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Original Article

Effects of aerobic exercise on the resting heart rate, physical fitness, and arterial stiffness of female patients with metabolic syndrome

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Abstract. [Purpose] The purpose of this study was to investigate the effects of aerobic exercise on the resting heart rate, physical fitness, and arterial stiffness or female patients with metabolic syndrome. [Subjects and Methods] Subjects were randomly assigned to an exercise group (n=12) or a control group (n=11). Subjects in the exercise group performed aerobic exercise at 60–80% of maximum heart rate for 40 min 5 times a week for 12 weeks. The changes in metabolic syndrome risk factors, resting heart rate, physical fitness, and arterial stiffness were measured and analyzed before and after initiation of the exercise program to determine the effect of exercise. Arterial stiffness was assessed based on brachial-ankle pulse wave velocity (ba-PWV). [Results] Compared to the control group; The metabolic syndrome risk factors (weight, % body fat, waist circumference, systolic blood pressure, diastolic blood pressure, and HDL-Cholesterol) were significantly improved in the exercise: resting heart rate was significantly decreased; VO_2max, muscle strength and muscle endurance were significantly increased; and ba-PWV was significantly decreased. [Conclusion] Aerobic exercise had beneficial effects on the resting heart rate, physical fitness, and arterial stiffness of patients with metabolic syndrome.

Key words: Aerobic exercise, Metabolic syndrome, Physical fitness

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INTRODUCTION

Metabolic syndrome is a known clinical risk factor for the development of atherosclerosis and cardiovascular disease (CVD)[1)]. Various research institutes[2, 3)] have suggested several diagnostic criteria for metabolic syndrome, including abdominal obesity, elevated triglycerides and decreased HDL-cholesterol associated with dyslipidemia, impaired fasting glucose or impaired glucose tolerance, and high blood pressure (BP). The simultaneous manifestation of three or more of these risk factors is associated with increased risk of the development of CVD and type 2 diabetes[4, 5)]. In addition, a recent prospective study reported that an increase in the resting heart rate (RHR), which determines autonomic nervous system activities, actions of circulating hormones, and cardiopulmonary fitness, can result in an increase in the risk of CVD and metabolic syndrome[6–8)].

An increase in RHR can be harmful to the heart because it can shorten the diastolic period in the cardiac cycle, increase cardiac workload due to a decreased coronary flow, and promote build up of atherosclerotic plaque[9)]. The arterial stiffness test is used for the clinical diagnosis and assessment of atherosclerosis[10)]. Arterial stiffness is a predictive index of CVD onset, and it is determined by the measurement of pulse wave velocity (PWV)[11)]. PWV, which has high reliability and reproducibility, records the pulse wave from both sides of the artery as the pulse wave progresses through the interior of the

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Table 1. Physical characteristics of the subjects

Group	Age (yrs)	Height (cm)	Weight (kg)	BMI (kg/m^2)
Exercise (n=12)	48.8 ± 11.0	156.8 ± 7.5	66.0 ± 10.0	26.7 ± 2.1
Control (n=11)	50.9 ± 9.2	157.5 ± 4.3	63.1 ± 8.3	25.4 ± 3.1

Values are Mean ± SD, BMI: body mass index

artery. It is calculated by dividing the distance between the two measurements points by the transit time from one point to the other[12)]. Previous studies have reported that high arterial stiffness resulted in high PWV, and PWV was found to be increased in patients diagnosed with metabolic syndrome[13, 14)]. In addition, a recent study by Park et al.[15)] suggested that there is an association between RHR and arterial stiffness.

Although the reduction of risk factors is emphasized for reducing the occurrence of metabolic syndrome, reduction of RHR and arterial stiffness may be just as important. Studies have revealed that aerobic exercise is effective at improving the symptoms of metabolic syndrome[16, 17)]. In addition, aerobic exercise reduces activation of the sympathetic nervous system, while increasing the activity of the parasympathetic nervous system resulting in reduced RHR[18)]. A reduction in RHR may be the result of improved fitness, which is one of the primary effects of exercise[19)]. Moreover, numerous studies of the effects of aerobic exercise on arterial stiffness have reported that aerobic exercise improves PWV in patients with obesity, type 2 diabetes, and hypertension[20–22)]. However, very few studies have investigated the effects of aerobic exercise on arterial stiffness and RHR, which are used as predictive indices of CVD in patients with metabolic syndrome. Therefore, the present study aimed to investigate the effects of aerobic exercise on RHR, physical fitness, and arterial stiffness in female patients with metabolic syndrome.

SUBJECTS AND METHODS

The subjects of in the present study were 23 females who had been diagnosed with metabolic syndrome. They were selected from among those who participated in exercise classes at a health promotion center in the “C” region of Korea. The 23 subjects were divided into an exercise (n=12) group and a control (n=11) group for the study. The study was approved by the Ethics and Research Committee involving human beings of the institution. All the subjects gave their written informed consent before participating in the study.

The patients were diagnosed as having metabolic syndrome if three of the following five diagnostic criteria suggested in the National Cholesterol Education Program Adult Treatment Panel III (NCEP-ATP III)[2)] were satisfied: abdominal obesity (waist circumference≥85 cm), hypertriglyceridemia (≥150 mg/dl), low HDL-cholesterol (≤ 50 mg/dl), fasting blood glucose (≥110 mg/dl), and high BP (systolic BP≥130 mmHg or diastolic BP≥85 mmHg). The physical characteristics of the participants are described in Table 1.

An automatic body-measuring instrument (Jawon Medical, Korea) was used to measure the subjects weight and height with resolutions of 0.1 kg and 0.1 cm, respectively. The weight and height measurements were used to calculate the body mass index (BMI). Waist circumference measurements were taken 0.1 cm from below the the 12th rib to the middle portion of the upper iliac crest. A body-fat analyzer (Jawon Medical, Korea) was used to measure % body fat via bioelectrical impedance analysis. BP measurements were taken after 10 min of rest with an automatic sphygmomanometer (Jawon Medical, Korea). Systolic and diastolic BP, were measured twice and the mean value was calculated. RHR was measured with wearing a wireless heart rate monitor (Polar Electro OY, Finland) for 1 min. For the blood test, blood was drawn after confirming 10 h of fasting. For blood analysis, a clinical chemistry analyzer (Hitachi 7020, Japan) was used to measure blood glucose, triglyceride, and HDL-cholesterol levels. A Helmas III (O_2run, Korea) was used for the physical fitness test. As a measure of cardiopulmonary fitness, maximum oxygen uptake (VO_2max) was measured on a bicycle ergometer under progressive workload. Grip strength was measured with a dynamometer by adjusting the width the maximum values (in kg) were measured twice in an upright positing. Muscle endurance was measured as the number of sit-ups performed in 30 s. Arterial stiffness was measured in a supine position using an automatic waveform analyzer (VT-1000, Colin CO, Komaki, Japan) after ≥10 min of rest. The sampling time for the 1st pulse wave recording was set to 10 s and two consecutive recordings were obtained for each participant. The mean of the automatically calculated values was used in the analysis. The 12-week aerobic exercise program consisted of warm-up exercise, main exercise, and cool-down exercise, in that order, and a total of 5 sessions were performed per week. Warm-up exercise consisted of 5 min of walking followed by 10 min of stretching, and the cool-down exercise consisted of 10 min of stretching. Aerobic exercise, which was the main exercise, consisted of 40 min of walking on a treadmill at 60–80% of maximum HR. During the aerobic exercise, the participants wore a Polar Heart Rate Analyzer (Polar Electro OY, Finland) to monitor exercise intensity and keep it within the target heart rate range.

Data analysis in the present study was performed via two-way ANOVA with repeated measures using SAS (version 9.1), and a significance level (a) of 0.05.

Table 2. Changes in metabolic syndrome risk factors

Variability	Group	Pre-test	Post-test
Weight (kg)	Exercise	66.0 ± 10.0	63.1 ± 8.9**
	Control	63.1 ± 8.3	62.3 ± 8.3
% fat	Exercise	37.0 ± 3.5	34.9 ± 3.4*
	Control	33.9 ± 3.4	33.0 ± 3.2
Waist circumference (cm)	Exercise	87.1 ± 5.7	85.1 ± 5.2**
	Control	86.0 ± 7.7	85.0 ± 7.2
Triglyceride (mg/dl)	Exercise	166.8 ± 72.0	151.0 ± 67.5
	Control	171.1 ± 61.1	162.8 ± 63.7
HDL-Cholesterol (mg/dl)	Exercise	38.3 ± 5.6	44.8 ± 5.3**
	Control	36.9 ± 9.6	37.7 ± 9.1
Fasting blood glucose (mg/dl)	Exercise	110.6 ± 13.6	103.2 ± 13.9***
	Control	109.3 ± 13.0	108.1 ± 12.6
Systolic blood pressure (mmHg)	Exercise	131.3 ± 9.9	125.8 ± 14.4**
	Control	132.6 ± 8.8	130.3 ± 9.8
Diastolic blood pressure (mmHg)	Exercise	81.6 ± 4.9	78.9 ± 6.8**
	Control	80.5 ± 2.8	79.7 ± 2.7

Values are Mean ± SD, *significant difference, p<0.05, **significant difference, p<0.01, ***significant difference, p<0.001

Table 3. Changes in resting heart rate and physical fitness levels

Variability	Group	Pre-test	Post-test
Resting heart rate (beats/min)	Exercise	79.4 ± 6.5	76.5 ± 5.9***
	Control	78.1 ± 6.6	78.3 ± 4.9
VO_2max (ml/kg/min)	Exercise	26.9 ± 3.0	29.3 ± 2.9***
	Control	25.1 ± 3.3	26.0 ± 3.2
Grip strength (kg)	Exercise	26.8 ± 5.3	28.2 ± 4.2**
	Control	24.8 ± 3.2	25.4 ± 3.8
Sit-up (count/30 s)	Exercise	6.6 ± 2.7	8.8 ± 3.1***
	Control	6.1 ± 2.4	6.5 ± 2.0

Values are Mean ± SD, **significant difference, p<0.01, ***significant difference, p<0.001

Table 4. Changes of pulse wave velocity

Variability	Group	Pre-test	Post-test
Right Ba-PWV (cm/s)	Exercise	1,281.5 ± 245.0	1,229.3 ± 248.7*
	Control	1,283.7 ± 232.8	1,332.7 ± 246.2
Left Ba-PWV (cm/s)	Exercise	1,319.0 ± 239.5	1,244.8 ± 244.2*
	Control	1,305.7 ± 251.4	1,330.6 ± 244.6

Values are Mean ± SD, Ba-PWV: Brachial-ankle pulse wave velocity

RESULTS

Risk factors of metabolic syndrome, such as weight (p<0.01), % body fat (p<0.05), waist circumference (p<0.01), fasting blood glucose (p<0.001), systolic BP (p<0.01), and diastolic BP (p<0.01) showed significant decreases in the exercise group at the end of the experimental period (Table 2). Although HDL-cholesterol (p<0.01) showed a significant increase, triglyceride levels did not show a significant change. The control group showed no significant changes in any of the risk factors between pre- and post-test values.

With respect to changes in RHR and physical fitness, compared to the control group, RHR of the exercise group was significantly decreased (p<0.001), while VO_2max (p<0.001), muscle strength (p<0.01), and muscle endurance (p<0.001) were significantly increased (Table 3). The control group showed no significant changes in these parameters between pre- and post-test (Table 3).

With respect to changes in PWV, PWV of both the left and right sides significantly decreased in the exercise group (both p<0.05). However, The control group did not showed no significant differences between pre- and post-test values of PWV (Table 4).

DISCUSSION

The present study investigated the effects of a 12-week aerobic exercise program on RHR, physical fitness, and arterial stiffness of female patients diagnosed with metabolic syndrome. Exercise has been discussed as a key intervention for managing clinical indicators of metabolic syndrome. The results of the present study show that aerobic exercise was effective at decreasing risk factors, such as weight, % body fat, waist circumference, fasting blood glucose, systolic BP, and diastolic BP, as well as increasing HDL-cholesterol. However, the triglyceride level did not show a significant change. These findings are similar to those of a previous intervention study that reported the risk factors of metabolic syndrome were ameliorated by aerobic exercise[16, 23]. Therefore, in addition to causing weight loss, aerobic exercise can contribute to improving metabolic dysregulation, which plays a pivotal role in the onset of metabolic syndrome.

Aerobic exercise plays a central role in the primary prevention and treatment of CVD, which is a comorbidity in many metabolic syndrome cases. Moreover, prospective studies have suggest RHR is an independent predictive factor of CVD, and elevated RHR has been shown to increase the risk of metabolic syndrome onset[24, 25]. Thus, measures for controlling RHR, which is related to the prognosis of CVD, have become important. The results of the present study show that aerobic exercise reduced RHR. This result is consistent with previous studies results, and is likely due to the inhibition of sympathetic nervous system activation and increased activation of the parasympathetic nervous system owing to the effects of cardiovascular adaptation elicited by aerobic exercise[26, 27]. In other words, aerobic exercise appears to play an important role in reducing

RHR, which can subsequently influence CVD onset. Further, RHR is associated with physical fitness, and that RHR can be reduced through improved physical fitness[28].

The present study also showed that aerobic exercise increased cardiopulmonary and muscle fitness. A study by Lakka et al.[29] verified that having higher fitness lowered the risk of metabolic syndrome development. This indicates that improved fitness, which is a benefit of exercise, is also important in metabolic syndrome. Therefore, it appears that aerobic exercise increases cardiopulmonary fitness and muscle fitness contributing to the lowering of CVD risk in patients with metabolic syndrome.

In the present study, brachial-ankle PWV was measured to examine the pattern of change in arterial stiffness associated with aerobic exercise. PWV is to the velocity of blood flow ejected from the heart, and it is an independent risk factor predicting CVD. In healthy people, PWV is low, but as atherosclerosis progresses, the elasticity of the blood vessels diminishes, causing PWV to increase[30]. A study by Boreham et al.[10] showed that PWV was elevated in patients diagnosed with metabolic syndrome, and according to a recently published meta-analysis by Huang et al.,[31] reported that aerobic exercise lower PWV. The present study also found that aerobic exercise reduced brachial-ankle PWV. Another study by Donley et al.[32] showed that 8 weeks of aerobic exercise resulted in reduced carotid-femoral PWV in metabolic syndrome patients, a result that is consistent with the results of the present study. This suggests that aerobic exercise reduces arterial stiffness, which is associated with each component of metabolic syndrome, thereby playing a role in increasing vascular function. In addition, Previous studies have reported that high levels of cardiopulmonary and muscle fitness are inversely correlated with arterial stiffness[33, 34]. Therefore, the improve ment in physical fitness after aerobic exercise, observed in the present study, may have contributed to reduced arterial stiffness. Aerobic exercise has a preventive effect on CVD by lowering PWV, which is useful in assessing the arterial stiffness that is comorbid in many metabolic syndrome cases.

In conclusion, in the present study, aerobic exercise was found to be effective at ameliorating the risk factors of metabolic syndrome. Moreover, it was also found to reduce RHR, increase physical fitness, and lower PWV, which is an indicator of arterial stiffness. Therefore, aerobic exercise can be considered as an important intervention strategy for reducing the risk of CVD in patients with metabolic syndrome.

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