THE EFFECT OF SQUARE STEPPING EXERCISES TRAINING ON LOWER EXTREMITY MOTOR PERFORMANCE, MUSCLE STRENGTH, AND MUSCLE QUALITY IN HEALTHY YOUNG PEOPLE: A SINGLE-BLIND, RANDOMIZED, CONTROLLED CLINICAL TRIAL

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Original scientific paper
DOI: 10.26582/k.57.1.4

Abstract:

The square stepping exercise (SSE), which is a new type of aerobic exercise, is preferred for various purposes. This study attempted to explore the effect of SSE training on lower-extremity motor performance, muscle strength, and muscle quality in healthy young individuals. Participants were 120 healthy young individuals aged between 20-25 years, who were randomly divided into two groups as the treatment group, which received SSE training (Group 1; n=60) and control group (Group 2; n=60). The participants' lower-extremity motor performance was analyzed through vertical jumping, side jumping, one leg squat, and step-up tests, whereas their muscle strength was analyzed through a hand-held dynamometer and their muscle quality was analyzed through Muscle Quality Index. The SSE was employed to the treatment group in 12 sessions, four days a week for three weeks and each session lasted 45 minutes. The control group did not receive any treatment and only evaluation was implemented. A significant improvement was observed in lower-extremity motor performance ($p<.001$), muscle strength of quadriceps femoris muscle ($p<.001$), and muscle quality ($p<.001$) in Group 1 in the post-training evaluations. This study revealed a significant improvement in favor of Group 1 in side jumping ($p<.001$), one leg squat ($p<.001$), step-up test ($p<.001$), quadriceps femoris muscle strength ($p<.001$), and muscle quality ($p<.001$). However, no significant change was observed between the groups in the vertical jumping test ($p=.099$). The results showed the effect of SSE training on the lower-extremity motor performance, muscle strength, and muscle quality of healthy young individuals.

Keywords**:** *square-stepping exercise, healthy young individuals, motor performance, muscle strength, muscle quality*

Introduction

Physical activity (PA) is defined as activities including energy expenditure through using muscles and joints in daily life, increasing heart and respiratory rate, performed at different intensities, and resulting in fatigue (Dhuli, et al., 2022). Failure to regularly perform PA at a sufficient level causes many health problems. Therefore, regular PA is among the most important recommendations of national and international public health guidelines to increase an active lifestyle. The American Association of Sports Medicine (AASM) and the American Dietetic Association guidelines recommended exercise five days a week and at least 30 minutes of moderate-intensity activity a day to adults (Piercy, et al., 2018). Regular PA is known to have positive effects on physical and mental health (Guo & Jiang, 2023). Regular PA is also found to maintain and increase muscle strength and joint mobility, to improve movement skills, to maintain and increase muscle and joint flexibility, to reduce fatigue, and to improve reflex and reaction time (Gualdi-Russo & Zaccagni, 2021). Additionally, it has psychological effects such as feeling well and happy, thinking positively, and improving the ability to cope with stress (Stanton, Happell, & Reaburn, 2014). Today, exercises such as brisk walking, jogging, cycling, swimming, aerobic dance, rowing, and skating are defined as aerobic exercises through which these benefits can be achieved (Erkkola, Vasankari, & Erkkola, 2021).

Aerobic exercise is a type of exercise that increases breathing rate by using large muscle groups regularly and at the same tempo, with 60-80% of the maximum number of heartbeats for a period of 15-20 minutes or longer. AASM defines aerobic exercise as a natural rhythm that can be maintained continuously in every activity in which large muscle groups are used (Li, Liu, Deng, & Wang, 2024). Fast, entertaining and various physical activities with music and rhythm make exercise enjoyable and long-term. Revealing different formats of aerobic exercises, which have induced great interest, also increases participation in these types of exercise (Sevinç & Tetik, 2018). The literature shows the effect of exercise training programs on healthy individuals and different disease groups in all periods of life (Chang, Wang, Chen, & Hu, 2017; Fisseha, Janakiraman, Yitayeh, & Ravichandran, 2017; Shigematsu, et al., 2008a; Shigematsu, Okura, Sakai, & Rantanen, 2008b; Teixeira, et al., 2013). Regularly performed aerobic exercises are found to have crucial health benefits. Aerobic exercises have a positive effect on health, coordination, body-fat ratio, muscle quality, muscle strength, flexibility, and endurance (On, Yıldız & Dündar, 2020; Yıldırım & Bozkuş, 2020; Unal, Altug, Tıkaç, & Altug, 2023).

Square-stepping exercises (SSE), developed by Shigematsu and Okura in 2006, is also a type of aerobic exercise that has positive effects on improving lower-extremity motor functions (Shigematsu & Okura, 2006). The literature reveals that SSE is employed for many purposes such as physical fitness, functionality, improvement of cognitive functions as well as for exemining its impact on the treatment of various diseases. This study investigates the effectiveness of square-stepping exercise training on lower-extremity motor performance, muscle strength, and muscle quality in healthy young people.

Methods

The study protocol was approved by the Pamukkale University Non-Invasive Clinical Research Medical Ethics Committee with the board decision dated June 11, 2019, and numbered 11. The clinical trial number of the study is NCT04910035.

Participants

The study was conducted between September 2019 and May 2020 in the Pamukkale University, Faculty of Physiotherapy and Rehabilitation, Department of Neurological Rehabilitation. One hundred and twenty participants, aged between 20-25 years, studying at the Pamukkale University, Faculty of Physiotherapy and Rehabilitation participated in the study.

The study was conducted with the participation of volunteers who met the inclusion criteria among the ones studying at Pamukkale University, Faculty of Physical Therapy and Rehabilitation. All volunteers were informed about the study and granted their written consent.

The participants were divided into two groups through block randomization in SPSS. A total of 12 sessions of SSE training were applied to the treatment group (Group 1, n=60) four days a week for three weeks and each session lasted 45 minutes. No exercise training was provided for the control group (Group 2, n=60).

Inclusion criteria

Treatment and control group:

- 20-25 years of age
- Not attending any exercise program for the last one year
- Not having a neurological, orthopedic disease or any disease affecting lower extremity functioning
- Having had no lower-extremity surgery
- No vision and/or hearing issues.

Exclusion criteria (before the study)

Treatment and control group:

- Having a vision and/or hearing problem
- Having neurological, psychiatric, and/or orthopedic problems that affect walking
- Having had lower-extremity surgery.

Exclusion criteria (during the study)

Participants who developed any pathology of the lower-extremity (sprain, fracture or development of a disease that might affect the lower extremity) during the training or evaluation weeks, those who in less than 75% of the exercise program, who were unable to complete the tests or unwilling to continue exercising at any stage of the study, and ones who joined any other aerobic exercise program were excluded from the study.

Outcome measures

The participants' demographic information was recorded in the registration form. Vertical jumping, side jumping, one-leg squat, and step-up tests were employed to identify the participants' levels of motor performance. The quadriceps muscle strength was identified through the hand-held dynamometer. Also, the Muscle Quality Index (MQI) was employed to determine the muscle quality of participants. All evaluation methods were applied to all

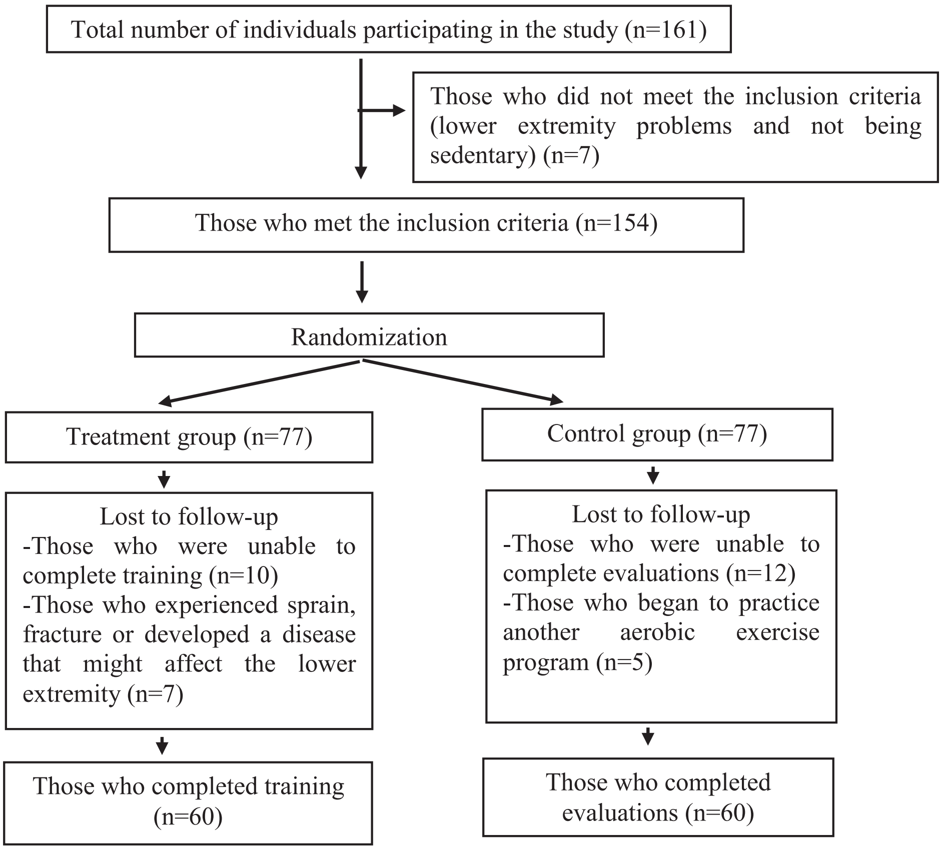

Figure 1. Flowchart of the study.

participants in Group 1 and Group 2 by a blinded physiotherapist in the pre and post 3-week training period.

Motor performance

Vertical jumping test. The vertical jumping test calculates the lower-extremity muscular workforce. Vertical jumping was first defined by Sargent in 1921. Participants stood sideways next to the measuring paper on the wall so that their dominant extremity would be on the measurement paper and touched the last point they could reach with their middle finger through bringing the dominant arm to 180 degrees of flexion and elbow extension. The participants then jumped up as high as they could by bringing their knees to a slight flexion and to mark again the last point they could reach. The distance between the two points determined was measured and recorded in centimeters. The test was repeated three times, and the best value was recorded (Anderson, et al., 1991; Östenberg, Roos, Ekdahll, & Roos, 1998; Reiman & Manske, 2009).

Side-jumping test. The side-jumping test is a valid and reliable test utilized to evaluate agility in aerobic work regimen. The test aims to evaluate individuals' lateral mobility. The individual's location was numbered as 1 at the beginning of the test; 75 cm apart the individual to the right and left were numbers 2 and 3. Along with the start command, the individual was required to complete a cycle by jumping first from number 1 to 2, from 2 to 1, then to 3 and again to number 1 (1→2, 2→1, 1→3, 3→1). The maximum number of cycles she/he managed to do in 20 seconds (s) was recorded as the participant's score (Safrit & Wood, 1995).

One-leg squat test. The one-leg squat test measures the extensor muscle strength of the extremity. Participants squatted on one leg and stood up repeatedly without touching the ground with their non-tested foot. The test was terminated when the individual became fatigued or if the non-tested foot touched the ground. The same measurement was repeated for the other leg. The results were recorded separately for each leg (Safrit & Wood, 1995).

Step-up test. The step-up test is a functional test that measures the lower-extremity muscle strength. Individuals stepped up and off the 45 cm high step using the same foot. Individuals first placed one foot on the step, climbed up, and then lowered the same foot to step down. Participants were instructed to continue the test until they became fatigued, and the number of repetitions was recorded. The dominant and non-dominant sides were evaluated separately (Von Bothmer & Fridlung, 2005).

Muscle strength

Analysis of muscle strength started with positioning the participant's hip at the edge of the bed and with the flexed at 90°. Participants brought their knees to full extension by performing a maximum voluntary contraction. Hand-held dynamometer (HHD) was placed in the distal part of the leg and resistance was provided. The participant was then required to hold this position for 4-5 seconds. The test was repeated three times and the highest power observed on the digital display was recorded in newtons (Bohannon, 2005; O'Sullivan, Schmitz, & Fulk, 2019). HHD's reliability has been proven (Martin, et al., 2006).

Muscle quality

Muscle quality was determined through Muscle Quality Index (MQI), which is a valid and reliable method developed by Takai et al. (2009). The MQI measures the duration of five repetitions of sit-to-stand test in seconds (s). MQI is calculated by measuring the 5-repetition sit-to-go test duration (s), body weight (kg), and leg length (L-m). In the calculation, the formula

$$(L-0.5)*5*weight*g/5$$

repetitions sit-to-stand test duration was employed.

To calculate length of the leg, individuals sit on the chair with the hip and knee flexed at 90 degrees and the feet in full contact with the floor. Thigh-length and knee height were added and recorded. Thigh-length is the length from the midpoint of the inguinal line to the midline of the patella along the midline of the thigh. Knee height is the distance from the lateral condyle of the femur to the heel. Body weight was recorded in kg by measuring the participant's weight without shoes. The expression g used in the calculation indicated the gravitational acceleration and was taken as $g = 9.8\ m/s^2$ in the measurement. For the 5-repetition sit-to-stand test, the time from the sitting position to return to the sitting position five times was recorded. Hands-on help was not allowed in the sit-to-stand test (Takai, et al., 2009).

Square-stepping exercise (SSE) protocol

The SSE is an aerobic exercise developed by Shigematsu and Okura in 2006 based on the fall mechanism for the elderly and ladder exercises for athletes (Shigematsu & Okura, 2006). Permission was obtained from Shigematsu for the exercise application, and the exercises to be performed were determined. Participants were introduced to certain step patterns and then repeated the same step pattern until they reached the end of the exercise mat. The pattern was repeated until all participants performed the pattern without errors (3-5 repetitions). After the pattern was performed, a mirror-image pattern of the same pattern was also performed. Examples of exercises are shown in Figure 2. Basically, a pattern was repeated 3-5 times and then the mirror-image pattern was repeated the same number of times. However, when participants had difficulty in applying the pattern, it was repeated until they learned it. Exercise training was performed by groups of 8-10 individuals and movement patterns were introduced by a physiotherapist. Participants executed the pattern introduced on the exercise mat, and they took turns at the head of the mat when they reached the end of the mat. (Shigematsu & Okura, 2006). In the study, SSE was applied four days a week for three weeks (a total of 12 sessions) and each session lasted 45 minutes.

Statistical analysis

The data were analyzed with SPSS Statistics 21.0 package program. Continuous variables were reported as mean ± standard deviation (Mean ± SD), and categorical variables as number (n) and percentage (%). The Kolmogorov-Smirnov test was employed to identify whether the data were distributed normally (Tabachnick & Fidell, 2013). When parametric test assumptions were provided, independent t-test for comparing differences between independent samples was used; when parametric test assumptions were not provided, the Mann-Whitney U-test was employed to compare independent group differences. In dependent group comparisons, the paired-sample t-test for parametric test assumptions and the Wilcoxon test for non-providing parametric test assumptions were utilized. A value of $p<.05$ was regarded as the level of significance. Cohen (d) calculation was applied to determine the effect size. In that regard, $d \geq 1$ was considered a very large effect, $1>d\geq 0.8$ a large effect, $0.8>d\geq 0.5$ a moderate effect, and $0.5>d\geq 0.2$ a small effect (Cohen, 1988).

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8	4	3	7
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6	2	1	5
8	4	3	7
6	2	1	5
8	4	3	7
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8	4	3	7
6	2	1	5

Figure 2. Square stepping exercise example steps.

Results

The 120 healthy young individuals were randomly divided into two groups. The treatment group (Group 1) included 60 individuals, 35 (58.3%) of which were female and 25 (41.7%) were male. The control group (Group 2) included 60 individuals, 35 (58.3%) of which were female and 25 (41.7%) were male. The demographic data of the groups are provided in Table 1. No statistically significant difference between the groups was observed in terms of demographic data (p>.05).

The motor performance levels of Group 1 and Group 2 showed no statistical difference in the pre-test (p>.05). All motor performance levels of Group 1 in the pre- and post-test showed a statistically significant difference, but a statistically significant difference was observed only in the one-leg squat-left leg value in Group 2 (p<.05). The comparisons of two groups' motor performance in the post-test revealed a significant difference in favor of Group 1 (p=.0001) in all motor performance parameters. The comparison of lower-extremity motor performance values within and between the groups is presented in Table 2.

The analysis of the muscular force of the groups in the pre-test showed no statistically significant

Table 1. Comparison of the demographic data of the groups

Variables	Group 1 (n=60) Mean±SD	Group 2 (n=60) Mean±SD	t/z	p
Age (year)	21.93±1.33	22.08±1.16	-0.654*	.514
Height (cm)	170.30±8.27	169.63±7.96	0.450*	.654
Body weight (kg)	67.53±13.09	64.18±12.75	1.420*	.158
BMI (kg/m²)	23.34±4.69	22.13±3.17	-1.483**	.138

Note. Group 1: exercise group, Group 2: control group, n: number of individuals, SD: standard deviation, cm: centimeter, kg: kilogram, kg / m²: kilogram / square meter, BMI: body mass index, t: independent groups t-test, z: Mann-Whitney U-test, * independent groups t-test, ** Mann Whitney U-test.

Table 2. Comparison of motor performance levels within and between the groups

Motor performance values	Pre-training Mean±SD	Post-training Mean±SD	p^2
Vertical jumping			
Group 1	29.28±8.20	33.46±8.35	.0001†
Group 2	30.46±7.92	31.26±6.55	.099†
p^1	0.423*	0.0001**	
Side jumping			
Group 1	5.98±1.34	7.65±1.19	.0001†
Group 2	6.40±1.42	6.61±1.16	.127†
p^1	0.102*	0.0001*	
One leg squat – right leg			
Group 1	39.65±29.32	73.16±51.21	.0001†
Group 2	35.40±26.95	37.35±31.05	.422†
p^1	0.410*	0.0001**	
One leg squat – left leg			
Group 1	41.61±38.44	85.13±98.98	.0001††
Group 2	32.93±25.99	35.86±26.23	.041††
p^1	0.330**	0.0001**	
Step up – right leg			
Group 1	41.11±19.14	62.16±55.48	.002†
Group 2	34.98±18.87	32.38±12.71	.166†
p^1	0.800*	0.0001**	
Step up – left leg			
Group 1	35.93±18.88	48.93±27.19	.0001††
Group 2	29.46±12.43	28.91±10.98	.825††
p^1	0.055**	0.0001**	

Note. Group 1: exercise group, Group 2: control group, * independent groups t-test, ** Mann Whitney U-test, † dependent groups t-test, †† Wilcoxon test, p^1: significance between the groups, p^2: intragroup significance level.

Table 3. Comparison of muscle strength within and between the groups

Muscle strenght	Pre-training Mean±SD	Post-training Mean±SD	p^2
Quadriceps femoris – right leg			
Group 1	147.26±42.85	196.75±49.82	0.0001†
Group 2	156.91±68.11	167.82±64.58	0.025†
p^1	0.355*	0.0001*	
Quadriceps femoris – left leg			
Group 1	133.80±48.46	180.02±53.14	0.0001†
Group 2	152.28±70.28	156.89±69.41	0.258†
p^1	0.096*	0.0001*	

Note. Group 1: exercise group, Group 2: control group, * independent groups t-test, † dependent groups t-test, p^1: significance level between the groups, p^2: significance level within the group.

Table 4. Comparison of muscle quality within and between the groups

Muscle quality	Pre-training Mean±SD	Post-training Mean±SD	p^2
Group 1	44127.62±14115.01	54129.99±15217.68	0.0001††
Group 2	42555.87±18358.73	40739.84±14744.86	0.131††
p^1	0.223**	0.0001*	

Note. Group 1: exercise group, Group 2: control group, * independent groups t-test, ** Mann Whitney U-test, †† Wilcoxon test, p^1: significance between the groups, p^2: intragroup significance level.

Table 5. Examining the success rates of the applied training

Variables	Group 1		Group 2	
	Success rate (%)	Cohen's d	Success rate (%)	Cohen's d
Motor performance				
Vertical jumping	16	1.11	5	0.21
Side jumping	31	1.60	6	0.20
One leg squat – right leg	161	0.83	19	0.10
One leg squat – left leg	142	0.58	48	0.17
Step up – right leg	52	0.42	1	0.18
Step up – left leg	45	0.75	26	0.05
Muscle strenght				
Qf right leg	37	1.52	14	0.29
Qf left leg	40	1.34	6	0.14
Muscle quality				
MQI	25	1.13	-1	0.24

Note. Group 1: exercise group, Group 2: control group, QF: quadriceps femoris, MQI: muscle quality index, Cohen's d: effect size.

difference ($p>.05$). The comparison of muscle strength in pre- and post-test revealed an increase in quadriceps femoris muscle strength of both legs in Group 1, but a statistically significant difference was observed in only the right-leg quadriceps femoris in Group 2 ($p<.05$). The comparisons of the muscle strength between the groups in the post-test revealed a statistically significant difference in favor of the treatment group ($p=.0001$).

The analysis of the groups' muscle quality in the pre-test showed no statistically significant difference between the groups ($p>.05$). A statistically significant difference was observed in only the treatment group when comparing the groups' muscle quality in the pre- and post-test ($p<.05$). The comparisons of muscle quality between the groups in the post-test revealed a statistically significant difference in favor of the treatment group ($p=.0001$).

The analysis of the effectiveness of SSE training in regard to motor performance revealed an improvement of 161% in one-leg squat – right leg value and 142% in one-leg squat – left leg value, 52% in step-up – right leg value and 45% in step-up – left leg value. Also, an improvement of 31% in the side jumping and 16% in the vertical jumping value was observed. The analysis of the effect level of SSE training in terms of motor performance showed a very large effect (d≥1) on vertical jumping and side jumping, a large effect (1>d≥0.8) on one-leg squat – right leg (1>d≥0.8), a moderate effect (0.8>d≥0.5) on one-leg squat – left leg and step-up – left leg, and a small effect (0.5>d≥0.2) on step-up – right leg in Group 1. On the other hand, a small effect (0.5>d≥0.2) was observed on all parameters in Group 2. The analysis of the effectiveness of SSE training in regard to quadriceps femoris muscle strength showed left-leg quadriceps femoris muscle strength increased by 40% and left-leg quadriceps femoris muscle strength increased by 37% in Group 1. The analysis of the effect level of SSE training in terms of quadriceps femoris muscle strength in Group 1 showed a very large effect (1>d≥0.8) on the right- and left-leg quadriceps femoris muscle strength. A small effect (0.5>d≥0.2) was noticed on the quadriceps femoris muscle strength in Group 2. The analysis of the effectiveness of SSE training in terms of muscle quality revealed a 25% increase in muscle quality level in Group 1. The analysis of the effect level of SSE training in terms of muscle quality showed a large effect (1>d≥0.8) of the training in Group 1. However, a small effect (0.5>d≥0.2) was observed on the muscle quality level in Group 2. The within-group efficiency and success rate of the training are presented in Table 5.

Discussion and conclusions

This study analyzed the effect of SSE on the lower-extremity motor performance, muscle quality, and muscle strength in healthy sedentary young individuals. In that regard, the study revealed a significant increase in the lower-extremity motor performance, muscle strength, and muscle quality in the treatment group. However, the control group was found to increase the performance of the one-leg squat – left leg and quadriceps femoris muscle strength – right leg.

The literature showed the positive effect of exercises with sufficient intensity, volume, and duration in various studies (Chan, et al., 2018; Zhou, Li, & Jiang, 2024). Also, the literature includes many studies reporting better values of individuals who do exercises than sedentary individuals in regard to physical fitness parameters such as balance and coordination, flexibility, endurance, and agility (Aslan, Eyuboğlu, & Koç, 2016; Chan, et al., 2018).

Along with the studies on the effect of aerobic exercise, studies on physical fitness factors such as general health, balance and coordination, flexibility and endurance, agility, body-fat ratio, muscle quality, and muscle strength take a large place in the literature (Li, et al., 2024; On, et al., 2020; Unal, Altug, Tıkac, & Altug, 2023; Yıldırım & Bozkuş, 2020). In a study with 60 females, aged 18-25, Saygın, Oktay, and Ceylan (2016) investigated participants' flexibility, aerobic fitness, muscular force and endurance, body composition, blood pressure (systolic, diastolic), and resting pulse. In that regard, an 8-week aerobics-based exercise was found to have a positive effect on flexibility, aerobic fitness, muscle strength and endurance, and body composition, but was found to not have a significant effect on blood pressure and resting pulse. Similar results were also observed in other studies (Li, et al., 2024; On, et al., 2020). In that similar vein, aerobic exercises were found to have a positive impact on motor performance, muscle strength, and muscle quality in the current study.

The literature also showed several studies on the effectiveness of SSE in geriatric age groups for various purposes. In that regard, studies focused more on ensuring physical fitness such as eliminating the problems of balance and falling, increasing strength, improving walking, increasing flexibility and speed of movement (Chang, et al., 2017; Fisseha, et al., 2017; Shigematsu, et al., 2008a, 2008b; Teixeira, et al., 2013). Investigating agility, flexibility, movement speed, leg strength, and balance parameters of 56 participants, whose age range was from 60 to 80, Shigematsu and Okura (2006) found significant changes in the participants who received SSE training. In that similar vein, the current study found a significant increase in agility, muscle strength, muscle strength in the lower-extremity motor performance, and muscle quality in favor of the SSE-training group.

In another study by Shigematsu et al. (2008a), 39 participants, aged 65-74 years, received SSE or strength-balance training. The analysis of particiipants' agility, flexibility, movement speed, leg strength, balance, and incidence of falling revealed SSE was as effective as strength-balance training on those parameters. Similar results were also noticed in other studies (Shigematsu, et al., 2008b; Teixeira, et al., 2013).

Combining SSE with a pedometer, Jindo et al. (2016) investigated 68 participants over 65 years of age in terms of the one-leg balance test, 5-repetition sit-to-stand test, timed up-and-go test, the performance of 5-m habitual walk, and timed reaction with their eyes open. The results indicated the benefits of SSE in terms of increasing the lower-extremity physical function of the participants who wore pedometer in addition to exercise.

Investigating the functional fitness of 102 individuals over 65 years of age, such as aerobic endurance, leg strength, flexibility, reaction time, static balance, and mobility, Chang et al. (2017) found positive improvements in aerobic endurance, leg muscle strength, and static balance in all groups; however, no significant difference was observed between the groups. Also, in mobility, SSE or ball games applied in addition to aerobic exercise were found to show a significant improvement compared to those who performed only aerobic exercise (Chang, et al., 2017).

The unexpected increase in one-leg squat performance (left leg) and quadriceps femoris muscle strength (right leg) in the control group, despite not receiving any training, may be attributed to several potential factors. Participants in the control group underwent baseline and post-test assessments. Repeated exposure to the testing procedures, especially for motor tasks like the one-leg squat test, could have led to performance improvements due to familiarization rather than actual physiological adaptation. Even though the control group did not participate in the SSE program, incidental physical activity in their daily lives (e.g., walking, stair climbing, standing up from a seated position) might have contributed to subtle neuromuscular adaptations, particularly in weight-bearing lower extremity muscles. Knowing they were part of a study, participants in the control group might have unconsciously exerted greater effort during post-testing compared to their initial performance. This could explain the improvements in the specific strength measures recorded.

The results of this study revealed the positive impact of SSE applied four days a week for three weeks on the lower-extremity motor performance, muscle strength, and muscle quality in healthy sedentary young individuals. The evaluation methods validated in the literature and implemented in objective ways, and study of healthy young individuals unlike the participant profiles in the literature are regarded as the significances of this study. Through developing a new point of view for SSE to be a new type of aerobic exercise that can be employed for the lower extremity, the widespread implementation of SSE was targeted in this study. However, not being conducted with different disease and age groups of participants, not being combined with different treatment methods, not keeping the exercise duration longer can be among the limitations of the study. Therefore, this study suggests the following studies to investigate SSE with different disease and age groups, integrate different treatment methods, make comparisons, and keep the exercise period longer.

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Submitted: October 21, 2022
Accepted: July 11, 2023
Published Online First: May 14, 2025

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