A Study on How a 6-Month Aerobic Exercise Program Can Modify Coronary Risk Factors Depending on Their Severity in Middle-Aged Sedentary Women

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Abstract

It is well known that physical exercise can reduce coronary risk factors. But how an aerobic exercise modifies coronary risk factors in relation to severity and physical fitness is still controversial.

Fifty-four middle-aged women (mean age, 55 years) completed a 6-month on-site and home-based anaerobic threshold-level exercise program. The changes in coronary risk factor profiles were observed during the pre-intervention and intervention periods. Before the intervention (during control period), most coronary risk factors showed a rather unfavorable trend. After the program, their mean body weight decreased from 56.7 to 55.7 kg ($p < 0.05$) and the proportion of body fat from 30.9 to 27.9% ($p < 0.05$) without any reduction in lean body mass. Systolic blood pressure (SBP) decreased from 129.0 to 125.0 mm Hg ($p < 0.05$) and diastolic blood pressure from 79.5 to 76.6 mm Hg ($p < 0.05$). Fasting plasma glucose (FPG) declined from 109.6 to 103.4 mg/dl ($p < 0.05$). Changes in SBP and FPG were most remarkable in their respective worst tertile. Serum lipids improved only modestly. Maximum oxygen uptake increased from 23.6 to 26.1 ml/kg/min ($p < 0.01$). However, no significant correlations were found between changes in coronary risk factors and those in physical fitness. We conclude that the 6-month aerobic exercise program would modify women's coronary risk factors depending on their initial values, probably independently of the changes in physical fitness.

Key words: aerobic exercise, coronary risk factors, physical fitness

Introduction

Modern technology has largely restricted our physical activity, resulting in a sedentary life.¹ Physical inactivity has been considered an important risk factor, comparable to the other established risk factors for coronary heart disease (CHD).²⁻⁷ Therefore, exercise training is widely used to reduce the risk of CHD, probably through a beneficial effect on the conventional coronary risk factor profiles.⁸⁻⁹ However, only a few intervention studies have demonstrated the effect of increased physical activity on coronary risk factors in women, and their results have been inconsistent.¹⁰⁻¹² Little information is available on the relationship between physical fitness and coronary risk factors, either. To

obtain further evidence, we examined how a 6-month aerobic exercise program modified coronary risk factors and physical fitness among apparently healthy, sedentary middle-aged women.

Subjects and Methods

Study Subjects

Many adult inhabitants in Aichi Prefecture routinely undergo automated multiphasic health testing, and are medically advised according to their test results at the Aichi Prefectural Center of Health Care, Nagoya, Japan. This comprehensive medical check-up includes the measurement of physique, blood pressure, and blood chemistry. From 1992 to 1997, 107 female subjects (mean age $\pm$ SD, 54 ± 7 years) who had undergone a medical check-up at least twice at the center and who proved to have one or more untreated coronary risk factors (hypertension, dyslipidemia, diabetes mellitus, and obesity) were recruited in a 6-month aerobic exercise program at the Health Promotion Unit of the Center. All subjects were sedentary housewives, free from

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clinically apparent cardiovascular disease in their past history and in electrocardiogram.

Measurements of risk factors, lifestyles, and fitness level

The subjects' body height and weight were measured, and their body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters. Lean body mass and percent body fat were simultaneously measured by an electronic scale (TBF 202, Tanita, Tokyo, Japan). Blood pressure was measured with an automatic mercury sphygmomanometer in a supine position after several minutes of bed rest. Venous blood samples were drawn from an antecubital vein after overnight fasting. All blood samples were immediately analyzed by the in-house chemical autoanalyzer Model-7350 (Hitachi Medical System, Tokyo, Japan). Plasma lipids were measured according to standard enzymatic procedures.¹³⁻¹⁴ Plasma glucose was also determined by enzymatic method (HK and G-6-PDH).

A questionnaire was administered to obtain medical history, physical activity and food intake in daily life. A pedometer (Calorie Counter, Suzuken, Nagoya, Japan) was used to assess the daily physical activity in this study. Subjects were instructed to wear it continuously for one week, except while bathing and sleeping. The number of steps in one day were automatically stored in the pedometer for one week and recalled thereafter. In addition, a two-day food record was used to assess the dietary intake of the subjects. The daily intake of total energy, fat, and protein was calculated by the dietitians at the center.

An exercise testing was performed using a bicycle ergometer with continuously increasing load at the rate of 1 watt per 3 seconds (Stress Test System ML5000, Fukuda Denshi, Tokyo, Japan; and Model 50, Combi, Tokyo, Japan). To determine general aerobic capacity, breath-by-breath oxygen uptake ($\dot{V}O_2$) and carbon dioxide excretion were measured under electrocardiographic and manometric monitoring. The subjects were encouraged to achieve "all-out", and the highest $\dot{V}O_2$ attained was considered $\dot{V}O_{2max}$. Anaerobic thresholds (AT) were determined according to the V-slope method.¹⁵ In addition, the measurement of muscle strength and muscle endurance was performed for all subjects. Muscle strength was measured by a hand-grip for each hand, and muscle endurance by sit-ups for one minute.

Aerobic exercise program

Each subject was provided with an individualized prescription: (1) on-site aerobic exercise at her AT level for 90 minutes once a week including walking or jogging on a treadmill (including warm-up) for 20 minutes, ergometer cycling for 20 minutes, aerobic dancing for 15-25 minutes, strenuous training for 10 minutes, stretching for 10 minutes, and intermittent short rests; (2) home-based exercise of the same intensity for 60 minutes 3-5 times a week. The intensity was mainly managed through her rating of perceived exertion (RPE)¹⁶ and ambulatory heart rate monitoring (Jogmate, Japan Precision Instrument, Tokyo, Japan). At the enrollment, the exercise physiologists explained the philosophy and methods to be used in the program, and consents were obtained from the subjects. To enhance compliance, details of each exercise session were recorded in a diary and reviewed by the exercise physiologists at least once a week.

Statistical Analysis

Coronary risk factors were evaluated at three time points, namely, an average 1.5 years prior to the intervention (characterized as the first measurement), just before the intervention (the second measurement), and just after the intervention (the third measurement). Values are expressed as mean $\pm$ standard deviation. Student's t-test was applied when comparing differences in numerical data between groups. Change of a variable was verified by paired t-test. When considering the manner of changes by the intervention, subjects were divided into tertiles of the first measurements and their data were compared between the second and the third measurements in order to avoid the so-called "regression to the mean" phenomenon.¹⁷ Simple correlation analysis was used to evaluate the association between changes in coronary risk profiles and those in physical fitness. A p-value less than 0.05 was considered statistically significant.

Results

Of the 107 subjects who participated in the 6-month aerobic exercise program, 53 dropped out before the completion of the program because of their personal problems (moving, family members' illness, etc). They were not significantly different in their initial demographical characteristics and coronary risk profiles from the remaining 54 women who completed the program (eligible subjects).

Between the first and second measurement (during the control period), we found an unfavorable trend in body weight (from 56.2 to 56.7 kg), systolic blood pressure (from 126.0 to 129.0 mm Hg), diastolic blood pressure (from 78.6 to 79.5 mm Hg), total cholesterol (from 232.7 to 235.7 mg/dl), triglyceride (from 101.7 to 105.3 mg/dl), fasting plasma glucose (from 106.2 to 109.6 mg/dl), and uric acid (from 4.4 to 4.6 mg/dl), although statistically insignificant (Table 1).

Between the second and third measurement (during the intervention period), the mean number of steps increased from 8,019 to 9,495 steps per day ($p < 0.05$), while major nutrient intake remained unaltered (from 1,676 to 1,644 kcal/day for energy, from 73.2 to 72.1 g/day for fat, and from 45.5 to 43.5 g/day for protein).

Changes in coronary risk factors during the intervention period are shown in Table 1. Body weight decreased from 56.7 to 55.7 kg ($p < 0.05$) and the proportion of body fat from 30.9 to 27.9% ($p < 0.05$) without any reduction in lean body mass. Systolic blood pressure decreased from 129.0 to 125.0 mm Hg ($p < 0.05$) and diastolic blood pressure from 79.5 to 76.6 mm Hg ($p < 0.05$). Fasting plasma glucose of 109.6 mg/dl declined to 103.4 mg/dl ($p < 0.05$). In contrast, serum lipid profiles were modestly improved. Total cholesterol decreased from 235.7 to 231.5 mg/dl, HDL-cholesterol increased from 57.3 to 58.3 mg/dl, and triglyceride decreased from 105.3 to 99.1 mg/dl, all of which did not reach statistical significance. Uric acid was also little changed (from 4.5 to 4.4 mg/dl, NS).

Figure 1 shows the changes in systolic blood pressure and fasting plasma glucose during the intervention period according to the tertile of their first measurements. Systolic blood pressure of the highest tertile decreased by 7 mm Hg from 146 to 139 mm Hg ($p < 0.05$), while those of intermediate and low tertiles did so by 4 and 1 mm Hg, respectively (both NS). Similarly, fasting plasma glucose of the highest tertile only significantly decreased from 133 to 118 mg/dl ($p < 0.05$). Other coronary risk factors showed similar patterns, although statistically insignificant.

Table 1 Coronary risk factors at three time points, an average 1.5 years prior to entry into the study (first measurement), just before and just after the 6-month aerobic exercise program (second and third measurement, respectively) for 54 female subjects

	First measurement	Second measurement (Before the program)	Third measurement (After the program)
Body weight (kg)	56.2 ± 9.0	56.7 ± 8.9	55.7 ± 8.4*
Lean body mass (kg)	NA	38.1 ± 5.0	38.8 ± 5.6
Body fat (%)	NA	30.9 ± 7.9	27.9 ± 7.4*
Systolic blood pressure (mm Hg)	126.0 ± 16.8	129.0 ± 17.6	125.0 ± 16.3*
Diastolic blood pressure (mm Hg)	78.6 ± 9.1	79.5 ± 10.3	76.6 ± 8.0*
Total cholesterol (mg/dl)	232.7 ± 44.0	235.7 ± 38.8	231.5 ± 44.1
HDL-cholesterol (mg/dl)	56.6 ± 14.2	57.3 ± 14.8	58.3 ± 16.0
Triglyceride (mg/dl)	101.7 ± 42.9	105.3 ± 49.3	99.1 ± 46.5
Fasting plasma glucose (mg/dl)	106.2 ± 26.7	109.6 ± 34.0	103.4 ± 19.2*
Uric acid (mg/dl)	4.4 ± 0.9	4.6 ± 0.9	4.5 ± 0.9

Values are means ± standard deviation

HDL-cholesterol indicates high density lipoprotein cholesterol

NA means not available

* $p < 0.05$ compared with the preceding measurement (by paired t-test) **Fig. 1** Changes in systolic blood pressure and fasting plasma glucose during the 6-month aerobic exercise program according to the tertiles of the first measurements for 54 female subjects. (Probability was calculated by paired t-test)**Table 2** Physical fitness indicators before and after the 6-month aerobic exercise program for 54 female subjects

	Before	After
Maximum oxygen uptake (ml/kg/min)	23.6 ± 4.9	26.1 ± 5.0**
Oxygen uptake at anaerobic threshold (ml/kg/min)	12.9 ± 2.9	14.3 ± 2.6**
Sit-ups (No.)	8.7 ± 8.0	12.2 ± 8.3**
Hand-grip (kg)	25.8 ± 4.1	26.7 ± 4.4**

Values are means ± standard deviation

** $p < 0.01$ (by paired t-test)

Discussion

To our best knowledge, this is the first study revealing the comprehensive associations between changes in coronary risk factors and those in physical fitness under a controlled exercise program. AT-level exercise, that is, maximum aerobic exercise, has the following characteristics: (1) excess fat can be most efficiently utilized for energy; (2) subjects can continue exercising with little fatigue; and (3) blood pressure increases only a little during the exercise.^{15,18} Therefore, AT-level is considered to be a reasonable and useful index for exercise prescription.

In this study, we compared the CHD risk factor profiles assessed, on average, 1.5 years prior to entry into the intervention (control period) with those measured just before the intervention. Unless any intervention was performed, coronary risk factor profiles were not improved or rather became slightly worse in their natural course. Our 6-month AT-level exercise program, however, demonstrated favorable changes especially in blood pressure and fasting plasma glucose, as well as in physical fitness. Since the subjects of this study were not asked to modify their dietary habits during the period, intake of total energy and major nutrients was almost identical before and after the exercise program. Accordingly, we could presume that the effects on the

Table 2 presents changes in physical fitness during the intervention period. All physical performances were significantly improved. $\dot{V}O_2$ max increased from 23.6 to 26.1 ml/kg/min ($p < 0.01$), and $\dot{V}O_2$ at AT increased from 12.9 to 14.3 ml/kg/min ($p < 0.01$). The number of one minute sit-ups increased from 8.7 to 12.2 ($p < 0.01$), and hand-grip from 25.8 to 26.7 kg ($p < 0.01$).

Table 3 shows the simple correlation coefficients between changes in each coronary risk factor profile and those in each physical fitness during the intervention period. Their coefficients were only within -0.237 to 0.197, and no significant correlations were found between changes in the two different kinds of parameters. When multivariate analysis was applied, the results were essentially unaltered (data not shown).

Table 3 Correlation coefficients between changes in each coronary risk factor and those in each physical fitness during the 6-month aerobic exercise program for 54 female subjects

	Systolic blood pressure	Diastolic blood pressure	Total Cholesterol	HDL Cholesterol	Trigly- ceride	Fasting plasma glucose	Uric acid
$\dot{V}O_{2\max}$	-0.113	0.123	0.177	0.197	0.038	-0.099	-0.085
$\dot{V}O_2$ at AT	-0.131	0.145	-0.075	0.049	-0.164	-0.138	0.074
Sit-ups	0.148	-0.070	-0.090	-0.028	-0.237	-0.053	-0.101
Hand-grip	-0.003	-0.086	0.161	0.128	0.040	-0.107	0.037

HDL cholesterol indicates high density lipoprotein cholesterol;

$\dot{V}O_{2\max}$, maximum oxygen uptake; $\dot{V}O_2$ at AT, oxygen uptake at anaerobic threshold

coronary risk profiles were mainly caused by exercise.

Previous studies indicated that endurance exercise training is effective in lowering blood pressure for both normal and hypertensive subjects.¹⁹⁻²² A recent meta-analysis for randomized controlled trials of long-term exercise showed that aerobic exercise training reduced systolic blood pressure by 4.7 mm Hg and diastolic blood pressure by 3.1 mm Hg.²³ Blood pressure reduction in our study was quite comparable with these results. A significant reduction in fasting plasma glucose was also shown, which is consistent with the findings of the previous studies.^{24,25} Interestingly, we found that changes in blood pressure and fasting plasma glucose were most remarkable in the worst tertile. Different from medication that lowers blood pressure or plasma glucose irrespective of their initial levels, programmed exercise training might modify CHD risk factors towards a desirable level.

Lipid profiles were improved very modestly. Findings of previous studies^{3,26} about the effect of exercise on lipid profiles have also been equivocal. One possible reason for our not-notable improvement in HDL-cholesterol is that the initial HDL-cholesterol level of the subjects (mean value, 57.3 mg/dl) was already high enough. Another explanation could be the intensity of the exercise. Since changes in HDL-cholesterol were associated with the exercise intensity,²⁷⁻²⁸ this prescription of exercise at AT level might be insufficient to raise the initially high HDL-cholesterol. For total cholesterol and triglyceride, lacking stringent weight loss might fail to reduce their serum concentrations.²⁹

As expected, physical fitness, including both $\dot{V}O_{2\max}$ and $\dot{V}O_2$ at AT, was significantly improved after the exercise program. But we could not find any significant correlation

between changes in coronary risk factors and those in physical fitness. Despres et al³⁰ also mentioned that $\dot{V}O_{2\max}$ was not significantly correlated with the response of plasma lipoprotein levels. This would suggest that the improvement in coronary risk factors was probably independent of the build-up of the bodies. Small numbers of examinees might also cause the lack of statistically significant associations between the parameters. Further investigations are warranted to clarify the physiological relationship between circulatory or metabolic factors and neuromuscular performance.

This study has some limitations. First, about half of the participants dropped out of the program. Although the pre-intervention data of the dropouts and completers were quite similar, there might be a certain kind of bias. Second, we did not set the non-intervention group as a reference. However, we contrasted the intervention effects with changes during the pre-intervention control period. Further randomized trials would clarify the effects of increased aerobic exercise both on the coronary risk factors and physical fitness.

In short, our 6-month aerobic exercise program favorably modified most coronary risk factors in middle-aged sedentary women, especially in those whose initial values were poorer, and probably independent of the changes in physical fitness. Thus, we conclude that programmed regular exercise training would contribute to health promotion in women as well.

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