**Effects of Modified Square-Stepping Exercise on Heart Rate Variability and Body Fat in the Elderly**

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**ABSTRACT**

Sawasdee C, Auvichayapat P, Punjaruk W, Leelayuwat N, Tunkamnerdthai O. Effects of Modified Square-Stepping Exercise on Heart Rate Variability and Body Fat in the Elderly. JEPonline 2020;23(6):41-52. The purpose of this study was to evaluate the effects of modified square-stepping exercise (MSSE) training on heart rate variability (HRV) and body fat in the elderly. Forty-three older subjects were each randomly allocated to either the Training Group (TG) (n = 22) or the Control Group (CG) (n = 21). Subjects in the TG performed MSSE for 30 min·d⁻¹, 3 d·wk⁻¹ for 12 wks; whereas, the subjects in the CG had no exercise intervention. Outcome variables of HRV and body fat were assessed before and after the study period. None of the parameters differed significantly between the two groups at baseline and there was no statistical change in the CG after the study period. After undergoing training, the TG showed significant decrease in biceps, triceps, subcapular, and suprailiac skinfold thickness (P<0.05). In addition, triceps, subcapular, and suprailiac skinfold thickness that had changed in the TG also differed significantly from those in the CG (P<0.05), except for biceps skinfold thickness. However, variables of HRV in time and frequency domains did not change significantly after the intervention nor did they differ significantly between the two groups. These results indicate that the MSSE training decreases body fat in the elderly.

**Key Words:** Body Composition, Cardiac Autonomic Activity, Low-Intensity Exercise Training
INTRODUCTION

The number of older people is growing around the world. The elder population in the world is projected to grow to about 1.4 billion people in 2030 and 2 billion in 2050 and reach 3.1 billion in 2100 (31). Furthermore, the number of the elderly in Thailand is growing continuously due to low birth rate and longer life expectancy. Thailand is also speculated to be complete aged society, accounting for 20% of the total population in 2021 and super aged society, accounting for 28% of the total population in 2031 (5). The ageing process causes physiological changes in many organs.

The autonomic nervous system is essential for functional modulation of visceral organs including the heart. Ageing is also associated with changes in the autonomic function (17). Cardiac autonomic dysfunction, characterized by increased sympathetic activity and reduced parasympathetic tone, has been reported in the elderly leading to a decrease in heart rate variability (HRV) (4,8,18), which is association with cardiovascular risk factor such as low physical activity and hypertension (24,27,28). Moreover, body fat is a risk factor of cardiovascular diseases leading to morbidity and mortality in older people (32). In addition, there are changes in body composition that lead to an increase in body fat and a decrease in lean mass and bone density when getting older (9). Therefore, an improvement of HRV and body fat may reduce the risk factors for cardiovascular disease in the elderly.

Several previous studies have shown the beneficial effect of exercise training and breathing exercise in older people. Exercise training improves body fat, functional fitness, and HRV in the elderly (2,6,21). In addition, pursed-lip breathing (PLB), which is a kind of breathing exercise, is commonly used in pulmonary rehabilitation program for chronic obstructive pulmonary disease (COPD) to alleviate and control dyspnea in COPD patients (15). It may also help to reduce dyspnea in older subjects (10). Moreover, Ramos et al. (20) reported that PLB promoted an increase in parasympathetic activity, which influenced the autonomic cardiac modulation in middle and older people with COPD. Therefore, exercise training consisting of physical activity and breathing exercise like PLB may also improve cardiac autonomic function and body fat in the elderly.

Square-stepping exercise (SSE) is an exercise training program that the subject walks on a mat with a length of 250 cm and a width of 100 cm, which is separated into 40 small squares. It could improve lower-extremity functional fitness to protect against the risk of falling in the elderly (26). Although exercise training like SSE could improve functional fitness in the elderly, autonomic dysfunction and increased body fat in the elderly are also important problems leading to an increase in the risk of chronic cardiovascular disease. Therefore, a combination of exercise and PLB may help to improve HRV and body fat. In fact, a previous study indicated that a modified arm swing exercise and PLB could improve HRV in middle age and older subjects with COPD (30). However, there has been no study to investigate about modified square-stepping exercise (MSSE), which is SSE combining with PLB in the elderly. Thus, this is the first study to determine the effect of MSSE training on cardiac autonomic function and body fat in the elderly. We hypothesized that the MSSE training could improve cardiac autonomic activity and body fat in older subjects.
METHODS

Subjects
The subjects were all elderly participants. They were recruited from Khon Kaen province in Thailand. The inclusion criteria were the following: 65 yrs of age or older who were not engaged in regular exercise (<3 times·wk⁻¹ and <30 min·d⁻¹). The exclusion criteria included hypertension, congestive heart failure, angina pectoris, third degree A-V block, uncontrolled diabetes mellitus, and presence of orthopedic or neuromuscular conditions interfering with the ability to perform the MSSE. Written informed consent forms were obtained from all subjects. This study was approved by the Khon Kaen University Ethics Committee for Human Research in accordance with the Declaration of Helsinki and the ICH Good Clinical Practice Guidelines (HE621459).

Study Design
This study was a randomized control trial. It was performed in a research laboratory room at Khon Kaen University, Faculty of Medicine, Thailand.

Experimental Design and Protocol
All subjects received the screening tests before participating in this study, which included an assessment of their medical history, anthropometric assessment, electrocardiography, physiological measurement (respiratory rate, heart rate, and blood pressure), and physical examination. After passing the screening tests, all subjects were instructed to carry out the MSSE 30 min·d⁻¹, 3 d·wk⁻¹ for 12 wks. Subjects in the CG were asked to continue with their usual physical activities during the study period. A researcher supervised the MSSE in the TG according to the intervention protocol.

The MSSE consisted of 4 Sessions. During Session 1, the subjects were instructed to walk starting with right leg on the mat to forward step with both arms swinging forward until reaching ear level and breathed in through their noses. Then, they breathed out slowly through pursed-lip during both arms moving down (Figure 1a). The subjects performed 10 steps-set⁻¹ and 5 sets-session⁻¹. They also performed Session 1 before each Session. During Session 2, the subjects were instructed to walk on the mat to lateral step as shown in Figure 1b for 40 steps-set⁻¹ and 5 sets-session⁻¹. During Session 3, the subjects were instructed to walk on the mat to lateral and forward step as shown in Figure 1c for 40 steps-set⁻¹ and 5 sets-session⁻¹. During Session 4, the subjects were instructed to walk on the mat to forward, backward, lateral, and oblique step as shown in Figure 1d for 40 steps-set⁻¹ and 5 sets-session⁻¹. HRV and body fat were measured in both groups before and after the 12-wk study period.
Outcome Measurements

Heart Rate Variability
The subjects’ HRV was measured in a quiet room with air temperature and humidity that ranged from 25 to 27°C and 48 to 65%, respectively. All subjects were instructed to avoid stimulant drinks such as tea or coffee. They were also requested to breathe regularly and as smoothly as possible in the sitting position after resting for 30 min. HRV was measured for 5 min by using SA-3000P® (Medicore Inc., Seoul, Korea). Variables of HRV in the time domain consisted of standard deviation of all normal-to-normal intervals (SDNN) and square root of the mean squared differences of successive normal-to-normal intervals (rMSSD). Parameters of HRV in the frequency domain consisted of total power (TP), very low frequency (VLF), low frequency (LF), high frequency (HF), and LF/HF ratio.

Body Fat
The subjects’ biceps, triceps, subscapular, and suprailiac skinfold thickness were measured using a skinfold caliper. The skinfold thickness was measured on the right-hand side of the body by pitching with the thumb and index fingers at the front side of middle upper arm for biceps skinfold thickness, at the back side of middle upper arm for triceps skinfold thickness with the arm by the side of the body. In addition, subscapular skinfold thickness was measured under the shoulder blade and suprailiac skinfold thickness was performed above the iliac crest.
Statistical Analyses

The data were analyzed using the SPSS software package version 19.0. The results were expressed as mean ± standard deviation (SD). The normal distribution of all data that were analyzed was done using the Kolmogorov-Smirnov test. The dependent samples t-test was used to compare differences in variables with paired samples. The independent samples t-test was used to evaluate inter-group changes in parameters at baseline. The analysis of covariance (ANCOVA) was used to detect differences in parameters between the two groups after the study period. A value of P<0.05 was considered statistically significant.

RESULTS

Subject Characteristics

A total of 43 older subjects were recruited for this study. They were randomized into either the CG or the TG. At baseline, there were no significant differences between the two groups in anthropometry and physiological characteristic (Table 1).

Table 1. Baseline Characteristics of Subjects.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>CG (n = 21)</th>
<th>TG (n = 22)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>68.95 ± 4.13</td>
<td>69.59 ± 4.35</td>
<td>0.501</td>
</tr>
<tr>
<td>Sex (male/female)</td>
<td>4/21</td>
<td>1/22</td>
<td>0.185</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>62.14 ± 12.37</td>
<td>61.32 ± 8.94</td>
<td>0.803</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>154.43 ± 7.97</td>
<td>154.59 ± 6.43</td>
<td>0.606</td>
</tr>
<tr>
<td>BMI (kg·m⁻²)</td>
<td>25.97 ± 4.15</td>
<td>25.69 ± 3.71</td>
<td>0.816</td>
</tr>
<tr>
<td>RR (breaths·min⁻¹)</td>
<td>18.47 ± 1.86</td>
<td>18.09 ± 2.09</td>
<td>0.416</td>
</tr>
<tr>
<td>PR (beats·min⁻¹)</td>
<td>71.57 ± 9.43</td>
<td>75.04 ± 13.82</td>
<td>0.408</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>127.29 ± 11.23</td>
<td>125.41 ± 10.65</td>
<td>0.577</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>71.57 ± 11.01</td>
<td>68.40 ± 10.81</td>
<td>0.408</td>
</tr>
<tr>
<td>MAP (mmHg)</td>
<td>89.76 ± 10.04</td>
<td>87.41 ± 9.97</td>
<td>0.445</td>
</tr>
</tbody>
</table>

Data are expressed as mean ± SD. CG = Control Group; TG = Training Group; BMI = Body Mass Index; RR = Respiratory Rate; PR = Pulse Rate; SBP = Systolic Blood Pressure; DBP = Diastolic Blood Pressure; MAP = Mean Arterial Pressure.
Heart Rate Variability
All data of HRV are shown in Table 2. Baseline variables of HRV did not differ significantly between the two groups. The subjects did not show changes in SDNN, rMSSD, TP, VLF, LF, HF, and LF/HF, regardless of whether or not they underwent the training intervention.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>CG (n = 21)</th>
<th>TG (n = 22)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>SDNN (ms)</td>
<td>29.90 ± 14.41</td>
<td>28.65 ± 10.31</td>
</tr>
<tr>
<td>rMSSD (ms)</td>
<td>24.79 ± 11.48</td>
<td>25.19 ± 11.18</td>
</tr>
<tr>
<td>TP (ms²)</td>
<td>5.95 ± 0.89</td>
<td>6.08 ± 1.00</td>
</tr>
<tr>
<td>VLF (ms²)</td>
<td>5.18 ± 1.19</td>
<td>5.43 ± 1.03</td>
</tr>
<tr>
<td>LF (nu)</td>
<td>4.20 ± 1.05</td>
<td>4.41 ± 1.24</td>
</tr>
<tr>
<td>HF (nu)</td>
<td>4.32 ± 0.99</td>
<td>4.33 ± 1.23</td>
</tr>
<tr>
<td>LF/HF</td>
<td>1.57 ± 2.51</td>
<td>1.64 ± 1.89</td>
</tr>
</tbody>
</table>

Data are expressed as mean ± SD. CG = Control Group; TG = Training Group; SDNN = Standard Deviation of all Normal-to-Normal Intervals; rMSSD = Square Root of the Mean Squared Differences of Successive Normal-to-Normal Intervals; TP = Total Power; VLF = Very Low Frequency; LF = Low Frequency; HF = High Frequency.

Body Fat
The subjects' skinfold thickness values between before and after the study period are presented in Table 3. Baseline variables of skinfold thickness did not differ significantly between the two groups. In the TG, there was a significant decrease in biceps, triceps, subscapular, and suprailliac skinfold thickness after the study period (P<0.05). In addition, triceps, subscapular, and suprailliac skinfold thickness in the TG were significantly lower than those in the CG after the study period (P<0.05). However, there was no significant difference in biceps skinfold thickness between the two groups after the 12-wk period of the study. Moreover, there was no significant difference in all data of skinfold thickness between before and after the study period in the CG.
Table 3. Effect of MSSE Training on Body Fat in Older Subjects.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>CG (n = 21)</th>
<th></th>
<th>TG (n = 22)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>Biceps Skinfold (mm)</td>
<td>7.11 ± 3.79</td>
<td>6.54 ± 2.38</td>
<td>8.51 ± 2.65</td>
<td>6.19 ± 2.10**</td>
</tr>
<tr>
<td>Triceps Skinfold (mm)</td>
<td>10.25 ± 4.41</td>
<td>9.30 ± 4.43</td>
<td>11.70 ± 5.06</td>
<td>6.05 ± 3.82**†</td>
</tr>
<tr>
<td>Subscapular Skinfold (mm)</td>
<td>11.95 ± 4.64</td>
<td>13.61 ± 4.56</td>
<td>13.13 ± 4.05</td>
<td>10.27 ± 4.82*††</td>
</tr>
<tr>
<td>Suprailiac Skinfold (mm)</td>
<td>15.55 ± 5.06</td>
<td>14.46 ± 4.34</td>
<td>15.15 ± 4.06</td>
<td>11.32 ± 4.34***††</td>
</tr>
</tbody>
</table>

Data are expressed as mean ± SD. CG = Control Group; TG = Training Group; *Significant difference between before and after the study period (P<0.05). **Significant difference between before and after the study period (P<0.001). †Significant difference after the study period between the two groups (P<0.05). ††Significant difference after the study period between the two groups (P<0.01).

**DISCUSSION**

This is the first study to examine the effects of MSSE on HRV and body fat in the elderly. The findings of this study partly supported our hypothesis as the subjects who engaged in the MSSE training showed an improvement in body fat. However, the exercise program did not have any beneficial effects on cardiac autonomic activity.

The decrease in HRV with the ageing process has been well documented. The mechanism of the decrease in HRV is due to the decrease in the parasympathetic tone and the increase in sympathetic activity (4,8,18). Several studies have found HRV modifications after aerobic exercise training (1,7,19). Goldsmith and coworkers (7) found that parasympathetic activity is substantially greater in trained men than in untrained men, during both waking and sleeping hours.

Moreover, aerobic exercise at 60% of the individual's heart rate reserve intensity for 12 wks could improve HRV in the older subjects (1). Similarly, intensive endurance training and moderate aerobic exercise enhanced parasympathetic parameters of HRV in elderly men (19). Besides the exercise training improving HRV, breathing exercise combined with physical exercise can also improve HRV. Respiratory yoga training for a 4-month training period of 2 classes-wk⁻¹ plus home exercises could improve sympathovagal balance in elderly
subjects (22). Liu and colleagues (12) also showed that 24-wks of Tai Chi training that consisted of three 60-min sessions·wk\(^{-1}\) can improve HRV in older subjects with depression. Similarly, Tai Chi Chuan reported that 1 hr, 3 d·wk\(^{-1}\) for 12 wks resulted in an increase in parasympathetic tone and a decrease in sympathetic nerve activity in elderly women (2).

SSE, which is a type of aerobic exercise training, has been reported to improve muscle strength, balance, and aerobic endurance in the elderly (25,26,29). In addition, breathing exercise like PLB exercise using a windmill toy is an effective breathing exercise intervention for improving lung function and respiratory muscle strength in both older subjects and patient with COPD (10,15). It can also increase parasympathetic activity in middle and older people with COPD (20).

However, there has yet to be a study to demonstrate the effect of SSE and/or PLB on HRV in the elderly. Therefore, the present study is the first to investigate the effects of the SSE combined with PLB on HRV in the elderly. The results of this study did not show any changes in HRV after the MSSE training. These findings are consistent with a previous study by Lu and Kuo (13). They found that all parameters of HRV were not significantly changed after a 40 min-session\(^{-1}\), 7 times·wk\(^{-1}\) for 12 wks of Tai Chi Chuan in the elderly. However, the effect of physical exercise combined with breathing exercise on HRV modification is still controversial. The findings in the present study versus the other studies (2,12,22) may be attributable to the differences in training protocol and duration of the exercise training. The lower intensity and/or shorter duration of exercise training in this study may be the reason for no significant changes in HRV. Therefore, further study exploring HRV modification by increased intensity and duration of MSSE training should be performed.

To the best of our knowledge, this is the first study to demonstrate that this specific exercise program had a role in decreasing body fat. This finding is in agreement with a previous study (11) of Nordic walking for 1 hr, 2 times·wk\(^{-1}\) for 8 wks that decreased body fat in women over 50 yrs of age. Furthermore, previous studies have shown a decrease in body fat and cardiovascular risk factor after aerobic exercise training in middle-age subject (16) as well as overweight or obesity older subjects (3,14). Body fat is a predictor of cardiovascular disease (33). Aerobic exercise training has been reported to change body composition by reducing fat mass while improving cardiovascular disease risk factors by reducing arterial stiffness and restoring vascular endothelial function (11,23). Therefore, a decrease in body fat after exercise training can reduce the risk of cardiovascular disease and improve fitness and health.

Limitations in this Study

Factors, such as diet, which are associated with an improvement in body fat were not assessed. Therefore, future study should investigate diet consumption in order to assess the factor influencing body fat. In addition, most subjects in this study were female, which generally have a higher percentage of body fat than men. Also, there are differences in regional fatty acid storage, mobilization, and oxidation that may contribute to gender-related differences in fat accumulation.
CONCLUSIONS

Based on the results from the present study, it can be concluded that the MSSE training is effective for improving body fat in the elderly, although the MSSE training did not improve cardiac autonomic function in older people. Therefore, regular MSSE may increase health-related fitness in the elderly.

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