Published Online: 2025 May 31 **Research Article**

The Effect of a 6-Week Nine-Square Step Exercise Protocol on Gait Components in Older Women

Majid Nikravesh [1], Yousef Moghadas Tabrizi [2,*], Mohammad Karimizadeh Ardakani [3], Aysan Tavakoli [1]

[1] Faculty of Sport Sciences and Health, University of Tehran, Iran
[2] Department of Sport Injuries & Biomechanics, Faculty of Sport Sciences and Health, University of Tehran, Iran
[3] Department of Sport Injuries and Biomechanics, Faculty of Sport Sciences and Health, University of Tehran, Iran

[*] ***Corresponding Author:*** Department of Sport Injuries & Biomechanic, Faculty of Health and Sport Science, University of Tehran, Tehran, Iran. Email: moghadas@ut.ac.ir

Received: 15 March, 2025; **Revised:** 15 May, 2025; **Accepted:** 27 May, 2025

Abstract

Background and Objectives: Given the growing elderly population and the importance of balance and gait in maintaining functional independence and preventing falls, this study aimed to investigate the effect of a 6-week nine-square step exercise protocol on gait components (step length, step width, step speed, and step rhythm) in older women. These components were selected due to their critical role in mobility and fall risk.

Methods: Twenty-eight older women (aged 63 - 85 years) were randomly assigned to an experimental group (n = 14) or a control group (n = 14) using a random number generator. Inclusion criteria included independent walking, adequate vision/hearing, and no gait-affecting conditions; exclusion criteria included missing > 2 sessions or new physical issues. The experimental group underwent a supervised 6-week nine-square step exercise protocol (3 sessions/week, 60 minutes/session), while the control group continued daily activities. Gait components were assessed via a 6-meter walk test (5 repetitions), analyzed using Kinovea software. Data were evaluated with an independent *t*-test for baseline comparisons and a 2 × 2 repeated-measures ANOVA ($P < 0.05$).

Results: The experimental group showed significant improvements in step length, step speed, and step rhythm, with significant group × time interactions. Step width showed a significant group effect (P = 0.027) but no significant time or interaction effects.

Conclusions: The nine-square step exercise protocol effectively improves gait components in older women, supporting its use in fall prevention programs. Limitations include the short intervention duration and single-gender sample.

Keywords: Older Women, Gait Components, Nine-Square Step Exercise, Fall Prevention, Functional Mobility

1. Background

The global and Iranian aging population is one of the most significant demographic shifts of the present century. According to the United Nations, by 2050, over 22% of the world's population will be over 60 years old (1). In Iran, with increasing life expectancy and declining birth rates, the proportion of older adults in the population is rising, posing new challenges for the healthcare system (2). Aging is associated with a decline in physical and motor abilities, which can impact functional independence and quality of life (3).

Gait, as one of the most fundamental daily activities, serves as a key indicator of mobility, functional independence, and quality of life in older adults (4). With aging, numerous physiological and neurological changes occur, including reduced muscle strength, impaired neuromuscular coordination, diminished proprioception, and a decline in balance systems (vestibular and visual), all of which directly affect gait components such as step length, step width, step speed, and step rhythm (5). These changes often lead to unstable gait patterns, reduced movement efficiency, and an increased step width as a compensatory strategy to maintain balance (6). Such impairments significantly

How to Cite: Nikravesh M, Moghadas Tabrizi Y, Karimizadeh Ardakani M, Tavakoli A. The Effect of a 6-Week Nine-Square Step Exercise Protocol on Gait Components in Older Women. J Motor Control Learn. 2025; 7 (2): e162824. https://doi.org/10.5812/jmcl-162824.

elevate the risk of falls, one of the most common and serious issues among older adults (7). According to the World Health Organization, over 37 million falls occur annually among older adults, resulting in severe injuries such as hip fractures, reduced confidence, functional limitations, and even mortality (7). Older women, due to physiological factors such as reduced bone density, post-menopausal hormonal changes, and greater lower extremity muscle weakness, are at a higher risk of falls and related complications compared to men (8). These issues not only threaten individual independence but also impose a significant economic and social burden on healthcare systems, underscoring the need for preventive interventions (9).

Exercise interventions, particularly those focusing on balance and coordination, have been recognized as effective strategies for improving gait and preventing falls in older adults (9). These exercises enhance lower extremity muscle strength, improve proprioception, and increase motor coordination, enabling older adults to adopt safer and more efficient gait patterns (10). Among these, the nine-square step exercise protocol, rooted in traditional Thai culture, has gained attention as a low-cost and engaging intervention (11). This protocol involves rhythmic stepping in various directions (anterior, posterior, lateral, and combined) on a mat divided into nine squares, creating multi-directional movement challenges that improve dynamic balance, coordination, and muscle strength (12).

Previous studies have confirmed the effectiveness of nine-square step exercises in improving balance, reducing fear of falling, and enhancing quality of life in older adults (9, 10). For instance, Puttipaibool et al. reported that these exercises improve physical fitness and quality of life in older adults (10). Additionally, Asadi Samani et al. demonstrated that square-stepping exercises enhance postural balance and confidence in older Iranian women (12). However, the specific impact of this protocol on detailed gait components (step length, step width, step speed, and step rhythm) in older Iranian women remains underexplored.

2. Objectives

Given the prevalence of gait impairments in older women and the need for accessible and engaging interventions, this study aimed to evaluate the effect of a 6-week nine-square step exercise protocol on gait components in older women. It was hypothesized that this intervention would lead to significant improvements in gait components compared to the control group. This study can contribute to the development of evidence-based rehabilitation programs in Iran and provide practical strategies for fall prevention in older adults.

3. Methods

3.1. Study Design

This study was with a pre-test and post-test design, conducted at the Barna Del Elderly Rehabilitation Center in Babolsar, Iran. The study was approved by the Ethics Committee of the Faculty of Sports Sciences and Health at the University of Tehran (ethics code: IR.UT.SPORT.REC.1402.035), and all participants provided informed consent.

3.2. Subject

From the clients of the care center, 28 older women (aged 63 - 85 years) who met the inclusion criteria were selected. Inclusion criteria included the ability to walk without assistive devices, adequate hearing and vision, and no conditions affecting gait. Exclusion criteria included unwillingness to continue, absence from more than two training sessions, or the development of physical issues. Participants were randomly assigned to an experimental group (n = 14) and a control group (n = 14) using a random number generator.

The sample size was calculated using G*Power software (version 3.1.9.7). Assuming a medium effect size (F = 0.25) based on similar studies (10, 12), a statistical power of 0.80, an alpha level of 0.05, two groups (experimental and control), and two measurement time points (pre-test and post-test), the minimum required sample size was estimated at 24 participants (12 per group). Accounting for a 15% dropout rate, the final sample size was set at 28 participants (14 per group).

3.3. Apparatuse and Task

Gait components were assessed using a 6-meter walk test (5 repetitions) at pre-test and post-test. Two 12-megapixel digital cameras, one positioned laterally and the other posteriorly at a distance of 3 meters from the walking path, recorded the participants' movements. Data on step length, step width, step speed, and step rhythm were extracted using Kinovea software (version 0.9.5). The definitions of the measured components are as follows.

3.3.1. Step Length

The longitudinal distance between the point of heel contact of one foot with the ground and the subsequent

heel contact of the same foot in one gait cycle, measured in centimeters.

3.3.2. Step Width

The lateral distance between the center of the heels of both feet during two consecutive contacts (one complete step), recorded in centimeters.

3.3.3. Step Speed

The distance covered in one step (step length) divided by the time between the heel contact of one foot with the ground and the subsequent heel contact of the same foot, calculated in meters per second.

3.3.4. Step Rhythm

The average number of steps taken by each participant per minute, reported as steps per minute.

3.4. Procedure

The experimental group underwent the nine-square step exercise protocol for 6 weeks (3 sessions per week, 60 minutes per session) (9, 10). Each session consisted of 15 minutes of warm-up, 35 minutes of square-stepping exercises, and 10 minutes of cool-down. The exercises were performed on a tatami mat divided into nine squares, involving stepping in anterior, posterior, lateral, and combined directions (10). From the fourth week, more advanced patterns with diagonal movements were introduced, designed to improve balance and coordination in older adults based on standard protocols (Appendix 1 in Supplementary File) (9). The control group continued their daily activities during this period.

3.5. Data Analysis

Data normality was confirmed using the Shapiro-Wilk test. Baseline group comparisons were conducted using an independent *t*-test, and the effects of the intervention were analyzed using a 2 (group) × 2 (time) repeated-measures ANOVA. Post-hoc pairwise comparisons were adjusted using the Bonferroni correction, with a significance level of $P < 0.05$. Analyses were performed using SPSS software (version 26).

4. Results

4.1. Demographic Characteristics and Descriptive Statistics

The demographic characteristics and baseline values of gait components are presented in Table 1. No significant differences were observed between the groups in terms of age, height, weight, or baseline gait components ($P > 0.05$).

The results of the repeated-measures ANOVA are presented in Table 2. The detailed effects are as follows.

4.1.1. Step Length

The main effect of time ($F = 7.12$, $P = 0.009$) and the group × time interaction effect ($F = 5.23$, $P = 0.028$) were significant, but the main effect of group was not ($P = 0.520$). The mean step length in the experimental group increased from 64.91 ± 8.26 cm to 107.57 ± 16.18 cm ($P < 0.01$), while the control group showed no significant change (94.78 ± 13.67 cm to 96.28 ± 13.08 cm, $P > 0.05$). This finding indicates that the nine-square step protocol specifically improved step length in the experimental group.

4.1.2. Step Width

The main effect of group was significant ($F = 5.34$, $P = 0.027$), but the main effect of time ($P = 0.179$) and the group × time interaction effect ($P = 0.056$) were not. The mean step width in the experimental group decreased from 10.44 ± 3.87 cm to 7.40 ± 2.78 cm, while the control group increased from 11.30 ± 3.20 cm to 11.86 ± 5.04 cm.

4.1.3. Step Speed

The main effect of time ($F = 15.67$, $P < 0.001$) and the group × time interaction effect ($F = 14.89$, $P < 0.001$) were significant, but the main effect of group was not ($P = 0.518$). The mean step speed in the experimental group increased from 1.23 ± 0.34 m/s to 1.89 ± 0.50 m/s ($P < 0.001$), while the control group showed no significant change (1.44 ± 0.40 m/s to 1.49 ± 0.41 m/s, $P > 0.05$). This indicates that the nine-square step protocol specifically improved step speed in the experimental group.

4.1.4. Step Rhythm

The main effect of time ($F = 16.45$, $P < 0.001$) and the group × time interaction effect ($F = 15.12$, $P < 0.001$) were significant, but the main effect of group was not ($P = 0.708$). The mean step rhythm in the experimental group increased from 44.80 ± 5.28 steps/min to 53.46 ± 4.93 steps/min ($P < 0.001$), while the control group showed no significant change (48.70 ± 5.96 steps/min to 48.05 ± 6.92 steps/min, $P > 0.05$). This suggests that the nine-square step protocol specifically improved step rhythm in the experimental group.

For a graphical representation of the comparison of gait component means between groups at pre-test and

Table 1. Descriptive Statistics of Demographic Characteristics and Baseline Gait Components [a]

Variables	Experimental Group (N = 14)	Control Group (N = 14)	P-Value
Age (y)	68.35 ± 3.15	68.92 ± 5.74	0.762
Height (cm)	161.37 ± 6.39	164.33 ± 5.68	0.231
Weight (kg)	70.91 ± 5.22	77.16 ± 6.13	0.071
Step length (cm)	64.91 ± 8.26	94.78 ± 13.67	0.082
Step width (cm)	10.44 ± 3.87	11.30 ± 3.20	0.573
Step speed (m/s)	1.23 ± 0.34	1.44 ± 0.40	0.196
Step rhythm (steps/min)	44.80 ± 5.28	48.70 ± 5.96	0.108

[a] Values are expressed as mean ± SD.

Table 2. Results of Repeated-Measures ANOVA for Gait Components

Variables	Main Effect of Group		Main Effect of Time		Group × Time Interaction	
	F	P	F	P	F	P
Step length	0.41	0.520	7.12	0.009	5.23	0.028
Step width	5.34	0.027	1.89	0.179	3.92	0.056
Step speed	0.43	0.518	15.67	< 0.001	14.89	< 0.001
Step rhythm	0.14	0.708	16.45	< 0.001	15.12	< 0.001

post-test, refer to Appendix 2 in Supplementary File.

5. Discussion

This study examined the effect of a 6-week nine-square step exercise protocol on gait components in older women, revealing that the intervention significantly improved step length, step speed, and step rhythm, while step width showed a trend toward reduction but did not reach statistical significance for the interaction effect. These findings align with previous research confirming the effectiveness of balance and coordination exercises in enhancing motor performance and preventing falls in older adults (9, 10). Improvements in step length, step speed, and step rhythm indicate enhanced movement efficiency and stability, which are critical for maintaining functional independence and reducing fall risk in older adults (6, 13). Specifically, an increased step length reflects the ability to cover greater distances with less energy expenditure, which is crucial for daily activities such as walking, shopping, or performing household chores (13). Enhanced step speed not only improves movement efficiency but also indicates greater confidence in performing faster movements, such as reacting to obstacles or crossing the street, potentially reducing fall risk in real-world situations (6). The increase in step rhythm, likely due to the multi-directional and rhythmic nature of the nine-square step exercises, enhances neuromuscular coordination and promotes more regular movement patterns (11). These results are consistent with Puttipaibool et al., who reported improvements in physical fitness and quality of life (10), and Asadi Samani et al., who demonstrated increased balance and reduced fear of falling in older Iranian women (12). However, Tachil and Thomas did not report significant improvements in step rhythm, possibly due to differences in intervention intensity, duration, sample characteristics, or measurement methods (14). These discrepancies highlight the need for more detailed investigations into exercise protocols and contextual factors such as age, baseline activity levels, or physiological conditions.

The increased step length and step speed in the experimental group further underscore the improvement in gait efficiency and stability, which are essential for maintaining functional independence and reducing fall risk in older adults (6). A longer step length implies the ability to cover more distance with less energy, which is significant for daily activities like walking or household tasks (13). Improved step speed reflects increased confidence and the ability to perform faster movements in real-world conditions, potentially aiding in fall prevention during challenging situations such as crossing the street (6). The enhanced step rhythm indicates improved neuromuscular coordination and more rhythmic movement patterns, likely attributable to the multi-directional and rhythmic

nature of the nine-square step exercises (11). These findings are in line with Puttipaibool et al., who reported improved physical fitness and quality of life (10), and Asadi Samani et al., who showed enhanced balance and reduced fear of falling (12). However, Tachil and Thomas found no significant improvement in step rhythm, possibly due to differences in protocol design or intervention duration (14).

The lack of a significant interaction effect for step width may be attributed to the short intervention duration (6 weeks) or individual differences in baseline gait patterns. Older adults often exhibit a wider step width as a protective strategy to compensate for instability (6). The main effect of group on step width suggests that the intervention may have shifted toward a narrower, more efficient gait pattern, but longer or more intense interventions may be required to achieve sustained and significant changes. This finding differs somewhat from Dejvajara et al., who reported a reduction in step width after 12 weeks of nine-square step exercises, indicating that intervention duration may be a key factor in this discrepancy (9).

From a physiological perspective, improvements in gait components can be attributed to strengthened lower extremity muscles (e.g., quadriceps and hamstrings), enhanced proprioception, and increased neuromuscular coordination (8). The nine-square step exercises, by simultaneously stimulating balance systems (vestibular, visual, and proprioceptive), improve dynamic stability and gait efficiency (3). Additionally, the rhythmic and group-based nature of these exercises may enhance participant motivation and adherence, a common challenge in exercise programs for older adults (11). This aspect is particularly relevant for older Iranian women, who may be less likely to engage in physical activities due to cultural or social factors.

It is noteworthy that the nine-square step protocol is a low-cost, safe, and feasible intervention that can be effectively incorporated into rehabilitation programs for older adults. Improvements in gait components, particularly step length, step speed, and step rhythm, confirm the potential of this exercise to reduce fall risk, enhance functional independence, and improve quality of life in older women. Due to its minimal equipment requirements (a tatami mat) and the ability to be implemented in small groups, this protocol is highly suitable for use in low-resource settings, such as day care centers or rural areas in Iran (10). Physiotherapists and rehabilitation specialists can utilize this exercise as part of comprehensive fall prevention programs, particularly for older women at risk of mobility decline. The engaging and social nature of these exercises, enhanced through group implementation, can improve participation and adherence among older adults, a critical factor in the success of exercise interventions (11). This is particularly significant in the cultural context of Iran, where group activities can enhance social motivation.

To expand on these findings, future research should explore longer exercise protocols (12 weeks or more) to assess more sustained effects, particularly on step width. Including more diverse samples, such as older men or individuals with specific conditions (e.g., osteoporosis or Parkinson's disease), could enhance the generalizability of the findings. Additionally, examining non-motor outcomes such as quality of life, confidence, or cognitive function, as well as postural variability, could provide a more comprehensive understanding of the intervention's effects. Comparing the nine-square step protocol with other exercise interventions, such as resistance training, Tai Chi, or yoga, could further clarify its unique benefits (7). Evaluating the long-term effects and adherence to this exercise in real-world settings, such as nursing homes or day centers, is also essential for practical application. The use of more advanced tools, such as motion sensors or gait analysis platforms, could provide more precise data on gait patterns and contribute to improving intervention design.

The study's limitations include the short intervention duration (6 weeks), lack of precise control over participants' daily activities, and the potential influence of individual physiological factors (e.g., medication use, nutritional status, or fatigue). The single-gender sample also limits generalizability to older men. Additionally, the study did not examine the long-term effects of the intervention or non-motor outcomes such as quality of life, confidence, or cognitive function. Furthermore, the relatively small sample size (n = 28) may have limited the ability to detect small changes in certain variables (e.g., step width).

5.1. Conclusions

The 6-week nine-square step exercise protocol significantly improved step length, step speed, and step rhythm in older women. These findings highlight the potential of this low-cost, engaging, and safe intervention to enhance gait performance, reduce fall risk, and improve functional independence in older women. Given its ease of implementation, minimal equipment requirements, and group-based nature, this protocol can be integrated into community-based rehabilitation programs in Iran and other low-resource settings. Physiotherapists, elderly care centers, and

health policymakers should consider incorporating these exercises into fall prevention and health promotion programs for older adults.

Supplementary Material

Supplementary material(s) is available here [To read supplementary materials, please refer to the journal website and open PDF/HTML].

Footnotes

Authors' Contribution: Study concept, design, and study supervision: Y. M. T.; Statistical analysis, study concept, and design: M. K.; Acquisition of data, drafting of the manuscript, study concept, and design: I. T.; Critical revision of the manuscript for important intellectual content: M. N.

Conflict of Interests Statement: The authors declare no conflict of interest.

Data Availability: The dataset presented in the study is available on request from the corresponding author during submission or after publication. The data are not publicly available due to privacy and ethical restrictions.

Ethical Approval: This study has been approved by the Ethics Committee of the Faculty of Sports Sciences and Health at the University of Tehran (ethics code: IR.UT.SPORT.REC.1402.035).

Funding/Support: The present study received no funding/support.

Informed Consent: Written informed consent was obtained from the participants.

References

1. United Nations. *World Population Ageing 2019 Report*. New York, USA: United Nations; 2019.
2. Noroozian M. The elderly population in iran: an ever growing concern in the health system. *Iran J Psychiatry Behav Sci*. 2012;**6**(2):1-6. [PubMed ID: 24644476]. [PubMed Central ID: PMC3940007].
3. Mesquita LS, de Carvalho FT, Freire LS, Neto OP, Zangaro RA. Effects of two exercise protocols on postural balance of elderly women: a randomized controlled trial. *BMC Geriatr*. 2015;**15**:61. [PubMed ID: 26033080]. [PubMed Central ID: PMC4451727]. https://doi.org/10.1186/s12877-015-0059-3.
4. Gomes MM, Reis JG, Neves TM, Petrella M, de Abreu DC. The effect of aging on balance and muscle activation patterns in elderly women. *Int J Gerontol*. 2013;**7**(2):106-11. https://doi.org/10.1016/j.ijge.2012.11.013.
5. Rizzoli R, Branco J, Brandi ML, Boonen S, Bruyere O, Cacoub P, et al. Management of osteoporosis of the oldest old. *Osteoporos Int*. 2014;**25**(11):2507-29. [PubMed ID: 25023900]. https://doi.org/10.1007/s00198-014-2755-9.
6. Aboutorabi A, Arazpour M, Bahramizadeh M, Hutchins SW, Fadayevatan R. The effect of aging on gait parameters in able-bodied older subjects: a literature review. *Aging Clin Exp Res*. 2016;**28**(3):393-405. [PubMed ID: 26210370]. https://doi.org/10.1007/s40520-015-0420-6.
7. Howe TE, Rochester L, Neil F, Skelton DA, Ballinger C. Exercise for improving balance in older people. *Cochrane Database Syst Rev*. 2011;**2011**(11). CD004963. [PubMed ID: 22071817]. [PubMed Central ID: PMC11493176]. https://doi.org/10.1002/14651858.CD004963.pub3.
8. Avelar BP, Costa JN, Safons MP, Dutra MT, Bottaro M, Gobbi S, et al. Balance Exercises Circuit improves muscle strength, balance, and functional performance in older women. *Age (Dordr)*. 2016;**38**(1):14. [PubMed ID: 26802006]. [PubMed Central ID: PMC5005874]. https://doi.org/10.1007/s11357-016-9872-7.
9. Dejvajara D, Aungkasuraphan R, Palee P, Piankusol C, Sirikul W, Siviroj P. Effects of Home-Based Nine-Square Step Exercises for Fall Prevention in Thai Community-Dwelling Older Adults during a COVID-19 Lockdown: A Pilot Randomized Controlled Study. *Int J Environ Res Public Health*. 2022;**19**(17). [PubMed ID: 36078234]. [PubMed Central ID: PMC9517798]. https://doi.org/10.3390/ijerph191710514.
10. Puttipaibool S, Akarasereenont P, Chomchai S, Udomphorn Y, Asavamongkolkul A. Effects of Different Durations of 9-Square Dance Exercise Versus Treadmill Exercise on the Physical Fitness and Quality of Life of Healthy Volunteers: A Pilot Randomized Controlled Trial. *Siriraj Med J*. 2022;**74**(12):883-90. https://doi.org/10.33192/Smj.2022.103.
11. Ou KL, Wong MYC, Chung PK, Chui KYK. Effect of Square Dance Interventions on Physical and Mental Health among Chinese Older Adults: A Systematic Review. *Int J Environ Res Public Health*. 2022;**19**(10). [PubMed ID: 35627716]. [PubMed Central ID: PMC9141523]. https://doi.org/10.3390/ijerph19106181.
12. Asadi Samani Z, Rahnama N, Reisi J, Lenjan Nejadian S. [Effect of 3 months square stepping exercise and resistance training on postural balance and fear of falling in elderly woman]. *Stud Sport Med*. 2019;**11**(25):59-80. FA. https://doi.org/10.22089/smj.2019.7369.1375.
13. Carlos-Vivas J, Perez-Gomez J, Delgado-Gil S, Campos-Lopez JC, Granado-Sanchez M, Rojo-Ramos J, et al. Cost-Effectiveness of "Tele-Square Step Exercise" for Falls Prevention in Fibromyalgia Patients: A Study Protocol. *Int J Environ Res Public Health*. 2020;**17**(3). [PubMed ID: 31973115]. [PubMed Central ID: PMC7037096]. https://doi.org/10.3390/ijerph17030695.
14. Thachil A, Thomas L. The effect of square-stepping exercises on muscle strength, step rhythm, and confidence in elderly women. *Indian J Gerontol*. 2022;**36**(3):303-15.