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Original Article

Effects of a seated upper-extremity exercise program designed to improve cognitive and upper-extremity functions in older females

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Abstract. [Purpose] The square-touch exercise is an upper-extremity exercise program that can be performed in a seated position and includes cognitive tasks. It was designed to maintain and improve cognitive function in older people. This study aimed to investigate the effects of a three-month square-touch exercise program on the cognitive and upper-extremity functions in older females. [Participants and Methods] The participants were divided into an intervention group of 15 individuals with a mean age of 78.1 ± 5.9 years and a control group of 16 individuals with a mean age of 81.7 ± 6.3 years. The intervention group participated in the square-touch exercise program once a week for three months. The mini-mental state examination, trail-making test, peg test, and grip strength were measured before and after the intervention. [Results] The intervention group showed improved mini-mental state examination scores as well as significantly improved attention and calculation, which are sub-items of the mini-mental state examination. [Conclusion] The square-touch exercise program may be effective for maintaining and improving cognitive function in older females.

Key words: Upper extremity exercise, Cognitive function, Older females

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INTRODUCTION

According to the Ministry of Health, Labor, and Welfare, dementia is the leading cause of nursing care among individuals, aged 65 years and over, in Japan[1)]. In 2012, the number of older people with dementia was 4.62 million[2)]. This equated to approximately one in seven older individuals, aged >65 years. This number is estimated to be 7.3 million or one-fifth of those aged >65 years by 2025[2)]. The increasing number of older people with dementia has become a major social problem, especially within an aging society.

Dementia progresses in stages, and the preliminary stage is diagnosed as mild cognitive impairment (MCI)[3)]. MCI is a condition in which memory loss is the main symptom but the impact on daily life is minimal and the person cannot be diagnosed with dementia[3)]. The number of patients with MCI in Japan was estimated to be approximately 4 million in 2012[4)]. Of these, 10% of MCI patients will develop dementia[5)]. Conversely, some have reported that MCI patients can recover to normal cognitive functions with appropriate interventions[6)]. Thus, the prevention and improvement of dementia and MCI in older people are considered important.

Frailty among older people is attracting attention from the perspective of care prevention in Japan[7)]. Frailty is defined as a state of increased vulnerability to stress due to a decline in physiological reserves in old age and is associated with a higher risk of adverse outcomes, such as impaired daily functioning, need for nursing care, and death[8)]. Frailty has several physical,

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psychological, and social aspects[9]. It has been reported that physical frailty increases the risk of cognitive decline[10], and that cognitive decline increases the risk of progressive physical frailty[11], suggesting that physical and cognitive declines affect each other in both directions. In other words, not only is it necessary to prevent dementia and nursing care among healthy individuals, but preventing cognitive decline in those with physical decline, as well as preventing physical decline in those with cognitive decline, must also be considered.

Exercise is one way to prevent dementia and improve physical function in older people. The benefit of exercise on cognitive and physical functions have been reported in numerous studies. Various types of exercises have been shown to have a positive effect on the maintenance and improvement of cognitive functions in older people[12]. These exercises include aerobic and resistance exercises. The majority of these exercises involve standing. For older people who have difficulties maintaining a standing position because of muscle weakness in the lower extremity, poor balance, or other diseases, doing exercises while standing is extremely challenging. It has been reported that the immediate effect of hand exercises that can be performed in a sitting position is improved executive functions[13]. Several studies have also reported on the benefit of dual-task exercises performed in a seated position. In particular, dual-task exercises in which muscle strength exercises and a simple cognitive task are performed simultaneously may improve cognitive function[14]. Considering the available evidence, it is desirable to develop exercises that can be performed in a sitting position for the maintenance and improvement of cognitive function among frail older people and other older people who have difficulties performing standing exercises. Consequently, by improving cognitive function, the need for nursing care especially high-level care may be minimized.

The square-stepping exercise (SSE) is a standing exercise for the prevention of dementia, in which participants move (step) continuously on a mat based on their memory of the step pattern shown by the instructor[15]. It is known that the SSE has a positive effect on cognitive function in older people[16, 17]. For this study, we developed a square-touch exercise (STE), an upper-extremity exercise program that can be performed in a seated position and incorporates cognitive tasks based on the SSE. The tasks involved short-term memory and attention. The program is based on a dual-task, such as a cognitive task added to an upper extremity exercise. If STE can be established as an exercise program that has a positive effect on cognitive and upper extremity functions in older people, it can be widely implemented as a recommended exercise program in local exercise salons or facilities for older people, including frail older people. This study aimed to investigate the effects of a 3-month STE program on the cognitive and upper extremity functions of older adults.

PARTICIPANTS AND METHODS

The participants were 42 older females participating in salon activities in regions A, B, and C. The participants were assigned to either the intervention group (STE group) or the control group (C group). Nineteen participants in region A were assigned to the STE group, and a total of 13 participants in region B and 10 participants in region C (23 participants) were assigned to the C group (Fig. 1).

The exclusion criteria include 1) those certified as requiring nursing care, 2) those with severe cognitive impairment who had difficulty understanding STE or measurements, 3) those with brain or orthopedic diseases that could affect STE or measurements, and 4) those who had difficulties performing STE.

Two participants in the STE group and five in the C group were excluded from the post-intervention measurements. Two participants in the STE group and two participants in the C group had missing items in the pre- and post-intervention

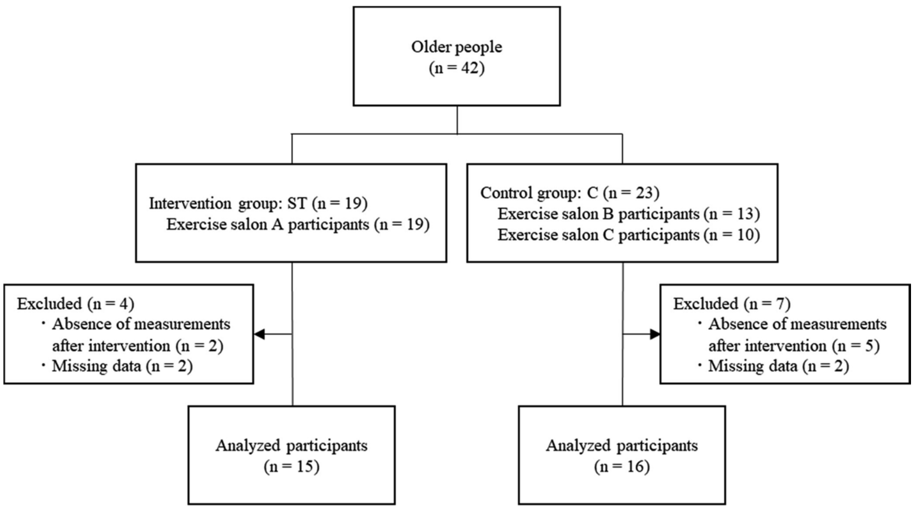

Fig. 1. The process of selecting the participants.

measures. After excluding these participants, the final analysis included 15 participants in the STE group (mean age: 78.1 ± 5.9 years, height: 146.1 ± 3.8 cm, weight: 56.0 ± 7.1 kg) and 16 participants in the C group (mean age: 81.7 ± 6.3 years, height: 144.2 ± 4.7 cm, weight: 49.2 ± 9.1 kg) (Fig. 1).

This study was conducted with the approval of the ethical review committee of the National Institute of Fitness and Sports in Kanoya (No. 4-45). The study complied with the Declaration of Helsinki and the Ethical Guidelines for Life Sciences and Medical Research Involving Human Subjects. After explaining the purpose of the study, the voluntary nature of research cooperation, the freedom to withdraw, and the possible benefits, disadvantages, and risks associated with participation in the study, only those individuals who provided written consent to participate were included in this study.

The STE group participated in a program involving STE once a week for 3 months (12 sessions in total). This 60-minute exercise program consisted of 10 min of preparatory exercise (mainly stretching), 40 min of main exercise (STE), and 10 min of cool-down exercise (mainly stretching). Preparatory and cooling-down exercises were performed in the sitting position and involved stretching of the upper extremities, trunk, and lower extremities.

The STE is an upper extremity exercise that uses a mat with eight 10 cm × 10 cm squares across and four squares vertically, (a total of 32 squares). The participant sat on a chair in front of a table with a mat on it and was required to touch the squares on the mat accurately with their upper extremities and fingers according to the task. In this study, the following four tasks formed an STE set: (1) a task to remember the squares indicated by the instructor and touch them in order (Fig. 2), (2) a task to place felt with numbers on the squares and touch them in the indicated order (Fig. 2), (3) a task to respond to cognitive questions, such as mathematical calculations, naming of vegetables, articulating words that begin with "a", and (4) a task to simultaneously stomp one's feet while performing upper extremity exercises. Tasks (3) and (4) incorporated elements of a double task. During the first half of the 3-month intervention period, tasks (1) through to (4) were performed in the sequence of low difficulty to and high difficulty.

The recreation and stretching programs performed by individuals in Group C were also chair-based. To evaluate the effects of the intervention, cognitive and physical functions were measured before and after the intervention in both the STE and C groups. Pre-intervention measurements were performed in March 2022, and post-intervention measurements were performed in June 2022.

The participants' birth dates, heights, and weights were recorded. Height was measured in 0.1 cm increments using a height scale (InLab, InBody, Tokyo, Japan). Weight was recorded in 0.1 kg increments using a scale (TANITA, HD-661, Tokyo, Japan) and a pre-set 0.5 kg of clothing was accounted for. Body mass index (BMI) was calculated from the measured height and weight.

Mini-mental state examination-Japanese (MMSE) was used to assess cognitive function[18, 19]. The MMSE is a self-administered, face-to-face verbal assessment that takes approximately 10 minutes. The MMSE sub-items include orientation (10 points), attention and calculation (5 points), registration (3 points), recall (3 points), and language (9 points), which are scored on a 30-point scale[18]. A physical therapist or a health and exercise instructor administered the test with the patient sitting in a chair. In this study, the total score of the MMSE and the scores of each sub-item were used as evaluation items.

Trail-making test, Japanese edition (TMT-J) was used to assess attentional function[20, 21]. The TMT-J is a standardized test that comprehensively measures a wide range of attention, executive function/working memory, spatial exploration, processing speed, retention, and impulsivity. TMT-J consists of Part A (TMT-A), in which numbers are connected in a sequence from 1 to 25, and Part B (TMT-B), in which numbers and Hiragana are connected alternately to 13[21]. As in the MMSE, a physical therapist or a health and exercise instructor performed the TMT-A and then the TMT-B, with the patient in the chair-sitting position. In this study, the time required for TMT-A and TMT-B was recorded in 0.01 second increments with a stopwatch, and these were used as the evaluation items. If the participants could not connect the pieces in the correct order or if they had difficulty continuing the task, they were recorded as not being able to perform the task.

To measure upper extremity dexterity, the peg test[22] was changed to a measurement method that can be performed in a chair-sitting position. A hand-arm test board used for the peg insertion test of the general aptitude test battery compiled by the Ministry of Health, Labor, and Welfare was used for the peg test[23]. The board consisted of two panels with 48 holes arranged in six rows and eight columns, which were joined at the top and bottom. In this study, considering the reachable range of the

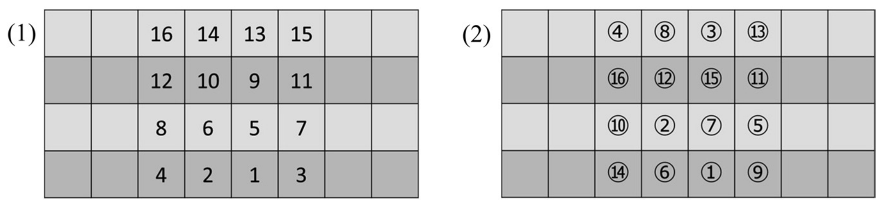

Fig. 2. Examples of square-touch exercise patterns.
(1) A task to remember the squares indicated by the instructor and touch them in order.
(2) A task to place felt with numbers on the squares and touch them in the indicated order.

participant's upper extremity on the testing board in the chair-sitting position, we used four rows and eight columns out of six rows and inserted pegs into the top of the board before starting the test. When the measurement began, the participant was instructed to remove one peg from the board (four pegs in total) in the first row on the right side of the board and insert it into the hole at the bottom of the board, corresponding to the position from which the peg was removed. Once they had finished moving one row of pegs, they proceeded to the next row, that is, rows two and three. The number of pegs inserted into the bottom board after 30 s was recorded. The participants initially performed the measurements with the non-dominant hand only and then with the dominant hand only. Measurements were taken once for each of the left and right hands.

Grip strength was measured in the seated position using a digital grip strength meter (T.K.K. 5401, Takei Kiki Co., Ltd., Niigata, Japan). The participant was instructed to hold the grip strength meter as tightly as possible. While holding the meter, the patient is asked to exhale in a relaxed position with both arms naturally lowered at the sides of the body. The grip width was adjusted such that the second joint of the second finger was at a right angle. Measurements were performed twice for each hand (four times in total), and the best value was recorded as the representative grip strength.

IBM SPSS Statistics 25 (Armonk, NY, USA) was used for all statistical analyses. Unpaired t-tests were used to compare the characteristics of the STE and C groups before the intervention. A two-way repeated-measures analysis of variance was used to compare changes in physical and cognitive functions before and after the intervention. The effect size η^2 was calculated. 0.01 was considered a small effect, 0.06 was a medium effect, and 0.14 was a large effect. The significance level was set at 5%[24].

RESULTS

Participant characteristics are shown in Table 1. There were no significant differences in age or height between the STE and C groups before intervention. For weight, there was only a significant group main effect for STE and C (F (1, 29)=4.683, p=0.039, η^2=0.14) and no group or time main effects. There were also no significant differences in the BMI.

The results of the cognitive and upper extremity functions are shown in Table 2. A significant difference (F (1, 29)=8.313, p=0.007, η^2=0.02) was found in the MMSE scores of the STE and C groups, before and after the intervention. Next, a significant time difference was found in the TMT-A (F (1, 29)=4.386, p=0.045, η^2=0.02) and the peg test with the dominant hand (F (1, 29)=4.781, p=0.037, η^2=0.01), whereas the main effect and differences between the groups were not significant. Other evaluated items were not significant. There were no significant main effects between the groups or time measurements, or interaction effects for grip strength, peg test with the non-dominant hand, or the TMT-B.

The results of the MMSE sub-items are presented in Table 3. A significant interaction was found between attention and calculation (F (1, 29)=7.411, p=0.011, η^2=0.02). In contrast, there were no significant group main effects, time main effects, or differences in orientation, registration, recall, or language.

DISCUSSION

This study examined the effects of a 3-month intervention using the STE program on cognitive and upper extremity functions in older females. The STE program involved an upper extremity exercise that can be performed in a seated position and incorporated cognitive tasks. The MMSE scores, a measure of cognitive function, improved in the STE group after the

Table 1. Characteristics before and after the intervention

	Pre Mean ± SD	Post Mean ± SD	Interaction p	Group p	Time p
Age (years)					
STE	78.1 ± 5.9				
C	81.7 ± 6.3				
Height (cm)					
STE	146.1 ± 3.8				
C	144.2 ± 4.7				
Body mass (kg)					
STE	56.0 ± 7.1	55.5 ± 7.6	0.075	0.039*	0.252
C	49.2 ± 9.1	49.3 ± 9.1			
BMI (kg/m²)					
STE	26.2 ± 3.1	26.0 ± 3.3	0.081	0.094	0.228
C	23.7 ± 4.4	23.7 ± 4.3			

SD: standerd deviation; STE: squre-touch exercise group; C: control group; BMI: body mass index. *p<0.05.

intervention. The STE group also showed significant improvement in attention and calculation, a subitem of the MMSE. These results indicate that STE may be an effective program to maintain and improve cognitive function in older females.

During the STE, the participants had to remember the squares indicated by the instructor and touch them in turn or touch the felt with numbers on it in turn. These tasks were based on square-stepping exercise tasks that required memory and atten-

Table 2. Cognitive and upper extremity functions before and after the intervention

	Pre Mean ± SD	Post Mean ± SD	Interaction p	Group p	Time p
MMSE (scores)					
STE	25.1 ± 2.9	26.7 ± 3.3	0.007*	0.806	0.084
C	25.8 ± 3.6	25.4 ± 4.3			
TMT-A (sec)					
STE	94.7 ± 47.9	78.6 ± 39.5	0.492	0.409	0.045*
C	104.9 ± 59.1	96.8 ± 50.0			
TMT-B (sec)					
STE	135.1 ± 107.8	128.9 ± 66.4	0.381	0.365	0.159
C	176.6 ± 94.1	150.7 ± 86.7			
Grip strength (kg)					
STE	22.8 ± 3.9	22.8 ± 4.7	0.303	0.098	0.217
C	20.0 ± 3.8	20.7 ± 3.8			
Peg test with dominant hand (number of pegs)					
STE	23.8 ± 2.4	24.7 ± 2.8	0.876	0.396	0.037*
C	22.6 ± 5.7	23.4 ± 4.5			
Peg test with non-dominant hand (number of pegs)					
STE	20.1 ± 2.8	20.9 ± 2.1	0.814	0.574	0.063
C	19.6 ± 4.3	20.2 ± 3.8			

SD: standerd deviation; STE: squre-touch exercise group; C: control group; MMSE: mini-mental state examination; TMT-A: trail-making test part A; TMT-B: trail-making test part B.
*p<0.05.

Table 3. Cognitive functions before and after the intervention

	Pre Mean ± SD	Post Mean ± SD	Interaction p	Group p	Time p
Orientation (scores)					
STE	8.9 ± 1.4	9.3 ± 1.7	0.098	0.379	0.835
C	8.8 ± 1.4	8.4 ± 1.8			
Attention and Calculation (scores)					
STE	2.4 ± 1.6	3.2 ± 1.7	0.011*	0.820	0.165
C	3.1 ± 1.8	2.8 ± 1.8			
Registration (scores)					
STE	3.0 ± 0.0	3.0 ± 0.0	0.341	0.341	0.341
C	2.9 ± 0.3	3.0 ± 0.0			
Recall (scores)					
STE	2.4 ± 0.7	2.6 ± 0.5	0.353	0.898	0.624
C	2.6 ± 0.9	2.5 ± 0.9			
Language (scores)					
STE	8.5 ± 0.7	8.7 ± 0.6	0.749	0.786	0.173
C	8.6 ± 0.7	8.7 ± 0.6			

SD: standerd deviation; STE: squre-touch exercise group; C: control group.
*p<0.05.

tion functions[15, 17]. In addition, dual tasks were performed, such as a cognitive task and an upper extremity exercise, or a task that involved exercising the lower extremity simultaneously with the upper extremity. These factors may have contributed to the improvement of cognitive function in the STE group. Previous studies have also reported improvements in cognitive function with dual tasks[25]. The results of this present study are consistent with the findings of previous studies. The STE cognitive tasks also included calculation tasks (addition, subtraction, multiplication, division, and a combination of these tasks). Kawashima et al. reported that performing calculation and writing tasks activate the prefrontal cortex and is effective in maintaining and improving cognitive and memory abilities[26]. The STE inferred that the calculation task improved the cognitive function of the intervention group, particularly contributing to the maintenance and improvement of attention and computational functions. However, there were no significant differences in the results of the TMT-A and TMT-B between the STE and C groups. In the present study, because of the specificity of the exercise incorporating calculation tasks in the STE, it is possible that the TMT-A and TMT-B, which comprehensively assess executive and attentional functions, did not improve, and only the attention and calculation subitem of the MMSE improved. In future studies, interventions using different cognitive function assessment indices should be considered.

A main effect of time was found in the peg test with the dominant hand in the assessment of upper-extremity function, but there were no differences between the groups. There were also no significant differences between the groups in the peg test performed with the non-dominant hand. Since STE is an upper extremity exercise that requires the designated squares to be accurately touched, we expected an improvement in upper extremity dexterity in the STE group, but there was no significant improvement. To improve cognitive function, the STE included many tasks that require short-term memory, attention function, and dual tasks. Therefore, there was likely insufficient exercise to improve upper-extremity motor function and dexterity. In the future, it will be necessary to adjust the content, intensity, and difficulty of the exercises to promote these aspects and ensure that a program to improve not only cognitive function but also upper extremity motor function and dexterity is established. Moreover, aside from STE, programs that combine STE with strength or stretching exercises that can be performed in a seated position may be effective. The STE program developed in this study was performed in a chair-sitting position, which is advantageous for ensuring the safety of the participant, compared with standing. By preparing several mats for STE, the program can be performed in a group. Thus, STE can be utilized for exercise and recreation in senior citizen facilities where many frail older people live. In the future, to promote the use of STE in the community, instruction manuals with detailed program content to enable facility staff and those engaged in exercise instruction to teach STE, should be developed.

One limitation of this study was that only female participants were included. To clarify the effect of STE on the older population, it is necessary to include both males and females in the study. Second, the assignment of the STE and C groups in this study was based on regions and random assignment was not possible. The possibility that regional characteristics may affect cognitive function in older adults cannot be denied. In addition, this study did not include older adults certified as requiring nursing care, it is necessary to examine the effects of STE on frail older adults in future investigations.

In conclusion, this study examined the effects of a 3-month STE program on the cognitive and upper extremity functions of older females. Our results suggest that STE is effective for maintaining and improving cognitive function in older females.

Funding and Conflict of interest

None.

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