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Effect of Aerobic Exercise on Blood Pressure and Arterial Compliance in Patients with Essential Hypertension

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ABSTRACT

Hong SK, Lee DG, Lee GC. Effect of Aerobic Exercise on Blood Pressure and Arterial Compliance in Patients with Essential Hypertension, **JEPonline** 2018;21(5):9-18. The purpose of this study was two-fold: (a) to determine the effect of aerobic exercise on blood pressure and arterial compliance in patients with essential hypertension; and (b) to suggest a regimen of aerobic exercise to prevent cardiac risk factors in patients with essential hypertension. There were 14 patients in this study. Seven patients were in the Experimental Group (Medication and Exercise) and 7 patients in the Control Group (Medication). All subjects had hypertension with systolic blood pressure (SBP) of 140 to 160 mmHg and diastolic blood pressure (DBP) of 90 mmHg. Each subject performed 12 wks of aerobic exercise, 4 sessions·wk^{-1}, 1 hr·session^{-1}. After 12 wks of aerobic exercise, there was a significant difference in SBP between the two groups ($P<0.01$). In both groups, SBP and DBP decreased, but it was not significant in the Control Group (Medication). The decrease in the Experimental Group (Medication and Exercise) was statistically significant ($P<0.001$). After 12 wks of aerobic exercise, there was a statistically significant difference in pulse wave velocity (PWV) between both Groups ($P<0.01$). The Experimental Group (Medication and Exercise) showed a significant increase after exercise ($P<0.05$), while the Control Group (Medication) showed no statistically significant difference. Thus, the 12-wk aerobic exercise program in patients with essential hypertension resulted in an increase in arterial compliance and a decrease in blood pressure and body weight.

Key Words: Aerobic Exercise, Blood Pressure, Hypertension

INTRODUCTION

In recent times, the increased incidence of cardiovascular diseases is associated with over-eating, irregular lifestyle, lack of exercise, and excessive stress. Individually and collectively, the factors are responsible for causing chronic degenerative diseases such as heart disease, hypertension, and stroke. In fact, according to the statistics on death caused by disease in Korea, cardiovascular disease as a single disease group is the largest cause of death in North Korea (19).

It is a well-known fact that hypertension is a major risk factor for cardiovascular diseases. Non-medication treatments are recommended in conjunction with medication as the main treatment method for patients with hypertension because of concerns regarding adverse effects of medication-only treatment. Some researchers (11) have argued that exercise therapy as a non-medication treatment to decrease blood pressure has unclear effects, while others (9) have reported that regular physical activity based on improvement of living conditions has an effect on reducing blood pressure. Several other studies (7,12,15) have reported that aerobic exercise has a positive effect on decreasing blood pressure.

In addition, it has been reported that pulse pressure is a strong risk prediction factor for cardiovascular disease when age, gender, and other risk factors are controlled (10). From a physiological point of view, pulse pressure is determined by three major hematologic factors that include ventricular ejection, arterial stiffness, and wave reflection. However, ventricular ejection decreases with age, which is why pulse pressure of individuals over 50 yrs of age is determined by arterial stiffness and wave refection. Therefore, the recent increase in aortic stiffness in patients with hypertension is known to be an independent risk factor that reflects the degree of risk of cardiovascular disease (2). Also, determining arterial stiffness is recognized as an important examination for assessing the degree of risk in patients with hypertension (6).

According to a study that investigated the effects of antihypertensive medication alone on vascular elasticity, spironolactone, angiotensin-converting-enzyme (ACE) inhibitor, and angiotensin II receptor blockers administered to improve arterial distensibility caused by structural transformation in the arterial walls prevents the deposition of collagen fibers on the artery wall. This decreases pulse wave velocity (PWV) by improving the expansion of arteries (5). However, since improvement of arterial reflection has not been studied after short-term antihypertensive medications, the effects of antihypertensive medications on vascular elasticity have not yet been established.

In studies on the effect of aerobic exercise on vascular elasticity, Alan et al. (1) reported that aerobic exercise in normal subjects showed an increase in forearm vascular compliance with increased cardiac output. Klemsdal et al. (17) reported that a decrease in vascular elasticity due to atherosclerosis can be evaluated by measuring vascular elasticity before and after exercise. In addition, Kingwell and colleagues (14) reported that PWV decreases with regular and continuous exercise, while DeSouza et al. (8) reported improvements in endothelia dependent vasodilation, arterial intima-media thickness, and central arterial compliance after 2 to 3 months of aerobic exercise on a treadmill or riding a bicycle. Still, more research needs to be done in this area to further clarify the variables involved.

Hence, the purpose of this study was to investigate the causality between vascular elasticity and aerobic exercise by examining the effects of aerobic exercise on the improvement of cardiovascular related vascular disease in patients with hypertension.

METHODS

Subjects

The present study was conducted with male out-patients between 45 and 55 yrs of age visiting the university hospital for more than 2 yrs of anamnesis of essential hypertension with systolic blood pressure of 140 to 160 mmHg and diastolic blood pressure of 90 mmHg (Korotkoff phase V). The selection criteria were as follows: (a) no physical abnormalities other than hypertension according to a physical examination; and (b) no secondary hypertension. Prior to the study, the patients were informed about the content, procedure, and expected effects of the experiment. Each subject submitted written consent for voluntary participation in the experiment (Table 1).

Table 1. Characteristic of Subjects in Both Groups.

	Experimental Group (Medication and Exercise) (n=7)	**Control Group (Medication)** (n=7)
Age (yrs)	50 ± 4.47	52.57 ± 3.51
Height (cm)	167 ± 4.40	166 ± 6.32
Weight (kg)	79 ± 5.69	76.29 ± 13.73

Procedures

The patients selected for this study were randomly assigned to an Experimental Group (Medication and Exercise) and a Control Group (Medication). Each Group consisted of 7 subjects. All subjects received antihypertensive medications, while only the Experimental Group also engaged in 60 min of exercise. The subjects' weight, blood pressure, vascular elasticity, and exercise stress were assessed and measured before and after the experiment.

Aerobic Exercise

The subjects in the Experimental Group underwent a 60-min session of aerobic exercise that consisted of fast walking and running using a treadmill set at an intensity level of 60% of the subjects' heart rate maximum (HR max), which is the individual target HR measured beforehand using a heart rate measuring watch. The subjects' aerobic exercise consisted of a 1 hr·session^{-1}, 4 times·wk^{-1} for a total of 12 wks.

Measurements of Blood Pressure and Vascular Elasticity

Without drinking any coffee or smoking cigarettes on the day of the experiment, the subjects arrived at the experimental center 30 min prior to the experiment for blood pressure measurement. The blood pressure of each subject was measured at the brachial artery using a mercury manometer with the subject in the supine position. A Sphygmocor (Atcormedical, Inc., Australia) was used to non-invasively measure the vascular elasticity in each subject. The sensors of the measuring probe were fixed on the right radial artery, and a blood pressure cuff was wrapped around the left arm to measure the blood pressure waveform generated with every beat of the heart for 30 sec (13).

Exercise Tolerance Test

The Exercise Tolerance Test for determining the each subject's training intensity of 60% HR max was conducted by testing up to the maximal heart rate using the Bruce protocol (20). The subjects arrived at the experimental center 30 min prior to the experiment and had a 15-min rest, sitting in a chair. Then, the subjects' blood pressure and pulse rate were measured before performing the test. The individual training intensity of 60% HR max was calculated using the Karvonen method: Target HR = Exercise intensity % (HR max – HR rest) + HR max (20).

Statistical Analyses

Statistical analysis was performed using the SPSS 11.0 software (SPSS, Inc., USA). The characteristics of each group were evaluated using descriptive statistics such as the average ± standard deviation. Also, in order to compare the changes in the subjects' weight, systolic blood pressure, diastolic blood pressure, PWV, and pulse rate, a paired *t*-test was performed for within-group comparison, while an independent *t*-test was used for the comparison between groups. Statistical significance was set at an alpha level of $P<0.05$.

RESULTS

Change in Weight

Comparing weight before and after training in each group revealed that the Experimental Group showed significant weight loss ($P<0.01$), while the Control Group did not. Significant differences were also observed between the two groups after the experiment ($P<0.01$) (refer to Table 2).

Table 2. Change of Weight (kg) in the Experimental and Control Groups Before and After Training.

Groups	Before Training	After Training	t
Experimental (Exercise and Medication) Group	79.00 ± 5.69	75.57 ± 4.47	4.768**
Control (Medication) Group	76.29 ± 13.73	75.81 ± 12.85	.952
t	.483	-.047**	

Values are shown as means ± SD. Significant difference were presented as *P<0.05, **P<0.01

Change in Blood Pressure

When comparing the blood pressure of the Experimental Group before and after training, a significant decrease was observed in both systolic blood pressure (Table 3) and diastolic blood pressure (Table 4) ($P<0.05$). The Control Group showed a decrease in both systolic blood pressure and diastolic blood pressure, but neither of the changes in blood pressure were statistically significant differences (Table 3). The post-experiment comparison between the two groups also indicated statistically significant differences ($P<0.05$).

Table 3. Change in the Systolic Blood Pressure (mmHg) of the Experimental and Control Groups Before and After Training.

Groups	Before Training	After Training	t
Experimental Group (Medication and Exercise)	157.57 ± 5.59	131.86 ± 5.84	11.002**
Control Group (Medication)	148.57 ± 19.30	127.86 ± 17.29	1.688
t	1.185	.580*	

Values are shown as means ± SD. Significant difference were presented as *P<0.05, **P<0.01

Table 4. Change in the Diastolic Blood Pressure (mmHg) of the Experimental and Control Groups Before and After Training.

Group	Before Training	After Training	t
Experimental Group (Medication and Exercise)	90.14 ± 6.59	81.71 ± 9.79	3.290*
Control Group (Medication)	87.86 ± 8.59	82.14 ± 6.36	1.255
t	.558	.119	

Values are shown as means ± SD. Significant difference were presented as *P<0.05

Change in PWV

When comparing the PWV of the Experimental Group before and after training, an increase in vascular elasticity was observed. This was due to a significant decrease in PWV ($P<0.05$).

On the other hand, the Control Group showed an increase in vascular elasticity but the difference between the pre-training and post-training measurements was not significant. The post-experiment comparison between the two groups also showed significant differences (P<0.01) (Table 5).

Table 5. Change in the Pulse Wave Velocity ($m \cdot sec^{-1}$) of the Experimental and Control Groups Before and After Training.

Group	Before Training	After Training	t
Experimental Group (Medication and Exercise)	9.01 ± 2.39	8.07 ± 1.84	3.602*
Control Group (Medication)	8.19 ± .94	7.89 ± .36	1.230
t	.853	.262*	

Values are shown as means ± SD. Significant difference were presented as *P<0.05

Change in Heart Rate

When comparing the heart rate before and after training within each group, the Experimental Group showed a significant decrease in heart rate (P<0.01), while the Control Group showed a decrease in heart rate that was not statistically significant. The post-experiment comparison between the two groups also indicated significant differences (P<0.01) (Table 6).

Table 6. Change in the Heart Rate ($beats \cdot min^{-1}$) of the Experimental and Control Groups Before and After Training.

Group	Before Training	After Training	t
Experimental Group (Medication and Exercise)	70.86 ± 7.17	64.57 ± 4.72	3.825**
Control Group (Medication)	70.86 ± 10.76	68.14 ± 9.42	1.999
t	.000	.041*	

Values are shown as means ± SD. Significant difference were presented as *P<0.05, **P<0.01

DISCUSSION

The purpose of this study was to investigate the effects of a 12-wk aerobic exercise program on the body weight, blood pressure, and vascular elasticity in hypertensive patients. In terms of weight change, a significant decrease was observed not only in the pre- and post-training comparison in the Experimental Group, but also in the post-training comparison between the two groups. This finding is similar to the result of studies published in the ACSM's Guidelines for Exercise Testing and Prescription (3) indicating that aerobic exercise alone is effective for reducing weight in patients with hypertension.

Kohrt et al. (18) reported people who exercise regularly accumulated less adipose tissue in the upper and central body regions with time. Hence, it is generally accepted that weight or fat mass is reduced by mid- and long-term aerobic exercise. While it is believed that the medication only group also engaged in general movements such as walking and movements or exercise of low or medium intensity, they did not engage in the consistent and continuous aerobic exercise that was performed by the Experimental Group with the combined aerobic exercise and medication. Thus, it appears that weight is not controlled simply by decreasing blood pressure through the use of general anti-hypertension medications such as Ca^{2+} channel blockers and ACE inhibitors.

In terms of blood pressure, the Experimental Group showed a significant decrease in systolic blood pressure from the pre- to post-training and the between-group comparison. These results are similar to previously published findings (3) that reported systolic blood pressure decreased by approximately 10 to 20 mmHg after medium intensity aerobic exercise. In addition, according to Kingwell et al. (14) and Reaven et al. (23), the major factors for the decrease in blood pressure after aerobic exercise training were aortic elasticity, decreased resistance, and elastic recovery of the peripheral blood vessels, plasma volume change, and changes in the endocrine system.

Accordingly, based on the results of decreased systolic blood pressure and diastolic blood pressure after 12 wks of aerobic exercise, Park (22) concluded that the decreased blood pressure can be attributed to the plasma protein increase caused by the increase in HDL-C and Apo-AI and the decrease in T-C, TG, and Apo-B after 12 wks of aerobic exercise. Kiyonaga et al. (16) also demonstrated the effectiveness of exercise therapy by reporting significant decreases in blood pressure in a stable condition after 30 to 60-min sessions at an intensity level of about 50% of VO_2 max 2 to 3 times·wk^{-1} for 3 to 8 months.

As for PWV indicative of vascular elasticity, the Experimental Group showed significant decreases in the pre- and post-training values as well as in the between-group comparison. These results are similar to the findings by Margo and colleagues (21). They inserted a pressure sensor inside the subjects' blood vessel to measure the pressure and elasticity of blood vessel and used a bicycle ergometer to measure vessel resistance and elasticity. They found that the arterial resistance decreased while the vascular elasticity increased after exercise. The findings of the present study are also similar to those of Alan et al. (1) who showed that aerobic exercise restored peripheral vascular resistance reduction and vascular elasticity. Thus, the changes in vascular elasticity after aerobic exercise in the present study corroborate the increase of vascular pressure and vessel expansion due to the higher blood flow rate during aerobic exercise (1).

It is also conjectured that aerobic exercise has a positive influence on vascular elasticity because it leads to the activation of the sympathetic nervous system, thus improving the stability of the sympathetic nervous system (4). The positive recovery of vascular elasticity after aerobic exercise seen in this study suggests that aerobic exercise therapy can help prevent adult diseases, such as hypertension, diabetes, coronary artery disease, and cerebrovascular disease that could be associated with cardiovascular disorders. However, to predict and better manage cardiovascular diseases through vascular elasticity, it is necessary to develop an effective measurement method that takes into account individual specificity, such as height, weight, blood vessel length, and location of the heart along with an assessment scale that will predict hypertension and cardiovascular diseases.

CONCLUSIONS

The present study confirmed that a 12-wk aerobic training program had a positive effect on increasing the vascular elasticity and lowering the blood pressure and weight of hypertensive subjects. Interventions such as aerobic training and vascular elasticity measurements before and after exercise in cardiovascular patients will not only provide important information for predicting and improving cardiovascular diseases, but will also suggest concrete steps to overcome cardiovascular diseases, such as considering approaches according to individual characteristics and classifications of exercise.

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