J Motor Control Learn. 2026 February; 8(1): e165097 https://doi.org/10.69107/jmcl-165097

Published Online: 2026 February 28 **Research Article**

The Effect of Square Step Exercise (SSE) on Cognition, Perceived Physical Literacy, and Communication Skills of the Elderly

Fariba Mollaei Zangi [1,*], Maryam Abdoshahi [1], Parvaneh Shamsipour Dehkordi [1], Sahar Mohammadzadeh [2]

[1] Department of Motor Behavior, Faculty of Sport Sciences, Alzahra University, Tehran, Iran
[2] Department of Sport Science, School of Humanities, Damghan University, Damghan, Iran

[*] ***Corresponding Author:*** Department of Motor Behavior, Faculty of Sport Sciences, Alzahra University, Tehran, Iran. Email: f.mollaei.z17@gmail.com

Received: 9 August, 2025; **Revised:** 1 October, 2025; **Accepted:** 19 February, 2026

Abstract

Background: As people age, many experience declines in cognitive function, motor skills, and communication abilities, which can substantially affect their quality of life. Simple, accessible exercises, such as the Square Step Exercise (SSE), have gained attention as effective methods for improving these abilities.

Objectives: The aim of this study was to investigate the effects of SSE on cognition, perceived physical literacy, and communication skills in older adults.

Methods: The study sample comprised 27 elderly women and men aged 60 - 70 years (M = 62.63, SD = 2.44) from a nursing home in Tabriz. Participants were selected purposively and assigned to two groups: Experimental (n = 14) and control (N = 13). The experimental group participated in a 6-week SSE training program consisting of three sessions per week, with each session lasting 70 minutes, whereas the control group continued the daily physical activities provided by the nursing home. Data were collected using the Montreal Cognitive Assessment (MoCA), the Communication Skills Questionnaire, and the Senior Perceived Physical Literacy Instrument (SPPLI).

Results: The results showed that SSE had a positive effect on perceived physical literacy in older adults. The experimental group showed significant improvements in three perceived physical literacy subscales: Attitude toward physical activity (Pre: 17.79 ± 3.83; Post: 17.23 ± 3.09; P = 0.033), Ability to do physical activity (Pre: 12.93 ± 1.44; Post: 14.14 ± 1.35; P = 0.028), and Social aspects around physical activity (Pre: 5.00 ± 1.88; Post: 6.14 ± 1.75; P = 0.013). However, no significant changes were observed in cognitive function (P = 0.178) or communication skills (P = 0.144).

Conclusions: Based on these results, SSE may be used to enhance perceived physical literacy in older adults. However, the short duration of the intervention and the absence of cognitive or social components may explain the lack of significant improvements in cognition and communication.

Keywords: Older Adults, Motor Function, Aging, Physical Activity, Cognitive Performance

1. Background

Physical alterations associated with aging are inevitable over the life course. Structural and functional changes affect the sensory, neuromuscular, and cognitive systems, thereby impairing essential lifelong skills (1). Sedentary lifestyles may further exacerbate these age-related declines and negatively influence executive function, body composition, and overall physical fitness (2). Evidence suggests that regular physical activity can enhance physiological capacity, help prevent cognitive decline, and provide emotional and psychological benefits for older adults (3). Older individuals who engage in consistent exercise demonstrate higher physical fitness and wellness, stronger motivation, greater confidence in achieving personal goals, and a lower risk of developing chronic diseases (4). Furthermore, regular physical activity improves cognitive functions such as memory, attention, reasoning, and praxis (4-6). Given these

How to Cite: Mollaei Zangi F, Abdoshahi M, Shamsipour Dehkordi P, Mohammadzadeh S. The Effect of Square Step Exercise (SSE) on Cognition, Perceived Physical Literacy, and Communication Skills of the Elderly. J Motor Control Learn. 2026;8(1):e165097. doi: https://doi.org/10.69107/jmcl-165097

findings, maintaining independence and autonomy in older adulthood is essential. The concept of active aging, introduced by the World Health Organization (WHO), emphasizes physical activity as an effective approach to reducing or preventing the negative consequences of aging and promoting healthier and more autonomous living among older adults (7).

According to Karr et al. (2014), incorporating both cognitive training and physical activity into an intervention program may optimize the benefits of training programs (8). Square Step Exercise (SSE) is a training program that integrates cognitive and physical exercise components (9). It is a stepping exercise program that is simple to perform in a group setting. It was developed as an inexpensive and straightforward training protocol with the primary goal of enhancing lower-body strength, agility, cognitive function, and functional skills (1). Benefits may occur at the cognitive level because the movements require focus and spatial awareness to be executed safely and effectively, and at the motor level because the trainer can teach users to shift their weight onto the tips or heels of their feet, thereby challenging static and dynamic balance, agility, and muscle strength (1, 10, 11). Additionally, when SSE is conducted in a group setting, it may promote social relationships (1, 12) and may thereby improve communication skills in elderly individuals. Communication skills have been defined as the process whereby an individual implements a set of goal-directed, interrelated, situationally appropriate social behaviors that are learned and controlled. Previous studies have indicated that participation in group-based physical activity programs can influence communication and social interaction among older adults, although findings have been inconsistent. For instance, Sato et al. and Arkkukangas et al. (13, 14) reported improvements in verbal engagement and social participation following group exercise interventions, However, the evidence remains heterogeneous with respect to communication-related outcomes, and further research is needed to clarify the effectiveness of structured motor-cognitive interventions such as SSE on communication abilities (15). These mixed results highlight the need for further research to determine whether structured motor-cognitive activities such as SSE can enhance communication-related outcomes in older adults.

Communication skills are an essential element of healthy aging because they enable older adults to maintain social relationships, access needed resources and services, and preserve independence. However, with aging, factors such as sensory impairments, cognitive decline, and limited social participation can negatively affect the quality and effectiveness of communication. These difficulties may lead to social isolation, reduce quality of life, and even exacerbate psychological problems such as depression and anxiety. Group physical activities such as SSE may provide opportunities for social interaction for elderly individuals, in addition to motor and cognitive benefits, and may strengthen communication skills. Therefore, improving or maintaining communication abilities in old age not only supports individual independence and motivation but also enables active participation in society and aligns with the overall goals of active and successful aging.

Another factor that may be influenced by SSE is physical literacy. Physical literacy is defined as the motivation, confidence, physical competence, knowledge, and understanding needed to value and participate in a physically active lifestyle (16). Examining the components of physical literacy in older adults and understanding how they interact can help facilitate lifelong participation in and enjoyment of physical activities, thereby improving physical and mental health, preventing age-related injuries and diseases, improving quality of life, and increasing independence (17). Although physical literacy plays an important role in promoting positive health habits, little attention has been paid to its consequences in the elderly population. Older adults may be more physically literate than younger generations, but research on this specific population is scarce (18).

Given the research background and the limited research on SSE and physical literacy among elderly individuals, this study was designed to investigate the dimensions of these factors in the elderly. SSE may help improve perceived physical literacy in the elderly by increasing strength, balance, and flexibility, which may lead to increased self-confidence and motivation for greater physical activity. By examining the impact of SSE on physical literacy, future research could help establish a new paradigm in older adults' exercise interventions, moving beyond isolated measures of fitness or cognition to address the broader capacities that enable older adults to lead active, independent, and social lives. This perspective is novel in the literature and highlights the potential of SSE not only as an educational tool but also as a pathway to foster lifelong physical literacy in older populations.

Despite the reported motor (1, 11, 19, 20), cognitive (1, 4, 9, 19, 20), psychological (1, 20, 21), and social benefits (9, 20) of SSE in the elderly, conflicting results remain. For example, in a systematic review and meta-analysis

by Wang et al. (2021), SSE did not have beneficial effects on cognitive function in the elderly (11). In addition, studies on the effect of SSE are very limited, and further studies are needed (22). Although most studies have emphasized the physical and cognitive outcomes of SSE, little is known about its influence on broader psychosocial domains, such as communication skills and perceived physical literacy. Therefore, the importance of the present study lies in its simultaneous targeting of 3 key areas in the elderly: cognition, physical-perceptual literacy, and communication skills. Given that declines in cognitive and physical abilities, as well as weakened social interactions, are common consequences of aging, identifying multidimensional approaches to address these problems is essential. Owing to its combined nature, SSE may enhance self-confidence, motivation, and motor skills as components of physical literacy, in addition to improving cognitive functions such as attention and working memory. Despite growing interest in multidomain interventions for aging, no prior study has simultaneously examined the effects of SSE on cognitive, physical literacy, and communication outcomes. Exploring these interrelated domains may provide a more comprehensive understanding of how motor-cognitive training contributes to both the physical and social aspects of healthy aging. In addition, performing these exercises in a group setting provides an opportunity for social interaction, which can lead to improved communication skills and reduced social isolation. Therefore, the results of this study can both fill a gap in the scientific literature on the role of multidimensional interventions in aging and provide a basis for designing practical programs to improve the quality of life of the elderly.

2. Objectives

This study aimed to provide evidence on the role of SSE in supporting cognitive health, physical literacy, and communication skills, thereby contributing to strategies for healthy and active aging.

3. Methods

3.1. Study Design

The present study used a quasi-experimental, pretest-posttest design with a control group. It was applied in terms of purpose.

3.2. Subjects

The sample included 27 older adults, including women (N = 17) and men (N = 10), aged 60 - 70 years (M = 62.63, SD = 2.44) from a nursing home in Tabriz. Participants were selected purposively and randomly assigned in equal numbers to the experimental (N = 14) and control (N = 13) groups.

3.3. Apparatus and Task

The Montreal Cognitive Assessment Test (MoCA): The MoCA was developed as a brief screening tool for diagnosing mild cognitive impairment. The materials include pencil and paper, and completion takes approximately 10 minutes. The maximum score is 30; scores of 26 or higher indicate no cognitive impairment, whereas scores below 26 suggest cognitive impairment. The psychometric properties of this scale have been verified in previous studies, and its validity and reliability have been confirmed (23, 24).

Communication Skills Questionnaire: This questionnaire was designed by Queendom in 2004 to measure adult communication skills. Each of the 34 items is rated on a 5-point Likert scale, ranging from always to never. This scale assesses 5 subdomains of communication ability: Listening skills, insight into the communication process, the ability to transmit and receive messages, emotional control, and assertive communication. The test-retest reliability and validity of this questionnaire have been reported as high and acceptable (25, 26).

Senior Perceived Physical Literacy Instrument (SPPLI): The SPPLI consists of 11 items rated on a 5-point Likert scale from strongly disagree to strongly agree and covers 3 components: Attitude toward physical activity, physical activity ability, and sociality around physical activity. Liu et al. examined the content validity, construct validity, and internal consistency of the instrument among 341 older adults in Southern Taiwan and confirmed that the SPPLI is a valid and reliable tool for assessing physical literacy in the elderly population (27). In addition, based on the study by Hamidi et al. (28), the Persian SPPLI demonstrated good content validity, concurrent validity, and internal consistency.

3.4. Procedure

After receiving the code of ethics (IR.DU.REC.1404.004) from Damghan University, which was a main condition for conducting the research, participants who met the eligibility criteria were provided with explanations about the research procedures to ensure that they were fully informed of all study steps. Participants who were willing to take

part provided informed consent by signing a written consent form. The inclusion criteria were age over 60 years, no specific physical or mental illness that would conflict with participation in the study, the ability to walk independently without assistance, the ability to understand and sign a written consent form to participate in the interventions, and no vision problems. Before the intervention, an initial medical screening, including a review of participants' medical records, was conducted at the nursing home health center to select suitable individuals. Throughout all stages of the exercise, nursing home supervisors and researchers were present to prevent potential injury. The exercise environment was also regularly assessed and secured by the researchers; for example, the floor was free of obstacles and was not slippery, sufficient light was provided, and adequate space for movement was available. To prevent fatigue in older participants, the intensity of the exercises was gradually increased from easy to difficult; if symptoms such as severe fatigue, dizziness, or pain were observed, the exercise was stopped. All participants had the right to withdraw voluntarily during the study without any negative consequences.

After this stage, a pretest was administered to participants in both the experimental and control groups. Participants in the experimental group then completed a 6-week SSE training program, with 3 sessions per week, each lasting 70 minutes. Participants in the control group continued their regular nursing home physical activities without any specific intervention. These activities included light stretching, short walks in the yard, and group recreational sessions 2 - 3 times per week, with each session lasting approximately 30 minutes. In the SSE sessions, the first 15 minutes consisted of exercises such as slow walking and simple stretching movements. The next 45 minutes were dedicated to the main exercises based on SSE. The SSE activities were performed on a mat measuring 250 × 100 cm and divided into 45 squares. The training process involved initial instruction of exercise patterns by an instructor; participants then memorized and performed the patterns. After becoming familiar with the stepping patterns, participants were required to walk on their toes without stepping on the square lines. According to their complexity, the 196 stepping patterns in SSE are divided into 8 levels: Beginner 1 and 2, intermediate 1, 2, and 3, and advanced 1, 2, and 3 (19) (Figure 1).

In the present study, according to the study duration, a total of 72 stepping patterns were performed across 6 levels: Beginner 1 and 2, intermediate 1, 2, and 3, and advanced 1. Depending on difficulty, the number of patterns taught in each session varied between 3 and 5.

Each stepping pattern was repeated 4 - 10 times according to participants' learning, with a 30-second rest period between consecutive patterns. At the end of each session, 10 minutes of light stretching exercises were performed to cool down and return the body to its original state. After completion of the training interventions, participants immediately completed a posttest. All pretest and posttest assessments, including cognitive and functional tests, were conducted by trained, blinded raters. These raters were unaware of participants' allocation to the SSE intervention or control group; therefore, scoring and data recording were based solely on participants' actual performance, reducing the potential for bias. To maintain blinding, the assessment sessions were conducted by separate individuals with no knowledge of the participants' training program.

3.5. Data Analysis

Data were described using the mean and standard deviation. Normality of the data distribution was assessed using the Shapiro-Wilk test, which confirmed that the data were normally distributed ($P > 0.05$). In addition, independent t-test results indicated no between-group differences in pretest scores for the dependent variables ($P > 0.05$). The study hypotheses were then tested using repeated-measures analysis of variance (2 × 2) and multivariate analysis of variance (MANOVA), with a significance level of 0.05. SPSS software version 22 was used for all analyses.

4. Results

The descriptive statistics for the study variables are presented in Table 1.

A repeated-measures analysis of variance (2 × 2) was conducted to assess the effect of SSE on participants' cognitive performance. The assumption of sphericity was evaluated using Mauchly's test. Because there were only 2 measurement points (pretest and posttest), the sphericity assumption was automatically met, and no correction (eg, Greenhouse-Geisser) was required. The results showed no significant main effects of time (Wilks' $\lambda = 0.994$, $F(1, 25) = 0.146$, $P = 0.705$, partial $\eta^2 = 0.006$) or group ($F(1, 25) = 1.101$, $P = 0.304$, partial $\eta^2 = 0.042$), and no significant time × group interaction (Wilks' $\lambda = 0.929$, $F(1, 25) = 1.920$, $P = 0.178$, partial $\eta^2 = 0.071$), indicating that SSE did not have a significant effect on cognitive performance. Overall, these findings

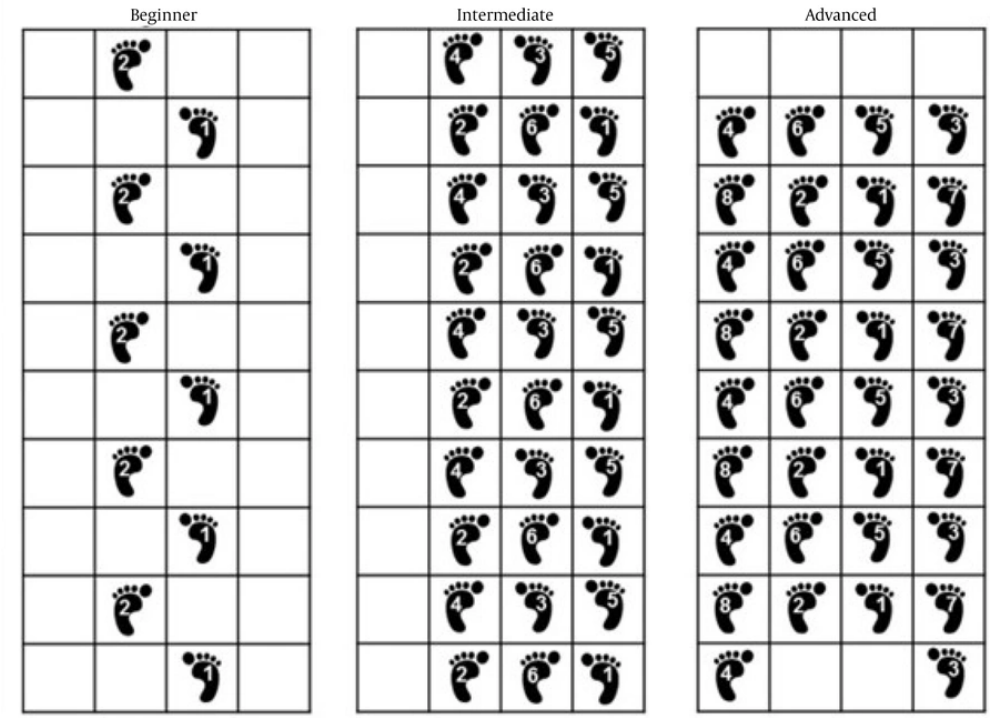

Figure 1. Examples of various patterns related to square stepping exercise at three levels: Beginner, intermediate, and advanced.

Table 1. Descriptive Statistics for the Study Variables [a]

Variables	Experimental group (n = 14)		Control group (n = 13)	
	Pre-test	Post-test	Pre-test	Post-test
Cognitive performance	24.71 ± 1.73	25.50 ± 1.16	24.62 ± 2.29	23.23 ± 3.55
Listening skill	37.57 ± 3.76	37.93 ± 3.73	38.85 ± 4.08	38.46 ± 3.93
Ability to transmit and receive messages	40.21 ± 3.47	38.29 ± 7.03	39.23 ± 4.02	38.92 ± 3.63
Insight into the communication process	24.79 ± 3.04	24.93 ± 3.00	25.61 ± 1.94	25.38 ± 2.33
Emotional control	20.50 ± 2.35	20.79 ± 2.36	20.62 ± 2.10	20.77 ± 1.83
Assertive communication	18.86 ± 3.25	19.07 ± 3.02	20.15 ± 1.68	20.00 ± 1.78
Attitude toward physical activity	17.79 ± 3.83	18.86 ± 3.39	17.23 ± 3.09	17.46 ± 3.09
Ability to do physical activity	12.93 ± 1.44	14.14 ± 1.35	13.85 ± 2.03	14.23 ± 2.05
Social around physical activity	5.00 ± 1.88	6.14 ± 1.75	5.69 ± 1.55	6.00 ± 1.41

[a] Values are expressed as mean ± SD.

indicate that SSE did not produce significant improvements in cognitive performance in this sample.

The MANOVA results indicated that the main effect of time (Wilks' $\lambda = 0.775$, $F(5, 21) = 1.218$, $P = 0.335$, partial $\eta^2 = 0.225$), the main effect of group (Wilks' $\lambda = 0.917$, $F(5, 21) = 0.381$, $P = 0.856$, partial $\eta^2 = 0.083$), and the time × group interaction (Wilks' $\lambda = 0.693$, $F(5, 21) = 1.864$, $P = 0.144$, partial $\eta^2 = 0.307$) were not significant for the components related to communication skills. However, for the components related to senior perceived physical literacy, the MANOVA results showed significant effects

of time (Wilks' $\lambda = 0.391$, $F(3, 23) = 11.919$, $P < 0.001$, partial $\eta^2 = 0.609$) and the time × group interaction (Wilks' $\lambda = 0.659$, $F(3, 23) = 3.964$, $P < 0.021$, partial $\eta^2 = 0.341$), whereas the main effect of group was not significant (Wilks' $\lambda = 0.939$, $F(3, 23) = 0.497$, $P = 0.688$, partial $\eta^2 = 0.061$).

Follow-up univariate tests showed significant time × group differences across all 3 components: Attitude toward physical activity ($F(1, 25) = 5.125$, $P = 0.033$, partial $\eta^2 = 0.170$), Ability to do physical activity ($F(1, 25) = 5.412$, $P = 0.028$, partial $\eta^2 = 0.178$), and Social around physical activity ($F(1, 25) = 7.131$, $P = 0.013$, partial $\eta^2 = 0.222$). Pairwise comparisons using the Bonferroni post hoc test showed that, for all 3 components, the change over time from pretest to posttest was significant in the experimental group ($P < 0.001$), whereas this change was not significant in the control group ($P > 0.05$). Therefore, SSE was effective in improving seniors' perceived physical literacy among participants in the experimental group.

5. Discussion

The aim of the present study was to investigate the effect of SSE on cognition, perceived physical literacy, and communication skills in elderly individuals. The findings showed that SSE had no significant effect on cognitive performance in the elderly. In a systematic review and meta-analysis conducted by Wang et al. (11), motor-cognitive training programs, including SSE, were found to produce limited or no significant improvements in global cognition among older adults. This aligns with the present findings, suggesting that the cognitive benefits of SSE may depend on training duration, cognitive task complexity, or participant characteristics. In the study by Shellington et al. (29), SSE did not improve global cognitive functioning in older adults, which is also consistent with the present findings.

Given that SSE challenges specific cognitive domains, including executive function, memory, and attention, it has been proposed that SSE enhances cognitive function (4). In SSE, participants must memorize, recall, and transform information to execute precise stepping patterns in the correct order after the instructor models them (11). Several studies (1, 4, 19, 20) have also shown that SSE improves cognitive function in the elderly, which is inconsistent with the results of the present study. Possible reasons for this inconsistency include differences in the number of training sessions. According to the principles of neuroplasticity, structural or functional changes in the brain are usually produced by long-term, repetitive training (27). In the present study, the 6-week intervention period may not have been sufficient to produce such changes. For example, the studies by Eskandari et al. (19) and Teixeira et al. (4) used interventions lasting 12 and 16 weeks, respectively, whereas the intervention in the present study lasted 6 weeks. It is also possible that improvements in cognition may begin after the end of the intervention. As previous studies have shown, changes in cognition may be observed 6 months after an exercise intervention (28). In addition, according to the theory of embodied cognition, cognitive processes are stimulated only when motor activities are accompanied by sufficient mental challenges (29, 30). SSE training may have been perceived as cognitively simple by participants, especially in the early stages of the program.

In addition, the tools used to measure cognitive function vary across studies, which could be another reason for inconsistencies across findings. However, overall, the potential effects of SSE on cognitive function require further investigation.

Another finding of the present study was that SSE did not affect communication skills in the elderly. This result contrasts with studies by Kawabata et al. (9, 20), which reported that SSE enhanced social communication, as well as bonding and intimacy, among sedentary older and younger adults. Because SSE is typically performed in a group context, it has the potential to strengthen social interaction (12). Moreover, SSE has been shown to promote adherence through its social component, group motivation, and positive impact on social cohesion and emotional well-being (1). A possible explanation for this discrepancy is the conceptual distinction between social connectedness or group cohesion and individual communication skills. Previous research has often used instruments such as the Physical Activity Group Environment Questionnaire (PAGEQ) to assess social interaction and group bonding, whereas the current study used a communication skills questionnaire focused on individual competencies, such as clarity of expression and listening. These domains may not be readily modified by short-term group physical activity. Another important factor that could have influenced these results is the sensitivity of the measurement instruments. Instruments such as the Queendom Communication Skills Test may be less responsive to short-term behavioral changes than measures of social cohesion (9). In addition, characteristics of the current study sample, including baseline levels of communication skills, personality

traits, and prior social participation, may have influenced the observed effects. Participants in the current study may have had limited opportunities or motivation to translate SSE group-based social participation into measurable improvements in personal communication skills. The duration and intensity of the intervention may also have contributed to these nonsignificant results. Shigematsu and Okura (12) emphasized that SSE, when conducted regularly in group settings, can foster greater social interaction. However, short-term intervention periods may be insufficient. Furthermore, the use of a control group without specific physical activity may limit the interpretation of the results, as improvements may have been observed simply from participation in any group activity, such as brisk walking, independent of the specific characteristics of SSE. Nevertheless, because only a limited number of studies have explored the effects of SSE on communication skills, a comprehensive comparison with previous findings is not possible. Further research is therefore warranted.

Another important finding of the present study was that SSE had a positive effect on perceived physical literacy in the elderly. Research on physical literacy with SSE represents a new and under-researched area in exercise and physical activity among older adults. Positioning SSE as a means of increasing physical literacy in older adults is innovative because it shifts the focus from short-term functional outcomes to a more holistic framework that emphasizes sustained motivation, self-confidence, and motor capacity. In addition, the concept of physical literacy, which has a positive impact on quality of life, is related to the ultimate goal of a quality program based on motivation, self-confidence, physical competence, knowledge, and understanding to value and take responsibility for maintaining purposeful physical activity and participating in a wide range of activities throughout the life span (31, 32). The existence of multiple definitions of physical literacy makes it a somewhat controversial concept. However, the convergence and common ground across definitions of physical literacy emphasize emotional, physical, and cognitive characteristics, as well as the skills necessary to participate in physical activities throughout the life cycle (33). Some studies show that physical literacy is a prerequisite for physical activity, whereas physical activity may also improve the level of physical literacy. In other words, individuals without an understanding of physical literacy may not participate in physical activities, but their participation in physical activities may improve their physical literacy (34). However, to the researchers' knowledge, no study has yet investigated the effect of SSE on perceived physical literacy in the elderly. Therefore, we were unable to compare the results of the present study with those of previous research.

5.1. Conclusion

The results of this study showed that SSE significantly improved perceived physical literacy in elderly individuals but did not produce significant changes in cognitive function or communication skills. These findings indicate that SSE can be used as a simple, safe, and low-cost motor-cognitive activity to enhance motivational components and motor competence in the elderly. From a theoretical perspective, the present study provides the first evidence on the use of SSE to promote physical literacy in the elderly and emphasizes the importance of structured motor experiences in maintaining motivation and physical participation in old age. At the same time, the lack of observed effects on cognition and communication skills may be due to the short intervention duration, the moderate exercise intensity, or the need for stronger cognitive and social elements in the program design.

To ascertain the therapeutic potential of SSE in a broader range of contexts, future studies should focus on randomized clinical trials that investigate its impact in populations with preexisting disorders, such as individuals with mobility difficulties or moderate cognitive impairment. Identifying the optimal duration of interventions is also crucial for maximizing benefits and facilitating recommendations for SSE. If this intervention is effective, it can be implemented in specialized elderly care centers, institutions, and associations. Based on the findings of this research, several recommendations are suggested: expanding research on physical literacy in older adults; using active control groups, such as brisk walking, tai chi, or dance; extending intervention duration and follow-up; and matching interventions to participants' personality traits.

5.2. Limitations

The present study had several limitations that should be considered when interpreting the results. The relatively small sample size and the use of only an inactive control group limited the generalizability and comparability of the results. In addition, the reasons for dropping out of the study were not fully reported, and the analyses were not fully conducted based on the intention-to-treat (ITT) approach. Furthermore, insufficient alternative explanations were provided for the nonsignificant results. Accordingly, it is suggested

that similar studies be conducted in future research with larger sample sizes, active control groups, such as brisk walking, full reporting of reasons for dropout, ITT analysis, and investigation of possible factors affecting nonsignificant results to increase the validity and generalizability of the findings.

Footnotes

AI Use Disclosure: The authors declare that no generative AI tools were used in the creation of this article.

Authors' Contribution: Fariba Mollaei Zangi contributed to the conceptualization and design of the study, data collection, data analysis, interpretation, and drafting of the manuscript. Maryam Abdoshahi, Parvaneh Shamsipour Dehkordi, and Sahar Mohammadzadeh participated in the conceptualization and design of the study, critical revision of the manuscript, and supervision of the research process.

Conflict of Interests Statement: The authors have 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.

Ethical Approval: This study is approved under the ethical approval code of IR.DU.REC.1404.004.

Funding/Support: The project was self-funded and received no financial support from any external institution or organization.

References

1. Franco-García JM, Carlos-Vivas J, Castillo-Paredes A, Mayordomo-Pinilla N, Rojo-Ramos J, Pérez-Gómez J. Impacts of square stepping exercise on physical-cognitive function, biomarkers, body composition, and mental health in healthy senior aged 60 and above: Systematic review. *Healthcare (Basel)*. 2024;**12**(23):2325. [PubMed ID: 39684951]. [PubMed Central ID: PMC11641620]. https://doi.org/10.3390/healthcare12232325.
2. Tremblay MS, Aubert S, Barnes JD, Saunders TJ, Carson V, Latimer-Cheung AE, et al. Sedentary Behavior Research Network (SBRN) - Terminology Consensus Project process and outcome. *Int J Behav Nutr Phys Act*. 2017;**14**(1). 75. [PubMed ID: 28599680]. [PubMed Central ID: PMC5466781]. https://doi.org/10.1186/s12966-017-0525-8.
3. Nelson ME, Rejeski WJ, Blair SN, Duncan PW, Judge JO, King AC, et al. Physical activity and public health in older adults: Recommendation from the American College of Sports Medicine and the American Heart Association. *Med Sci Sports Exerc*. 2007;**39**(8):1435-1445. [PubMed ID: 17762378]. https://doi.org/10.1249/mss.0b013e3180616aa2.
4. Teixeira CVL, Gobbi S, Pereira JR, Vital TM, Hernandéz SSS, Shigematsu R, et al. Effects of square-stepping exercise on cognitive functions of older people. *Psychogeriatrics*. 2013;**13**(3):148-156. [PubMed ID: 25913763]. https://doi.org/10.1111/psyg.12017.
5. Bherer L, Erickson KI, Liu-Ambrose T. A review of the effects of physical activity and exercise on cognitive and brain functions in older adults. *J Aging Res*. 2013;**2013**:657508-8. [PubMed ID: 24102028]. [PubMed Central ID: PMC3786463]. https://doi.org/10.1155/2013/657508.
6. Mora JC, Valencia WM. Exercise and older adults. *Clinics in Geriatric Medicine*. 2018;**34**(1):145-162. [PubMed ID: 29129214]. https://doi.org/10.1016/j.cger.2017.08.007.
7. Franco-García JM, Carlos-Vivas J, Pereira-Payo D, Adsuar JC, Mendoza-Muñoz M, Granado-Sánchez M, et al. Effects of 6-month square stepping exercise intervention on physical and cognitive competence, Regucalcin, and body composition in older people: Study protocol for a randomised control trial. *Int J Environ Res Public Health*. 2022;**19**(5):3086. [PubMed ID: 35270778]. [PubMed Central ID: PMC8910098]. https://doi.org/10.3390/ijerph19053086.
8. Karr JE, Areshenkoff CN, Rast P, Garcia-Barrera MA. An empirical comparison of the therapeutic benefits of physical exercise and cognitive training on the executive functions of older adults: A meta-analysis of controlled trials. *Neuropsychology*. 2014;**28**(6):829-845. [PubMed ID: 24933486]. https://doi.org/10.1037/neu0000101.
9. Kawabata M, Gan SR, Goh G, Omar SAB, Oh ITF, Wee WQ, et al. Acute effects of Square Stepping Exercise on cognitive and social functions in sedentary young adults: A home-based online trial. *BMC Sports Sci Med Rehabil*. 2021;**13**(1). 82. [PubMed ID: 34334140]. [PubMed Central ID: PMC8325990]. https://doi.org/10.1186/s13102-021-00309-w.
10. Jindo T, Kitano N, Tsunoda K, Kusuda M, Hotta K, Okura T. Daily life physical activity modulates the effects of an exercise program on lower-extremity physical function in Japanese older adults. *J Geriatr Phys Ther*. 2017;**40**(3):150-157. [PubMed ID: 27088549]. https://doi.org/10.1519/JPT.0000000000000087.
11. Wang YH, Liu YH, Yang YR, Wang RY. Effects of square-stepping exercise on motor and cognitive function in older adults - A systematic review and meta-analysis. *Geriatr Nurs*. 2021;**42**(6):1583-1593. [PubMed ID: 34773911]. https://doi.org/10.1016/j.gerinurse.2021.10.022.
12. Shigematsu R, Okura T. A novel exercise for improving lower-extremity functional fitness in the elderly. *Aging Clin Exp Res*. 2006;**18**(3):242-248. [PubMed ID: 16804371]. https://doi.org/10.1007/BF03324655.
13. Sato M, Salas G, Freeborn L, Tajabadi A. TBLT, Engagement, and Group Synchronicity: Exploring the Relationships between Affective, Social, and Cognitive Aspects of Task-Based Performance. *TESOL J*. 2025;**59**:S88-S114. https://doi.org/10.1002/tesq.3408.
14. Arkkukangas M, Strömqvist Bååthe K, Tonkonogi M, Liljeroos M. More Than Just Exercise: Older Adults' Experience of the Peer-Led Group-Based FallFitness Program. *Clin Interv Aging*. 2025;**1**(20):931-939. [PubMed ID: 40621091]. https://doi.org/10.2147/CIA.S527142.
15. Khajehpour MH, Ayoubi-Mahani S, Mohammad-Rezakhani H, Farokhzadian J. Fostering active aging in older adults: results of a communication and social skills program. *BMC Geriatrics*. 2025;**25**(1). [PubMed ID: 40814074]. https://doi.org/10.1186/s12877-025-06333-6.
16. Whitehead M. *The Concept of Physical Literacy*. Routledge; 2010.
17. Petrusevski C, Morgan A, MacDermid J, Wilson M, Richardson J. Framing physical literacy for aging adults: An integrative review. *Disabil Rehabil*. 2022;**44**(26):8149-8160. [PubMed ID: 34913771]. https://doi.org/10.1080/09638288.2021.2012841.
18. Galán-Arroyo C, de los Ríos-Calonge J, Rojo-Ramos J, Parraca JA, Fonseca C, Castillo-Paredes A, et al. Physical literacy in older adults: A scoping review protocol. *Front Public Health*. 2024;**11**. 1217773. [PubMed

ID: 38303962]. [PubMed Central ID: PMC10830641]. https://doi.org/10.3389/fpubh.2023.1217773.

19. Eskandari M, Nezakat Alhosseini M, Safavi Homami S. Comparison of memory, balance and fear of falling in older women after performing yoga and square-stepping exercises. *Salmand: Iranian Journal of Ageing*. 2024;**19**(3):438-451. https://doi.org/10.32598/sija.2023.3632.1.
20. Kawabata M, Gan SR, Shen-Hsing AC. Effects of Square Stepping Exercise on cognitive, physical, psychological, and group functioning in sedentary older adults: A center-based hybrid trial. *BMC Geriatr*. 2024;**24**(1). 374. [PubMed ID: 38664613]. [PubMed Central ID: PMC11046944]. https://doi.org/10.1186/s12877-024-04904-7.
21. Pereira JR, Gobbi S, Teixeira CVL, Nascimento CMC, Corazza DI, Vital TM, et al. Effects of Square-Stepping Exercise on balance and depressive symptoms in older adults. *Motriz: Revista de Educação Física*. 2014;**20**(4):454-460. https://doi.org/10.1590/s1980-65742014000400013.
22. Siqueira VAAA, Shigematsu R, Sebastião E. Stepping towards health: A scoping review of square stepping exercise protocols and outcomes in older adults. *BMC Geriatr*. 2024;**24**(1). 590. [PubMed ID: 38987666]. [PubMed Central ID: PMC11238358]. https://doi.org/10.1186/s12877-024-05187-8.
23. Nasreddine ZS, Phillips NA, Bédirian V, Charbonneau S, Whitehead V, Collin I, et al. The Montreal Cognitive Assessment, MoCA: A brief screening tool for mild cognitive impairment. *J Am Geriatr Soc*. 2005;**53**(4):695-699. [PubMed ID: 15817019]. https://doi.org/10.1111/j.1532-5415.2005.53221.x.
24. Emsaki G, Molavi H, Chitsaz A, Movahed Abtahi M, Asgari K. Psychometric properties of the Montreal Cognitive Assessment (MoCA) in Parkinson's disease patients in Isfahan. *Journal of Isfahan Medical School*. 2011;**29**(158):1606-1615.
25. Queendom; Queendom. *Queendom*. 2004, [cited 2026 May 21]. Communication Skills Test-Revised [Internet].
26. Hosseinchari M, Fadakar M. Investigating the effects of higher education on communication skills based on comparison of college and high school students. *Teaching and Learning Research*. 2006;**3**(2):21-32.
27. Mandolesi L, Polverino A, Montuori S, Foti F, Ferraioli G, Sorrentino P, et al. Effects of physical exercise on cognitive functioning and wellbeing: Biological and psychological benefits. *Front Psychol*. 2018;**9**. 509. [PubMed ID: 29755380]. [PubMed Central ID: PMC5934999]. https://doi.org/10.3389/fpsyg.2018.00509.
28. Colcombe S, Kramer AF. Fitness effects on the cognitive function of older adults: A meta-analytic study. *Psychol Sci*. 2003;**14**(2):125-130. [PubMed ID: 12661673]. https://doi.org/10.1111/1467-9280.t01-1-01430.
29. Barsalou LW. Grounded cognition. *Annu Rev Psychol*. 2008;**59**(1):617-645. [PubMed ID: 17705682]. https://doi.org/10.1146/annurev.psych.59.103006.093639.
30. Herold F, Törpel A, Schega L, Müller NG. Functional and/or structural brain changes in response to resistance exercises and resistance training lead to cognitive improvements: A systematic review. *Eur Rev Aging Phys Act*. 2019;**16**(1). 10. https://doi.org/10.1186/s11556-019-0217-2.
31. Samadi H, Moradi J, Aghababa A. Psychometric properties of Persian version of the Perceived Physical Literacy Instrument (PPLI). *Motor Behavior*. 2023;**14**(50):161-186. https://doi.org/10.22089/mbj.2022.12765.2033.
32. Yılmaz A, Kabak S. Perceived physical literacy scale for adolescents (PPLSA): Validity and reliability study. *International Journal of Education and Literacy Studies*. 2021;**9**(1):159-171.
33. Ahmadi A, Khalesi M, Rajabpour M. Prediction of the physical activity level of adolescent girls based on perceived physical literacy: The mediating role of cognitive abilities. *Pajouhan Sci J*. 2023;**21**(2):104-112. https://doi.org/10.61186/psj.21.2.104.
34. Choi SM, Sum RKW, Leung EFL, Ng RSK. Relationship between perceived physical literacy and physical activity levels among Hong Kong adolescents. *PLoS One*. 2018;**13**(8). e0203105. [PubMed ID: 30148876]. [PubMed Central ID: PMC6110504]. https://doi.org/10.1371/journal.pone.0203105.