Changes in Aerobic Capacity and Coronary Risk Factors during Long-term Exercise Training in Women with Ischemic Heart Disease: A 36-month Follow-up

Masaki Takeda[1], Kiyoji Tanaka[2], Hideya Unno[3], Teruo Hiyama[3] and Katsumi Asano[2]

1) Department of Health and Exercises, Doshisha University
2) Institute of Health and Sport Sciences, University of Tsukuba
3) Division of Cardiology, Higashi Toride Hospital

Abstract. We evaluated the time course of alteration in aerobic capacity and coronary risk factors associated with a 36-month exercise program in women with ischemic heart disease (IHD). Twenty-one patients participated in supervised exercise and home-based exercise programs for 36 months. However, of all patients, 11 patients completed the entire program. Oxygen uptake corresponding to lactate threshold ($\dot{V}O_2LT$), peak oxygen uptake ($\dot{V}O_2$peak), percent of body fat (%BF), systolic (BPs) and diastolic (BPd) blood pressure, total cholesterol (TC), low-density lipoprotein cholesterol (LDLC), high-density lipoprotein cholesterol (HDLC) and triglycerides (TG) were assessed before and 4, 8, 12, 24, and 36 months after exercise. The intensity of exercise was set at individually determined LT, i.e., 60 to 70% $\dot{V}O_2$peak. The daily amount of exercise during 36 months averaged 24.0 ± 11.4 minutes per day. During the course of exercise program, $\dot{V}O_2LT$, $\dot{V}O_2$peak, BPs, BPd, and TG improved significantly at month 4. Although %BF decreased significantly at month 8 to 12, it tended to return to the initial level at month 36. On the other hand, a significant increase in HDLC was found at month 24 and improved state of HDLC remained unchanged thereafter. No changes were found in TC and LDLC. These results suggest that most of the beneficial effects of exercise on aerobic capacity and coronary risk factors in women with IHD are obtained within 4-8 months, with some further improvement seen with continued exercise up to 24 months.

(Appl Human Sci, 15 (3): 115-121, 1996)

Keywords: ischemic heart disease, exercise, coronary risk factor

Introduction

There is a large body of evidence supporting the beneficial effects of exercise on aerobic capacity and coronary risk factors in patients with ischemic heart disease (IHD). Most of those results have been obtained from studies that used men as the subjects. No information have been obtained on the effects of exercise in women with IHD. It must be separated from women to men in the assessement, because different developmental and physiological characteristics between the sexes may lead to different physiological responses to exercise (Cochrane et al., 1992; Mitchell et al., 1992).

Moreover, the period of exercise program which have ever been reported lasted from several months to 1 year. Although the role of exercise as a secondary prevention of IHD has not yet been clearly proved, O'Connor et al. (1989) performed a meta analysis of all randomized trials, involving 4,554 patients. In this analysis, after an average of 36-month follow-up, total mortality (odds ratio=0.80 [0.66, 0.96: 95% confidence interval]), cardiovascular mortality (odds ratio=0.78 [0.63, 0.96: 95% confidence interval]), and fatal reinfarction (odds ratio=0.75 [0.59, 0.95: 95% confidence interval]) of rehabilitation group were lower than that of control group. Oldridge et al. (1988) compared the total mortality, cardiovascular mortality, and nonfatal recurrence of myocardial infarction (MI) in exercise periods of less than 3 months, 12 months, and 36 months. In their study, the length of the exercise period correlated with a decrease in total mortality and nonfatal recurrence of MI. Therefore, it is important to assess the long-term effects of exercise on aerobic capacity and coronary risk factors in IHD patients, assuming those factors affect total mortality and nonfatal recurrence of MI.

Several follow-up studies lasting 3 to 5 years have focused on aerobic capacity (Ben-Ali et al., 1986; Hedbäck and Park, 1987; Kellerman, 1973; Oldridge et al., 1978; Perk et al., 1989), blood pressure (Heath et al., 1983; Kallio et al., 1979; Perk et al., 1989), total cholesterol

(TC) (Kallio et al., 1979), triglycerides (TG) (Kallio et al., 1979), and smoking habits (Kallio et al., 1979; Perk et al., 1989). However, it should be noted that most of these have used the study design of pre-post evaluation. Data regarding the change over time of aerobic capacity and coronary risk factors have not yet been obtained. Moreover, to our knowledge, no long-term trials have reported on the changes in body composition and high-density lipoprotein cholesterol (HDLC) associated with regular involvement in aerobic exercise.

With the above in mind, this study was undertaken to investigate the change in aerobic capacity and coronary risk factors over a 36-month exercise program in women with IHD.

Methods

Subjects

Twenty-one women with IHD began the study. However, 10 women progressively dropped-out from the study before completing the program (Fig. 1). None of these patients left the study because of clinical problems. Full 36-month program was completed by 11 patients (age: 55.3 ± 10.1 years). We considered only those subjects who completed the full 36-month program in the analysis.

Table 1 profiles the baseline characteristics of the study group. Of the 11 patients, two were diagnosed as having had a myocardial infarction, while the 9 were diagnosed with stable angina pectoris. Patients were diagnosed with IHD if they met two or more of the following criteria: (1) a history of chest pain consistent with IHD, (2) a coronary angiogram consistent with IHD, and (3) electrocardiographic changes consistent with

IHD including 24-hour Holter monitoring. The cardiac function of these patients corresponded to I or II in the functional class of New York Heart Association. Eight women underwent coronary angiography and 2 underwent aortocoronary bypass surgery. All patients were taking one or more medications for IHD such as calcium antagonists, beta-adrenergic blocking agents, nitrates, and antihypertensive agents before starting the exercise program, but the regimens were not significantly altered in any of the patients during the study. All such medications were not taken on the day of testing to prevent interference with the assessment of cardiovascular function during exercise, resting BP and serum lipids.

None of patient had a smoking habit before starting the exercise program. None of the patients were exercising regularly before beginning the study. Informed consent was obtained from each patient.

Assessment of aerobic capacity and coronary risk factors

All variables were measured at the beginning of the study and after 4, 8, 12, 24, and 36 months of exercise program.

Body composition: Body density (Db) was measured with a portable four-terminal bio-impedance measurement system (Selco SIF-891, Yokohama, Japan). The Db was estimated from the following empirically derived equation developed by Nakadomo et al. (1990) for Japanese women: $Db = 1.1628 - 0.1067 (Wt \cdot Z/Ht^2)$, where Wt is body weight (Wt) in kilograms, Z is impedance in ohms, and Ht is body height in centimeters. The percentage body fat (%BF) was derived from Db according to the equation described by Brozek et al. (1963). Fat-free weight (FFW) was calculated as the difference between Wt and BF. We also measured skinfold thickness using an Eiyoken-type skinfold caliper at 4 sites: the triceps, subscapular, suprailiac, and umbilical regions.

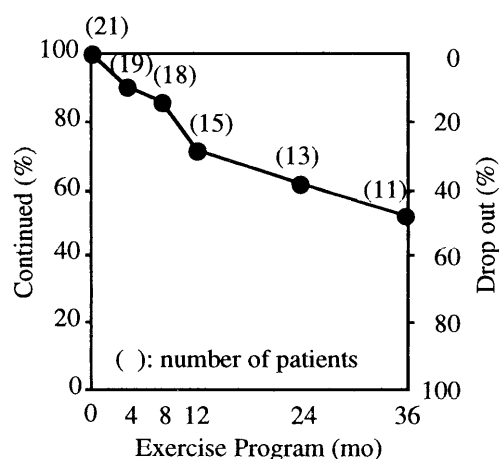*Aerobic capacity*: Oxygen uptake corresponding

Fig. 1 The number of patients who dropped out from 36-month exercise program in women with ischemic heart disease.

Table 1 Physical characteristics of women with ischemic heart disease who completed the full 36-month exercise program

Variables	Mean ± SD
Age (yr)	55.3 ±10.1
Height (cm)	151.3 ± 4.6
Weight (kg)	56.6 ± 9.9
Body Mass Index	24.8 ± 4.8
Name of diseases	Number
Myocardial infarction	2
Stable angina pectoris	9
Total	11

to lactate threshold ($\dot{V}O_2LT$) and peak oxygen uptake ($\dot{V}O_2$peak) as an index of aerobic capacity were determined during a graded exercise test, using a Monark cycle ergometer. Following 2 minutes of warming-up at 0 watt, the work rate was increased every minute by 15 watts until exhaustion or symptom-limited maximal exercise level was reached. The frequency of pedaling was 60 revolutions per minute. During exercise, expired air was analyzed continuously for O_2 and CO_2 using standard techniques of open-circuit spirometry with the Fukuda Sangyo IS-6000 system. $\dot{V}O_2LT$ was defined as the $\dot{V}O_2$ corresponding to the point at which blood lactate concentration exhibited a systematic increase above a resting base-line value (Beaver et al., 1985). To determine the LT, blood samples of 0.5-1.0 ml were taken from an antecubital vein through an indwelling needle every minute. All blood samples were analyzed by the electrochemical enzymatic method using a Yellow Springs lactate analyzer (Model 23L). For establishing the LT, the log [$\dot{V}O_2$]-log [la] transformation method was used (Beaver et al., 1985).

Resting heart rate and blood pressure: Heart rate (HR) was recorded at rest by an electrocardiograph and resting systolic (BPs) and diastolic (BPd) blood pressures were measured by a mercury manometer following 15- to 20-min rest on a chair before conducting any measurements.

Serum lipid and lipoproteins: All patients were asked to abstain from alcohol on the day before testing and to fast for 12 hours before coming to the hospital. Blood samples were taken at rest from the antecubital vein before the exercise test. After centrifuging the blood sample, blood serum was taken. Then TC and TG were analyzed by enzymatic methods. HDLC was determined in the supernatant after manganese-heparin precipitation. LDLC was calculated from the Friedewald's equation (1972), i.e., LDLC=TC − HDLC − TG/5. The ratio of LDLC to HDLC (LDLC/HDLC) was also calculated.

Exercise training program

The exercise training program consisted of two components, i.e., supervised exercise program and home-based exercise program as reported previously described by Tanaka et al. (1992, 1993). Exercise program consisted of aerobic and large muscle group dynamic type activities such as stationary cycling, ground walking, jogging, ball games, rhythmic dance, or light muscle strength training. The intensity of exercise was set at an individually determined LT level, i.e., work rate (WR), HR and/or ratings of perceived exertion (RPE) corresponding to LT were prescribed for all patients. After starting exercise program, the LT levels of all patients were measured at 4, 8, 12, 24, and 36 months and the intensity of exercise was set at a new LT level.

The relative exercise intensity was almost constant, i.e., 60 to 70% of $\dot{V}O_2$peak for 36 months. This procedure enables each patient to exercise continually at her LT level during the entire study period. During exercise, WR, HR, or RPE as indices of exercise intensity were periodically checked and adjusted if necessary. In the home-based exercise program, patients were asked not to exceed thier prescribed LT level to ensure safety. The duration of exercise was 1 hour per session in the supervised program and 15 to 60 minutes in the home-based program, depending on the patient's motivation. The frequency of exercise was 1 to 2 times per week in the supervised program and 0 to 5 times per week in the home-based program. The type, intensity, and duration of exercises conducted in the supervised programs were recorded in a diary by the investigators and those in the home-based exercise by the individual subjects. The mean values and standard deviations of aerobic type exercise duration were 24.0 ± 11.6 minutes per day for 36 months. This duration of exercise was almost constant in all subjects during the 36 months.

Statistical analysis

One-way repeated-measures analysis of variance was used to test the significance of differences during the 36-month exercise program for each variable. Schefee F-test was used for the variables which significant difference was found after analysis of variance. Since age range of sample is large in this study, Pearson product-moment correlation coefficients was used to evaluate linear relationships between the age and the absolute amount of change in each variable. P values less than 0.05 were considered as statistically significant. All values in Tables and Figures are expressed as the mean ± the standard deviation.

Results

The mean and the standard deviation of all test variables are shown in Table 2.

Changes in variables during 36-month exercise program

Body composition: A significant decrease in Wt was found at month 4, while improvements in %BF (Fig. 2), FW, and FFW were not significant. The sum of the 4 skinfold thickness significantly decreased at month 8. However all anthropometric variables returned to their initial levels at month 36.

Aerobic capacity: During the 36 months of exercise program, the largest increase in $\dot{V}O_2LT$ (28.6%) was observed at month 4 (Fig. 3). Although no further increase (P > 0.05) in $\dot{V}O_2LT$ was found after that, the increased level was maintained for the rest pe-

Table 2 Changes in selected variables in 11 womens with ischemic heart disease over the 36-months exercise program

Variables	pre	4 mo	8 mo	12 mo	24 mo	36 mo
Wt (kg)	51.5 ± 4.2	50.7 ± 3.7a	50.3 ± 4.4a	50.3 ± 4.7a	51.1 ± 4.7	50.9 ± 4.8
%BF (%)	30.8 ± 6.2	28.6 ± 4.5	29.3 ± 4.0	28.3 ± 4.9	28.7 ± 6.2	32.3 ± 6.7bd
FW (kg)	15.8 ± 3.5	14.4 ± 2.3	14.7 ± 2.9	14.2 ± 2.9	14.8 ± 3.9	16.7 ± 4.7d
FFW (kg)	35.5 ± 4.5	36.2 ± 3.8	35.6 ± 4.0	36.0 ± 3.8	36.3 ± 3.4	34.7 ± 4.2bde
Sum of 4 skinfold Thicknesses (mm)	93.2 ±21.1	81.9 ±15.7	75.3 ±14.8a	77.0 ±14.6a	82.1 ±17.1	83.7 ±18.8
$\dot{V}O_2LT$ (ml/kg/min)	12.6 ± 3.0	16.2 ± 4.1a	17.2 ± 3.6a	16.5 ± 3.0a	15.7 ± 3.1a	15.4 ± 3.4ac
$\dot{V}O_2$peak (ml/kg/min)	17.5 ± 4.0	22.5 ± 6.9a	24.0 ± 6.2a	23.9 ± 5.0a	23.6 ± 5.9a	25.4 ± 4.3a
BPs (mmHg)	141.3 ±12.4	127.5 ±14.3a	127.6 ±12.8a	130.1 ±13.4	131.5 ±15.0	130.8 ±11.3
BPd (mmHg)	88.4 ±12.2	79.5 ± 9.3a	80.3 ± 7.3a	82.1 ± 8.0a	85.7 ± 7.5cd	84.4 ± 6.7ac
TC (mg/dl)	2006.3 ±33.6	210.0 ±25.5	204.6 ±31.0	216.3 ±35.1	219.2 ±27.8	209.9 ±27.3
HDLC (mg/dl)	54.3 ±11.8	51.7 ±10.9	54.4 ± 9.9	56.8 ± 8.2	63.4 ±10.4a	64.6 ± 9.2a
LDLC (mg/dl)	131.5 ±34.3	142.9 ±28.6	136.6 ±31.5	138.8 ±27.5	141.8 ±32.0	126.0 ±37.3
TG (mg/dl)	99.4 ±55.7	76.5 ±38.3a	68.5 ±21.4a	62.9 ±28.0a	71.2 ±34.2	71.5 ±35.8
AI (LDLC/HDLC)	2.6 ± 0.9	3.0 ± 1.3	2.6 ± 0.8	2.5 ± 0.7	2.3 ± 0.8	1.8 ± 0.9a

Data were presented as mean value ± standard deviation. a: significantly different from pre value; b: significantly different from 4-month value; c: significantly different from 8-month value; d: significantly different from 12-month value; e: significantly different from 24-month value.
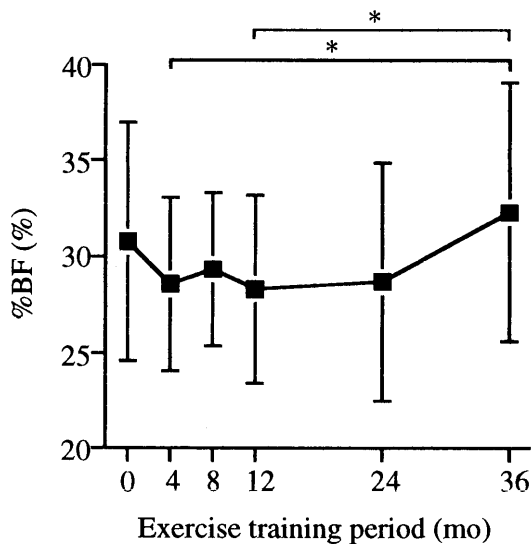
Fig. 2 Changes in %BF during 36-month exercise program. * significantly different from 0-month value.
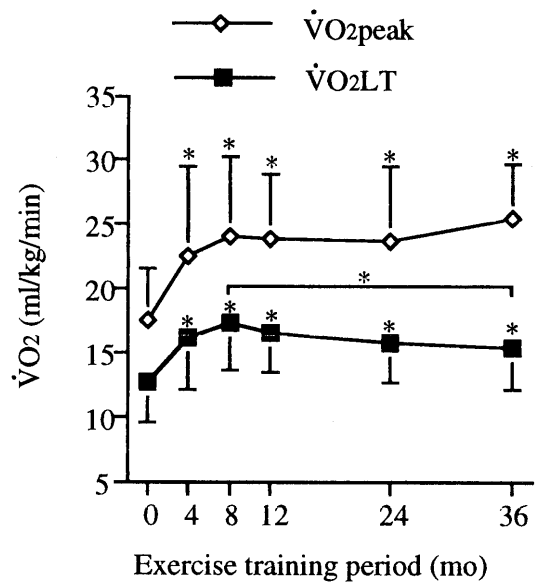
Fig. 3 Changes in $\dot{V}O_2LT$ and $\dot{V}O_2$peak during 36-month exercise program. * significantly different from 0-month value.

riod of the exercise program. Similarly, the $\dot{V}O_2$peak (28.6%) showed the largest increase at month 4 (Fig. 3).

Blood pressure: BPs and BPd decreased to normal levels at month 4 and the decreased levels were maintained after that (Fig. 4).

Blood lipids and lipoproteins: HDLC showed a statistically significant increase at month 24 (Fig. 5). The increased HDLC levels were maintained up to month 36. The largest decrease in TG was found at month 4,

while the lowest mean value of TG was observed at month 12 (Fig. 6). TC and LDLC did not change significantly during the entire study period, while LDLC/HDLC significantly decreased at month 36.

Relationship between age and the absolute amount of change

A significant relationship between age and the absolute amount of change in TG (r = − 0.47) was found with no relationships for other variables.
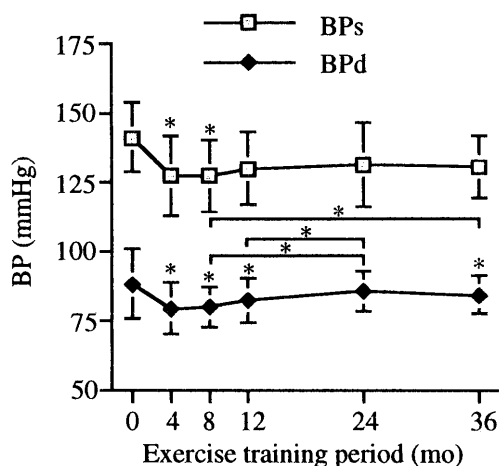
Fig. 4 Changes in BPs and BPd during 36-month exercise program. * significantly different from 0-month value.
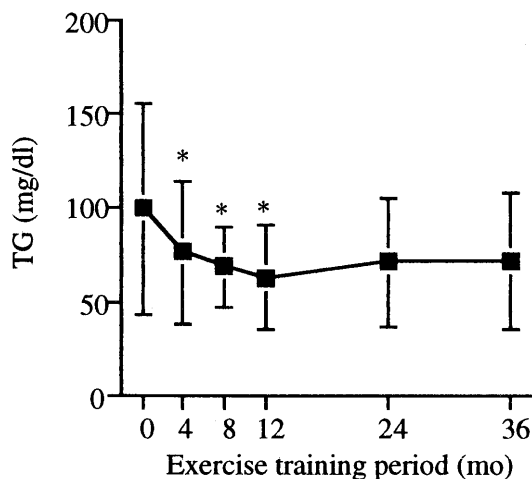
Fig. 6 Changes in TG during 36-month exercise program. * significantly different from 0-month value.
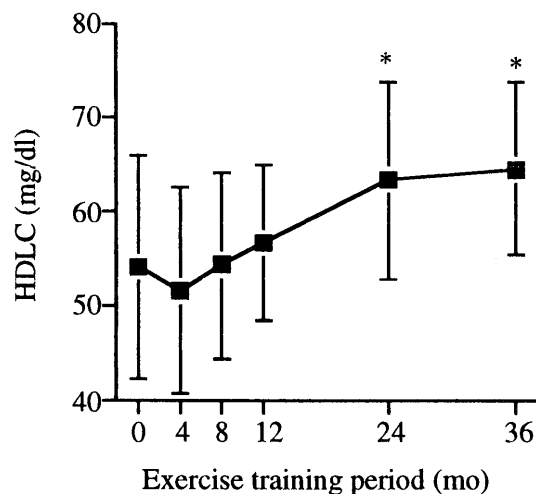

Fig. 5 Changes in HDLC during 36-month exercise program. * significantly different from 0-month value.

Discussion

The present investigation examined the long-term effects of exercise program on aerobic capacity and coronary risk factors in women with IHD. In particular, a focus was on the time course of change in these variables over the 36-month study period. One of the principal findings of our study is that aerobic capacity, BP, and TG improved within 4-8 months of exercise program. Our observed improvements in these variables induced by several months of exercise program are consistent with previous studies (Clausen, 1976;

Detry et al., 1971; Heath et al., 1983; Juneau et al., 1987; LaRosa et al., 1982; Oldridge et al., 1988; Schuler et al., 1988; Verani et al., 1981). However, it is interesting to note that no further improvements in these variables were found during the subsequent period of maintained exercise in our study.

Exercise training altered the body composition of patients within 8 to 12 months. However, %BF returned to initial levels after 36 months. Food intake was not restricted and the amount of exercise was almost constant during the 36 months in our study. Therefore, we assume the increase in %BF observed at month 36 is accounted for by the increase in food intake after month 24. In fact, some patients reported increased intake of diet during this period. These results suggest the difficulty of maintaining or further improving body composition by exercise intervention alone. Dietary intervention is needed in conjunction with exercise program, in order to see further improvement in body composition, if the periods of exercise exceeds 12 months.

The most interesting finding in this study is that HDLC improved at month 24 with no further change after a subsequent period of maintained exercise. An increase in HDLC after a period of exercise has been frequently reported in men with IHD patients (Ballantyne et al., 1982; Hartung et al., 1981; Heath et al., 1983; Streja and Mymin, 1979). For instance, Streja and Mymin (1979) reported a significant increase in HDLC after walking or jogging of 20 - 30 minutes at an intensity of 70 - 85%HRmax, 3 times per week, for 3 months in previouly sedentary men with IHD. It has been pointed out that a larger dose of exercise would be required in women to produce significant increases in HDLC (Haskell,

sclerosis 37: 231-238.

Friedewald WT, Levy RI, Frederickson DS (1972) Estimation of the concentration of low density lipoprotein cholesterol in plasma without use of the preparative ultracentrifuge. Clin Chem 18: 499-502

Gordon T, Castelli WP, Hjortland MC, Kannel WB, Dawber TR (1977) High density lipoprotein as a protective factor against coronary heart disease. The Framingham Study. Am J Med 62: 707-714

Hartung GH, Squires WG, Goto AM Jr (1981) Effect of exercise training on plasma high-density lipoprotein cholesterol in coronary disease patients. Am Heart J 101: 181-184

Haskell WL (1991) Dose-response relationship between physical activity and disease risk factors. In Oja P, Telema R eds. Sport for All. Elsevier Science Publishers, Amsterdam, 125-133.

Heath GW, Ehsani AA, Hagberg JM, Hinderliter JM, Goldberg AP (1983) Exercise training improves lipoprotein lipid profiles in patients with coronary artery disease. Am Heart J 105: 889-895

Hedbäck B, Perk J (1987) 5-year results of a comprehensive rehabilitation programme after myocardial infarction. Eur Heart J 8: 234-242

Hurley BF (1989) Effects of resistive training on lipoprotein-lipid profiles: a comparison to aerobic exercise training. Med. Sci. Sports Exerc, 21: 689-693

Juneau M, Rogers F, Santos VD, Yee M, Evans A, Bohn A, Haskell WL, Taylor CB, DeBusk RF (1987) Effectiveness of self-monitored, home-based, moderate-intensity exercise training in middle-aged men and women. Am J Cardiol 60: 66-70

Kallio V, Hämäläinen H, Hakkila J, Luurila OJ (1979) Reduction in sudden deaths by a multifactorial intervention programme after acute myocardial infarction. Lancet 24: 1091-1094

Kellerman JJ (1973) Physical conditioning in patients after myocardial infarction. Schweiz Med Wochenschr 103: 79-85

LaRosa JC, Cleary P, Muesing RA, Gorman P, Hellerstein HK, Naughton J (1982) Effects of long-term moderate physical exercise on plasma lipoproteins. The National Exercise and Heart Disease Project. Arch Intern Med 142: 2269-2274

Mitchell JE, Tate C, Raven P, Cobb F, Kraus W, Moreadith R, O'Toole M, Saltin B, Wenger N (1992) Acute response and chronic adaptation to exercise in women. Med Sci Sports Exerc 24: S258-S265

Nakadomo F, Tanaka K, Hazama T, Maeda K (1990) Validation of body composition assessed by bioelectric impedance analysis. Jpn J Appl Physiol 20: 321-330

O'Conner GT, Buring JE, Yusurf S, Goldhaber SZ, Olmstead EM, Paffenberger RS, Hennekens CH (1989) An overview of randomized trials of rehabilitation with exercise after myocardial infarction. Circulation 80: 234-244

Oldridge NB, Nagle FJ, Balke B, Corliss RJ, Kahn DR (1978) Aortocoronary bypass surgery: Effects of surgery and 32 months of physical conditioning on treadmill performance. Arch Phys Med Rehabil 59: 268-274

Oldridge NB, Guyatt GH, Fischer ME, Rimm AA (1988) Cardiac rehabilitation after myocardial infarction. Combined experience of randomized clinical trials. JAMA 260: 945-950

Perk J, Hedbäck B, Jutterdal S (1989) Cardiac rehabilitation: evaluation of a long-term programme of physical training for out-patients. Scand J Rehab Med 21: 13-17

Schuler G, Schlierf G, Wirth A, Mautner HP, Acheurlen H, Thumm M, Roth H, Schwarz F, Kohlmeier M, Mehmel HC, Kübler W (1988) Low-fat and regular supervised physical exercise in patients with symptomatic coronary artery disease: reduction of stress-induced myocardial ischemia. Circulation 77: 172-181

Seals DR, Hagberg JM, Hurley BF, Ehsani AA, Holloszy JO (1984) Effects of endurance training on glucose tolerance and plasma lipid levels in older men and women. JAMA 252: 645-649.

Streja D, Mymin D (1979) Moderate exercise and high-density lipoprotein-cholesterol. Observations during a cardiac rehabilitation program. JAMA 242: 2190-2192

Tanaka K, Watanabe Y, Hiyama T, Takeda M, Yoshimura T (1992) Changes in vital age of CHD patients following a supervised aerobic conditioning program. Jpn J Atheroscler Soc 20: 597-603.

Tanaka K, Hiyama T, Watanabe Y, Asano K, Takeda M, Hayakawa Y, Nakadomo F (1993) Assessment of exercise-induced alterations in body composition of patients with coronary heart disease. Eur J Appl Physiol 66: 321-327

Verani MS, Hartung GH, Hoepfel-Harris J, Welton DE, Pratt CM, Miller RR (1981) Effects of exercise training on left ventricular performance and myocardial perfusion in patients with coronary artery disease. Am J Cardiol 47: 797-803

Wood PD, Stefanick ML, Dreon DM, Frey-Hewitt B, Garay SC, Williams PT, Superko HR, Fortmann SP, Albers JJ, Vranizan KM, Ellsworth NM, Terry RB, Haskell WL (1988) Changes in plasma lipids and lipoproteins in overweight men during weight loss through dieting as compared with exercise. N Engl J Med 319: 1173-1179