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The Effect of Eight Weeks of Square Stepping Exercise on the Risk of Falls in Elderly Men

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ABSTRACT

Aims Preventing falls among the elderly is a significant public health priority in aging populations. This study examined the impact of an eight-week square stepping exercise program on fall risk in elderly men.

Materials & Methods In this randomized clinical trial, 30 elderly men aged 60-75 were recruited from senior day care centers in Tehran and randomly assigned to either a square stepping exercise group or a control group. Fall risk was measured using the Biodex Balance System and Fall Risk Test at levels 10 to 12. The exercise group participated in a structured square stepping exercise regimen three times per week, with each session lasting 60 minutes, over an eight-week period. The control group continued their usual daily routines. Fall risk was reassessed after the intervention, and analysis of covariance (ANCOVA) was used to compare pre- and post-intervention results between groups.

Findings After verifying the ANCOVA assumptions, results indicated a significant group effect in the post-test, with a substantial reduction in fall risk in the exercise group (2.35±1.15) compared to the control group (4.85±1.70; p=0.001) following the eight-week intervention.

Conclusion Square stepping exercises provide a straightforward, effective, and affordable option for reducing fall risk among elderly individuals, supporting its potential as a practical home-based intervention.

Keywords Accidental Fall; Exercise Therapy; Elderly; Postural Balance

CITATION LINKS

[1] Effects of a multicomponent exercise on dual-task performance and executive function among ... [2] Measuring biological aging in humans ... [3] Physical exercise prevents age-related decline in precursor cell activity in the mouse ... [4] Mobility but not balance limitations are associated with cognitive decline among ... [5] Association between gait and cognition in an elderly population ... [6] Effects of expressive arts therapy in older adults with mild cognitive impairment ... [7] Exercise for preventing falls in older people living in the community: An abridged Cochrane ... [8] A prospective study of the relationship between feared consequences of falling and avoidance of activity in community-living ... [9] Fear of falling: A manifestation of executive ... [10] Prevention of falls in the elderly ... [11] Effect of square-stepping exercise and basic exercises on functional fitness ... [12] Effect of PNF stretch techniques on knee flexor muscle EMG activity in older ... [13] Effect of Pilates training on depression and some motor functions associated with falling ... [14] Age-related changes in trunk neuromuscular activation patterns during a controlled functional transfer task include amplitude ... [15] Literature review: The effect of square stepping exercise on dynamic balance levels in reducing the risk ... [16] Tools for assessing fall risk in the elderly: A systematic ... [17] Test-retest reliability of biodex balance sd on physically ... [18] Effect of 3 months square stepping exercise and resistance training on postural balance and fear ... [19] Square-stepping exercise and fall risk factors in older adults: A single-blind, randomized ... [20] The relationship between concerns about falling and daily life activity in ... [21] Understanding the association of older adult fall risk factors by age and sex ... [22] Effect of a corrective exercise program on the frequency spectrum of ground reaction force during drop-landing ... [23] The effect of 8 weeks of fall-proof exercises on mini BESTest scores in elderly women with ... [24] Confounding by Indication ... [25] Effects of square-stepping exercise on motor and cognitive function in older adults-A systematic ... [26] Power training improves balance in healthy ... [27] Effect of square stepping exercise for older adults to prevent fall and injury related to fall ... [28] Exercise based reduction of falls in communitydwelling older adults ... [29] Multiple-modality exercise and mind-motor training to improve mobility in older adults ... [30] Interventions for preventing falls in older people living ... [31] Exercise to prevent falls in older adults ... [32] Effect of biodex training on balance impairment in patients with chronic obstructive ...

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Introduction

Aging is defined as a dynamic process of increasing age that leads to a decline in functional capacity [1]. Studies indicate that the global population of individuals over 65 is rapidly growing, projected to reach 1.6 billion by 2050 [2]. In Iran, the elderly population is also steadily rising, with many considering it a future challenge due to shifts in population proportions. Aging often brings issues like reduced balance, cognitive power, and coordination. These physical and cognitive declines are generally interconnected [3, 4], leading to problems such as walking difficulties and a higher risk of falls in older adults [5, 6]. Frachi *et al*. report that 25% of elderly individuals experience at least one fall per year, with fall-related injury rates rising with age [7]. Additionally, fear of falling and reduced confidence can diminish performance levels [8, 9]. Magnus *et al*. emphasize that fall-prevention interventions should be delivered to high-risk elderly groups in a structured manner to minimize falls [10].Numerous studies have explored ways to reduce fall risk in older adults, discussing various methods [7, 10, 11]. Exercise programs are among the most effective strategies for reducing fall risk [11]. Recently, square-stepping exercises have emerged in Japan as a practical, affordable method to enhance physical and mental fitness in older adults [12]. This program aims to impact both physical and cognitive functioning. Research shows that square-stepping exercises, as an effective intervention for executive function [13] and cognitive status in the elderly, can improve physical and cognitive performance by combining physical and cognitive training. Shigematsu *et al*. first demonstrated in 2006 that square-stepping exercises could significantly improve balance, flexibility, agility, leg strength, and speed among older adults, thereby enhancing functional fitness. Subsequent research has investigated square-stepping exercises' effects on postural stability and balance from various angles [12].Asadi *et al.* studied the three-month effects of square-stepping and resistance training on postural balance and fear of falling in elderly women in Iran, finding that square-stepping exercises could enhance postural stability and positively impact postural balance and fear of falling [14]. Recent reviews further confirm that square-stepping exercises can significantly improve dynamic balance in older adults, reducing fall risk as a result [15]. However, most studies rely on field tests, such as the Y Balance Test and various questionnaires, to assess fall risk. A recent systematic review suggests that none of these tests offer an adequate tool for evaluating fall risk in the elderly [16]. Studies show that stability measurement systems capable of simulating falls provide more accurate tools. These devices enable biomechanical assessments of balance. Perraca *et al*. noted that Biodex Balance System measures are highly reliable and useful for assessing fall risk and monitoring fall-prevention programs in older adults [17].

Most studies examining the effectiveness of various fall-prevention programs have focused on elderly women [18-20]. However, fall risk factors may differ by gender; for instance, women might be more prone to falls due to concerns about falling, leading to reduced physical activity and lower gait quality [21]. On the other hand, a recent systematic review reveals that older men have a higher fall risk due to combined physical and mental health limitations compared to women, particularly in the 65-74 age group [22]. This study thus aims to examine the impact of an eight-week square-stepping exercise program on fall risk in older men, using the Biodex Balance System.

Materials and Methods

This randomized clinical trial was conducted in the fall of 2023 among elderly men in day care centers in Tehran. Two active centers were identified, and male residents were invited to participate. Using G*Power software version 3.1, a sample size of 28 was calculated based on a test power of 0.80, effect size of 0.55, and alpha error of 0.05, with previous studies referenced [23].

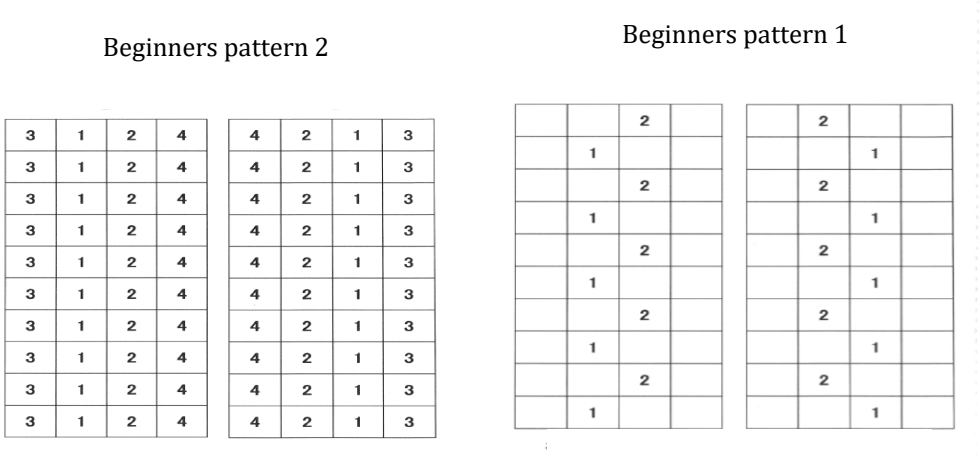

Figure 1. Protocol for performing exercises (examples of beginner levels 1 and 2)

Considering a potential dropout rate of 10%, 30 participants were enrolled and randomly assigned to either a square-stepping exercise group (n=15) or a control group (n=15). Simple randomization (lottery method) was used. All participants signed consent forms, and their medical records were reviewed for study criteria. Assessments were conducted before and eight weeks after the intervention.

Participants eligible for inclusion in this study were elderly men aged 65 and above who were able to walk independently without the need for walking aids and had no significant cognitive impairments, as assessed by a standardized cognitive test. Those who regularly engaged in physical activity or exercise programs within the last three months were excluded to minimize the influence of previous physical training on the study's outcomes. Additionally, participants with any severe musculoskeletal, neurological, or cardiovascular disorders that could interfere with safe exercise participation or affect balance performance were also excluded from the study. During the study, one participant withdrew due to death, and another left due to lack of interest.

Fall Risk Test Implementation

The Biodex Balance System SD, made by Biodex in the U.S., was used to assess fall risk in the Sports and Wellness Sciences Laboratory at Shahid Beheshti University. This tool has high reliability and validity for evaluating fall risk in elderly men [19]. According to the protocol, participants stood on the balance platform with foot positions adjusted accordingly. Test difficulty was set at level 10 to 12 based on pilot results. Each trial lasted 20 seconds with three attempts and a 10-second rest between each. A circular target appeared on a screen in front of each participant, allowing them to adjust their spatial positioning to maintain stability. Tests were conducted with participants' eyes open for safety.

Stepping Square Exercise Protocol

The intervention group participated in monitored training sessions twice a week over an eight-week period at the Vaghte Zandegi Elderly Day Care Center. Each session included 10 minutes of warm-up activities, such as stretching and physical exercises, 40 minutes of stepping square exercises, and 10 minutes of cooling down. The stepping square exercise protocol, initially developed by Shigematsu, was performed on a grid (100 × 250 cm) with 40 squares (25 cm each) marked on the gym floor. Participants were instructed to follow a specified stepping pattern (Figure 1) from one end of the grid to the other. Once they reached the end, they were asked to return to the starting point via the right side of the grid and line up for the next stage.

After familiarizing themselves with each stepping pattern, participants were further instructed to step on the balls of their feet (heel-high) without stepping on the square boundaries. Each pattern was repeated 4 to 10 times to ensure proficiency, and then the participants progressed to a more complex stepping pattern. In total, 196 step patterns were developed and categorized into eight levels (beginner, 1-2; intermediate, 1-3; and advanced, 1-3) based on gradually increasing complexity. Participants were encouraged to concentrate on executing increasingly complex patterns successfully. They were allowed to perform at their own pace. While they initially took 15-20 seconds to complete each basic pattern, by the final sessions, they could complete each pattern in less than 15 seconds. Given the study duration and specific conditions, only beginner levels one and two were performed in this study. Participants wore athletic shoes and attire throughout the exercises.

Data Analysis

SPSS version 26 was used for data analysis. Descriptive statistics, such as mean and standard deviation, were used to describe the data. Before conducting ANCOVA, the assumptions of homogeneity of variances (Levene's test), normality of distribution (Shapiro-Wilk test), and regression slope equality (testing the absence of interaction between covariate and independent variable) were verified. The significance level was set at 95%.

Findings

There were no significant differences between the groups in terms of age, height, weight, and body mass index (p>0.05; Table 1).

Table 1. Participants demographic characteristics

Group	Experimental	Control	p
Age (years)	70.3±14.65	70.28±4.10	0.921
Height (m)	1.72±4.96	1.71±6.32	0.623
Weight (kg)	72.3±57.27	72.07±4.62	0.730
BMI (kg/m^2)	24.1±65.41	24.1±8.36	0.282

As the data met the assumptions for ANCOVA, this test was used to determine the intervention's effect. The results of Levene's test confirmed homogeneity of variance for the dependent variable (fall risk scores), and the Shapiro-Wilk test indicated a normal distribution (p>0.05). Finally, the regression slope homogeneity test showed no significant interaction between the covariate and the independent variable (p>0.05), confirming equal regression slopes across the groups (Table 2).

Table 2. Bonferroni test for comparing the effect of group and covariate (risk of falling between the two groups in the pre-test and post-test (n=28)

Effect	Sum of Squares	df	Mean Square	F	p-value	Effect Size
Group	45.31	1	45.31	43.41	0.001	0.63
Covariate (Pre-test Fall Risk)	28.83	1	27.63	3.93	0.001	0.52

Following confirmation of ANCOVA assumptions, results revealed a significant main effect for the group at the post-test stage, indicating that the stepping square exercises significantly reduced fall risk in elderly men after eight weeks of training (p=0.001).

Table 3. Analysis of Covariance (ANCOVA) test for comparing the risk of falling between the two groups in the pre-test and post-test (n=28)

Group	Intervention		Control		F-Statistic	Mean Difference	p-value	Partial Eta
	Pre-test	Post-test	Pre-test	Post-test				
Fall Risk	5.00±1.51	2.35±1.15	4.92±1.81	4.85±1.70	43.41	2.57	0.001	0.63
Confidence Interval	4.28-5.78	1.78-3.00	4.00-6.00	3.95-5.78		-		

*Interpretation of effect size: trivial (0-0.19), small (0.20-0.59), moderate (0.60-1.0), large (1.1-1.19), very large (1.2-3.9), and extremely large (>3.9).
**Partial eta squared calculated effect size.

According to the observed effect size, the intervention had a small effect on reducing fall risk among the elderly (Table 3).

Bonferroni post-hoc tests for estimated marginal means also demonstrated that stepping square exercises were more effective in reducing fall risk in the intervention group (2.33) compared to the control group (4.88).

Discussion

This clinical trial was conducted to examine the effect of stepping square exercises on fall risk in elderly men, measured using a balance assessment device. After eight weeks, we observed a significant reduction in fall risk among elderly men who performed these exercises.

Several similar studies have investigated the impact of stepping square exercises on fall risk [24]. For instance, Teixeira *et al*. have found out that stepping square exercises significantly reduces fall risk compared to a non-exercising control group [11]. Shigematsu *et al*. also report a decrease in fall risk following stepping square exercises, although the effect was comparable to a control group engaging in daily outdoor walking [19]. In a recent systematic review, Wang *et al.* suggest that these exercises can effectively reduce fall risk [25]. The observed improvements in fall risk reduction may reflect benefits related to sequential center of gravity shifts, toe-standing, and single-leg stances, which challenge balance control during the exercises [25].

Orr *et al*. conducted a study showing that light-load foot strengthening exercises (20% max strength) improve balance by keeping muscles active during the concentric phase of walking, thus maintaining output force. The exercise intensity and movements in their study are comparable to our stepping exercises, incorporating slight knee and ankle bends. Foot exercises like these are presumed to enhance neuromuscular function by reducing response delay, improving postural muscle engagement, and enhancing sensory information processing [26]. Furthermore, multidirectional steps i.e. forward, backward, lateral, and diagonal, engaged during stepping exercises likely result in better activation of foot synergist and agonist muscles. Thus, stepping square exercises may reduce fall risk by improving muscle strength and timing.

A meta-analysis by Fisseha *et al*. reveals that stepping square exercises effectively reduce fear of falling, which improves balance in older adults. These researchers conclude that these exercises improve balance by enhancing reaction time, feedback, and correction processes, based on active and reactive responses [27]. Other review studies in 2017 and 2020 indicate that exercise alone, or in combination with other interventions, can reduce fall risk and related injuries, aligning with the current study's findings [28, 29]. Gillespie *et al*. highlighte that home-based exercises are effective for fall risk reduction. Balance exercises conducted three times per week can reduce fall risk by up to 40% [30]. Stepping square exercises are conducted under the guidance of a coach and sports specialist, which may enhance training effectiveness.. Another study explores the effect of Biodex balance training on fall risk in elderly individuals with COPD, showing that combining Biodex-based balance training with standard balance and respiratory exercises yields better results in managing balance impairment and fall risk in COPD patients [31].

Stepping square exercises, a type of gait training, are group-friendly, low-cost, and require minimal equipment, making them suitable for indoor settings, free from challenges posed by outdoor conditions like rain or cold, which may hinder elderly participation. These exercises incorporate physical and cognitive engagement and, as a group activity, have the potential to improve social interactions among older adults. Based on prior studies, stepping square exercises are recommended as a practical and effective approach to reducing fall risk and improving balance in elderly individuals. The main limitation of this study was the training duration. Most studies have suggested that stepping square exercises should be conducted for at least 12 weeks for optimal effectiveness; however, time constraints prevented this in our study. Additionally, the relatively wide age range used due to limited participant availability may limit the generalizability of the results.

Conclusion

Performing Square stepping exercises (SSE) reduces the risk of falling in elderly men

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Ethical Approvals: The ethical code for this study was approved and registered by the Ethics Committee of the Research Institute of Physical Education and Sport Sciences under code IR/SSRI.REC.1402.278. Additionally, the study is registered in the Iranian Registry of Clinical Trials

with code IRCT20230124057206N1. It is worth noting that study participants were blinded to their training program and group allocation, making this study single-blind.

Conflict of Interest: The authors have reported no conflicts of interest.

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