligaments, lower the risk of falls and injuries. The SSE exercise was developed to enhance both proactive and reactive responses, which in turn improves reaction time during corrective stepping [23]. Additionally, SSE can be conducted indoors, offering advantages over unidirectional and outdoor walking in terms of fall prevention. Hence, the present study recommended that square stepping exercise along with weighted vest exercise can be used as a homebased exercise programme for fall prevention in elderly population by improving balance, strength and functional mobility.

Limitation in this study, participants were community-dwelling older adults, which may not represent the diversity of elderly populations, including those in assisted living or those with significant comorbidities. Relatively small group of participants, limiting the generalisability of the study findings to the larger population of community dwelling older adults. Recommendation are conducting longer intervention periods and incorporating extended follow-up assessments would allow for a better understanding of the long-term efficacy of the exercises on fall prevention and overall mobility. Adding more objective measures, such as gait analysis or balance tests using technology (e.g., force platforms or wearable devices), would provide more precise and unbiased data on the participants' improvements. Future studies could combine square stepping and weighted vest exercises with other fall prevention strategies, such as strength training, nutritional support, or cognitive interventions, to address the multifaceted nature of fall risk.

Conclusions

The current study concluded that square stepping exercises combined with weighted vest exercises have significant effects on preventing falls in ambulatory older adults living in the community by improving balance, muscle strength which there by reduce the risk of fall. Thus, also the exercises were effective in improving their mobility, thus preventing their dependence on others and also from consequences of falls. The integration of these two exercises effectively addresses multiple risk factors for falls, such as poor balance and muscle weakness, providing a comprehensive approach to fall prevention.
In addition to lowering fall rates, the intervention will also help to enhance older persons' confidence in everyday mobility, reduce their fear of fall and improve their quality of life. This intervention can be easily implemented in community settings with limited equipment and space requirements. It may be tailored to the specific needs of the individual and capacities of the elderly, making it an effective and adaptable intervention for fall prevention programs.

Conflicts of interest

The authors declare no conflict of interest.

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