

Effects of combined exercise on changes of lower extremity muscle activation during walking in older women

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Abstract. [Purpose] The purpose of this study was to demonstrate the effects of combined exercise for a period of 12 weeks on the changes in lower extremity muscle activation during walking in older women. [Subjects] The subjects of this study were 22 elderly women who were 65 years of age or older and living in B-City. The subjects had no nervous system or muscular system diseases that might affect walking in the previous two years. [Methods] Muscle activation was measured by using surface EMG (QEMG-8, Laxtha, Daejeon, Republic of Korea). The subjects were asked to walk on an 8 m of footpath at a natural speed. In order to minimize the noise from the cable connecting the EMG measuring instrument to the electrodes, tape was used to affix the electrodes so that they would not fall off the subjects. The EMG data were analyzed by using the RMS. [Results] Muscle activation of the rectus femoris, biceps femoris, tibialis anterior, and gastrocnemius was increased significantly after combined exercise for 12 weeks. However, no increase was observed in the left biceps femoris. [Conclusion] It was demonstrated that our exercise program, which includes aerobic walking exercises, senior-robics, and muscle strengthening exercises using elastic bands, is very effective for reorganizing the normal gait pattern in the cerebral cortex and improving muscle strength.

Key words: Combined exercise, Muscle activation, Elderly women

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INTRODUCTION

Since the 1960s, the number of elderly individuals in the Republic of Korea has been increasing rapidly. In recent years, this segment of the population has been increasing more rapidly than in any other country in the world. In 2000, 7.2% of the population was 65 years old and older. It is assumed that in 2018, the percentage of elderly individuals will increase to 14.3%, making the Republic of Korea an “aged society”. It is also expected that in 2026, the percentage will be 20.8%, making it a “super-aged society”¹⁾. The increased number of elderly individuals has a positive aspect: people are living longer. However, variables such as hereditary, lifestyle-related and chronic diseases cause physical dysfunction and therefore deteriorate the quality of life of elderly individuals²⁾. The main cause of physical dysfunction in older people is diminished activity, because

the older a person gets, the more likely he is to be reluctant to engage in physical activity. Diminished activity causes muscle degeneration and weakens the power and endurance of muscle tissue. Diminished activity also causes calcification of tendons and ligaments. These factors lead to a vicious cycle of reduction in normal daily activities, which in turn further deteriorates the quality of life of elderly ones. Park and Kim³⁾ said that the lack of exercise is one of the factors that deteriorates the quality of life of the elderly, so for the purpose of maintaining and promoting health, it is very important to encourage elderly individuals to get appropriate amounts of exercise. Eun and Lee⁴⁾ also said that regular exercise and good posture are very important because lack of exercise, bad living habits, and malnutrition can cause an imbalance of the musculoskeletal system and an abnormal gait pattern. Lee⁵⁾ also stated that physical dysfunction can be prevented by good habits and a healthier lifestyle. So a variety of methods are needed in the promotion of good health. For example, it has long been known that a healthy diet, abstinence from smoking, moderation in drinking, body weight control, stress management, and exercise can promote good health. Among those methods, exercise is considered to be the most important factor in promoting good health^{6, 7)}. However, when trying to apply a specific kind of exercise to elderly persons, we have to select an intensity of exercise that

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Table 1. The 12-week combined exercise program

Division	Intensity	Frequency	Time	Type	
Warming up			10 min.	Flexibility exercises, stretching	
Main exercises	1–4 weeks, HRmax 40%		3 times per week	15 min.	Walking exercises, senior-robic
	5–8 weeks, HRmax 50%				
	9–12 weeks, HRmax 60%				
	1–4 weeks, RPE 8–9				
Resistance	5–8 weeks, RPE 10–11		15 min.	Resistance exercise with elastic bands	
	9–12 weeks, RPE 12				
Cooling down			10 min.	Flexibility exercises, stretching	

can prevent injury and at the same time provide beneficial effects. So the types of appropriate exercise are quite limited for elderly persons⁸⁾. Hence, when we prescribe exercise for elderly persons, we cannot apply the same types of exercise that we would for a younger adult. It is advisable to let the elderly follow an exercise program that widens range of motion and increases muscle strength without overloading or causing pain in the joints^{9, 10)}. Various studies have been performed to come up with an appropriate exercise program for the elderly. Hwang¹¹⁾ reported that, after letting elderly individuals perform resistive exercise using elastic bands and aerobic exercises, which were a form of senior-robics, their muscle strength, flexibility, and balance control improved. The American College of Sports Medicine¹²⁾ reported that regular walking exercise has positive effects on improving muscle strength of the lower extremities, muscle endurance, BMI, and walking speed in older persons. It also improves the function of the aerobic system, thereby improving long distance walking and daily quality of life. However, because most of the studies performed previously dealt with improvement of muscle strength and flexibility only before and after exercise, they could not actually explain how exercise affects normal activities of daily life (ADL). Therefore, the purpose of this study was to demonstrate the direct effects of muscle activation of the lower extremities on ADLs in elderly women who have gone through a 12-week program of walking, senior-robic exercises, and muscle strengthening exercises for the lower extremities using elastic bands. This study is expected to provide a scientific basis for use of exercise and treatment programs for prevention of fall injuries and improvement of effective gait motion in the elderly, which have recently become serious social issues. It is expected that a combined exercise program of aerobic and anaerobic exercise would be effective and appropriate for elderly women.

SUBJECTS AND METHODS

The subjects of this study were 22 elderly women who were 65 years of age or older and living in B-City. The subjects had no nervous system or muscular system diseases that might affect walking in the last 2 years. They were capable of following a combined exercise program. The purpose and methods of the research were fully explained to the participants before the experiment was carried out. This study complied with the ethical standards of the Declaration

of Helsinki, and written informed consent was received from each participant. The subjects were randomly divided into an experimental group and a control group. There were 11 people in each group. The average age of the experimental group was 73.7, the average height was 152.8 cm, and the average weight was 48.6 kg. For the control group, the average age was 74.6, the average height was 154.9 cm, and the average weight was 55.0 kg. To examine the effect of the combined exercise program, the muscle activation of the lower extremities was measured, and after 12 weeks of exercise, the same muscles were measured again. The muscle activation was measured by using surface EMG (QEMG-8, Laxtha, Daejeon, Republic of Korea). The subjects were asked to walk on an 8 m of footpath at a natural speed. They were trained to take 35 cm steps at a pace of 2.1 km/h. Muscle activation was measured 5 times altogether, and after every measurement, the subjects had 1 minute of rest. The first, second, and last measurements were discarded, and only the 3rd and 4th measurements were used for analysis. The temperature of the laboratory was maintained at 23 °C, and the humidity was 70%. To minimize the electromagnetic waves and noise in the lab, the use of phones or other electronic equipment was prohibited. To minimize the electric resistance between electrodes and the skin, hair was removed with a razor, and after cleansing the skin with alcohol-soaked cotton, a surface electrode was attached to the skin. The electrodes were attached to the right and left rectus femoris, biceps femoris, tibialis anterior, and muscle belly of the gastrocnemius. The ground electrode was attached at the back of the neck. To minimize the noise from the cable that connecting the EMG measuring instrument and the electrodes, tape was used to fix the electrodes so that they would not fall onto the subjects. The EMG data were analyzed by using the RMS. For 12 weeks, the combined exercise program was performed 3 times a week, with each session lasting 50 minutes. The combined exercise program included a 10-minute warmup, 15 minutes of aerobic exercise, 15 minutes of resistive exercise, and a 10-minute cooldown, as shown in Table 1. IBM SPSS Statistics for Windows (ver. 21.0) was used for statistical analysis. To reduce the standard deviation, the highest and lowest values for both the experimental group and the control group were excluded, so the EMG value of 9 subjects from the experimental group and 9 subjects from the control group were used for analysis. First, to examine the homogeneity of the two groups, the independent t-test was conducted. Next, to examine the change before and after

the exercise in the experimental group and control groups, the paired t-test was conducted. To examine the differences in the changes in muscle activation between before and after the exercise, the ANCOVA test was conducted. The significance level was $\alpha=0.05$.

RESULTS

Table 2 shows the results regarding the effects of the 12-week combined exercise program on the lower extremity muscle activation of elderly women. No statistical difference in lower extremity muscle activation of the rectus femoris, biceps femoris, tibialis anterior, and gastrocnemius was demonstrated in the experimental group and the control group before the exercise.

For the experimental group, the muscle activation of the right rectus femoris initially was 66.2 μV ; after the exercise it increased to 168.4 μV ($p<0.05$). The muscle activation of the left rectus femoris was 61.6 μV , and it increased significantly to 237.3 μV ($p<0.05$). For the right biceps femoris, the muscle activation before the exercise it was 42.3 μV , and it increased significantly to 183.1 μV ($p<0.05$). On the other hand, there was a significant decrease in the muscle activation of the left biceps femoris, that is, from 158.4 μV to 113.1 μV ($p<0.05$). For the right tibialis anterior, the muscle activation before the exercise was 79.8 μV , and it increased to 95.4 μV , with no statistical difference. However, for the left side, there was a significant increase, that is, from 63.2 μV to 162.8 μV ($p<0.05$). For the right gastrocnemius, the muscle activation before the exercise was 64.2 μV and after the exercise, it increased to 91.7 μV ($p<0.05$) and the left gastrocnemius showed a significant increase from 66.2 μV to 111.1 μV ($p<0.05$).

However, the control group showed different results from the experimental group. First, the muscle activation of the right rectus femoris was 66.4 μV before the exercise, and it decreased to 64.8 μV . The muscle activation of the left side was 62.2 μV , and decreased to 60.8 μV , but there was no statistical difference. For the biceps femoris, the muscle activation of the right side was 45.0 μV and after the exercise, it decreased to 43.3 μV , the change was not significant. For the left side, the muscle activation was 157.6 μV , and it decreased significantly to 155.2 μV ($p<0.05$). For the right tibialis anterior, the muscle activation before the exercise was 78.2 μV and after the exercise, it was 76.6 μV . For the left side, it was 62.3 μV before the exercise, and it decreased to 61.2 μV ; the change was not significant. For the right gastrocnemius, the muscle activation was 64.8 μV before the exercise, and after it decreased to 62.9 μV ; the change was not significant. For the left side, it decreased significantly from 66.3 μV to 61.8 μV ($p<0.05$).

Comparing the differences in results for the experimental group and the control group, we could see that the right rectus femoris ($p<0.05$), left rectus femoris ($p<0.05$), right biceps femoris ($p<0.05$), left tibialis anterior ($p<0.05$), right gastrocnemius ($p<0.05$), and left gastrocnemius ($p<0.05$) increased in the experimental group but decreased for the control group. Both the experimental group and the control group showed a decrease in the left biceps femoris, but the rate of decrease was greater in the experimental group ($p<0.05$).

Table 2. The differences in muscle activation between the experimental and control group (unit: μV)

Muscles	Side	Group	Pre-exercise (mean \pm SD)	Post-exercise (mean \pm SD)
Rectus femoris	Right†	Experimental*	66.2 \pm 30.3	168.4 \pm 113.6
		Control	66.4 \pm 29.4	64.8 \pm 29.0
	Left†	Experimental*	61.6 \pm 23.6	237.3 \pm 115.0
		Control	62.2 \pm 23.9	60.8 \pm 24.3
Biceps femoris	Right†	Experimental*	42.3 \pm 16.7	183.1 \pm 142.2
		Control	45.0 \pm 19.3	43.3 \pm 19.4
	Left†	Experimental*	158.4 \pm 32.2	113.1 \pm 44.4
		Control*	157.6 \pm 33.7	155.2 \pm 33.9
Tibialis anterior	Right	Experimental	79.8 \pm 28.5	95.4 \pm 31.5
		Control	78.2 \pm 26.7	76.6 \pm 25.5
	Left†	Experimental*	63.2 \pm 16.9	162.8 \pm 90.1
		Control	62.3 \pm 17.7	61.2 \pm 17.5
Gastrocnemius	Right†	Experimental*	64.2 \pm 19.5	91.7 \pm 37.4
		Control	64.8 \pm 20.6	62.9 \pm 20.7
	Left†	Experimental*	66.2 \pm 21.3	111.1 \pm 46.0
Control*		66.3 \pm 16.4	61.8 \pm 16.0	

† $p<0.05$ by ANCOVA test, * $p<0.05$ by paired t-test

DISCUSSION

People tend to be less active as they get older. However, inactivity leads to deterioration of flexibility, muscle strength, and balance, and it increases the incidence of injury from fall¹³). Generally, falls resulting in injury often occur when individuals are walking. A high percentage, 20.2%, of the elderly 65 years old and older have experienced injuries from a fall¹⁴). The ability to walk implies that an elderly person is capable of independence in daily life. Hence, it is necessary to improve muscle strength and dynamic balance to improve walking ability so that injuries from fall can be prevented¹⁵). Therefore, this study was performed to develop a combined exercise program that can improve muscle strength and dynamic balance, and to examine its effects. The results demonstrated an increase in activation of the rectus femoris and right and left gastrocnemius. An increase was also demonstrated in the activation for the right biceps femoris and left tibialis anterior. In contrast, a decrease was demonstrated in the biceps femoris. Comparing the experimental group and the control group, we could see an increase in both the left and right rectus femoris and gastrocnemius, and left tibialis anterior in the experimental group. However, decreases were observed in the muscles in the control group. These results are similar to the results of other experiments. Ponngnenon et al.¹⁶) found that if gradual resistance is added to walking exercises in hemiplegic patients, walking ability and lower extremity muscle strength is improved. It was reported that an increase in the number of steps produces an improvement in muscle strength. So we can conclude that repeated walking improves walking ability and improves muscle strength. Colado et al.¹⁰) researched the effects of proprioceptor stimulation while walking on lower extremity muscle activation. Compared with their general exercise

group, there was a significant increase in muscle activation in their proprioceptor stimulation group. This result showed that stimulation of proprioception is helpful for advancing walking ability. Kouidi et al.¹⁷⁾ reported the effects of combined aerobic and strength training for six months on the muscles of hemodialysis patients. They found that the cross-sectional areas of type I and II muscle fibers significantly increased. Moreover, ultrastructural analysis revealed that the muscles appeared to be normal, including positive adaptations of capillaries and mitochondria. They suggested that the change was related to enhance oxidative capacity, to increase muscle metabolism, and to improve efficiency of functional energy by exercise training. Consequently, aerobic exercise and muscle strengthening exercise cause an increase in the number of muscle fibers, so they can improve muscle strength. Hence, from this study we could say that aerobic exercise including walking, senior-robic, and resistive exercises improve walking, balance, and muscle strength, leading to improvement of muscle activation. On the other hand, we observed that the muscle activation of the biceps femoris decreased after the exercise. However, if we consider the high muscle activation of the left biceps femoris compared with the right, we could say that the abnormal gait pattern was improved through exercise and hence that the muscle activation had decreased. In connection with this, Mun¹⁸⁾ stated that functional electrical stimulation (FES) resulted in improvement of walking ability in hemiplegic patients when they tried to use it to induce a normal gait pattern. This is because FES results in data regarding a normal gait pattern being sent to cerebral cortex as feedback, so the normal gait pattern is reorganized. Therefore, we can conclude that when a normal gait pattern is practiced repeatedly, it is possible for the cerebral cortex to respond and reorganize it. So it could be concluded that in our study, walking ability was improved by the combined exercise for 12 weeks and that the program led to better balance between the left and right sides, resulting in a decrease in the abdominally high muscle activation. The results demonstrated that our exercise program, which includes aerobic exercise (walking and senior-robics), and muscle strengthening exercise with elastic bands, is very effective for reorganization of the normal gait pattern in the cerebral cortex, and improvement of muscle strength. Based on the results of this study, combined exercise can improve walking ability and performance of ADL functions, which will improve the quality of life of the elderly. In addition, when attempting to create exercise programs to improve the walking ability of elderly women, walking, muscle strengthening exercises, and balance-improving exercises need to be included. Nevertheless, this study was only performed on elderly women, so it is difficult to apply it to all elderly persons. Therefore, it is recommended that studies be performed on subjects of various ages and both genders

in the future. Our study was limited to 12 weeks, so it was not possible to consider all potential effects of the combined exercise program. Therefore, other studies are needed to examine the effects of short-term combined exercise programs and the effects of long-term combined exercise programs.

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