Effects of Low-Intensity Aerobic Training on the High-Density Lipoprotein Cholesterol Concentration in Healthy Elderly Subjects

Yoshiyuki Sunami, Mitsugi Motoyama, Fujihisa Kinoshita, Yoshiko Mizooka, Kazuyo Sueta, Akira Matsunaga, Jun Sasaki, Hiroaki Tanaka, and Munehiro Shindo

The concentration of high-density lipoprotein cholesterol (HDL-C) is inversely correlated with the risk of coronary heart disease. The effects of low-intensity aerobic training on serum HDL-C and other lipoprotein concentrations were examined in healthy elderly subjects. The subjects were randomly assigned to two groups matched for sex, age, height, and weight. The training group (n = 20, 10 men and 10 women aged 67 ± 4 years) participated in a supervised physical exercise regimen using a bicycle ergometer at an intensity of 50% estimated maximal oxygen consumption ($\dot{V}O_2max$) for 60 minutes two to four times per week for 5 months. In contrast, the control group (n = 20, 10 men and 10 women aged 68 ± 4 years) did not perform any particular physical training. The training protocol resulted in significant increases in the $\dot{V}O_2max$ ($P < .05$), HDL-C, HDL_2-C, and HDL_2-C/HDL_3-C ratio ($P < .01$). The change in HDL_2-C ($r = .57$, $P < .01$) and HDL_2-C/HDL_3-C ($r = .63$, $P < .01$) was positively associated with an increase in the total exercise duration per week. In addition, the total weekly exercise duration also showed a significant positive relationship with HDL-C ($r = .75$, $P < .01$), HDL_2-C ($r = .81$, $P < .01$), and HDL_2-C/HDL_3-C ($r = .71$, $P < .01$) after the training period. The changes in body weight and the $\dot{V}O_2max$ were not significantly correlated with any lipid parameters. Low-intensity aerobic training may improve the profile of HDL-C and its subfractions in healthy elderly subjects. Also, the total exercise duration may be an important factor for improving HDL-C and HDL_2-C in elderly subjects.

HIGH PLASMA LEVELS of high-density lipoprotein cholesterol (HDL-C) are believed to protect against the development of coronary heart disease.[1,2] HDL-C is composed of HDL_2-C and HDL_3-C subfractions. Epidemiological studies have shown that the HDL_2-C subfraction is most inversely associated with a reduced risk of coronary heart disease.[3,4] Several cross-sectional studies have demonstrated that elite endurance runners[5-7] and physically active people[8,9] have a higher level of HDL_2-C than sedentary people. Numerous studies have been reported regarding the effects of aerobic training on HDL-C subfractions in young[10] and middle-aged[11-18] subjects. These reports all indicated that HDL_2-C can be maintained at high levels with an improvement in regular physical activity, which is thus considered a necessary and important component of coronary heart disease prevention.

Nevertheless, there is little information on the effect of aerobic training on HDL-C subfractions in elderly subjects.[19,20] Previous reports have noted that high-intensity training may improve HDL-C subfraction profiles. However, there are no data on the effect of low-intensity endurance training on HDL-C subfractions in elderly subjects. In this study, we investigated the effects of low-intensity aerobic training on serum lipid and lipoprotein concentrations in healthy elderly subjects, especially regarding the HDL-C subfraction profiles.

From the Department of Exercise Physiology, Faculty of Sports and Health Science, and Department of Internal Medicine, School of Medicine, Fukuoka University, Fukuoka; and the Faculty of Life Science, Seika Women's Junior College, Fukuoka, Japan.

Submitted January 5, 1998; accepted February 25, 1999.

Supported in part by grants from the Fukuoka University Research Fund and the Japanese Ministries of Health and Welfare (00209065, 00264886, and 00464607).

Current address: M.M., Faculty of Education, Wakayama University, Wakayama 640-8510, Japan; F.K., Department of Health Promotion, Wakayama Wellness Foundation, Wakayama 640-8555, Japan.

Address reprint requests to Munehiro Shindo, MS, Department of Exercise Physiology, Faculty of Sports and Health Science, Fukuoka University, 8-19-1 Nanakuma, Jonan-ku, Fukuoka 814-0180, Japan.

0026-0495/99/4808-0010$10.00/0

SUBJECTS AND METHODS

Subjects

Forty healthy elderly Japanese subjects (20 men and 20 women) participated in the study. The mean age was 67 years (range, 60 to 77). The health status was evaluated by a physical examination including blood pressure measurement, routine blood analyses, and an electrocardiogram. Individuals were excluded from the study if they had any medical problems that could interfere with performance of the exercise program.

The subjects were randomly assigned to the training group and control group matched for age, height, and weight. Each group consisted of 10 men and 10 women. The training group accepted the following criteria: (1) the total exercise duration per week was fixed during the training period, and (2) no change in regular physical activity was allowed. None were taking medications known to influence lipid or lipoprotein metabolism. The control group did not perform any particular physical training. All subjects were advised to maintain their previous lifestyle throughout the study period, including diet, alcohol consumption, and regular physical activity. Informed consent was obtained from all subjects after an explanation of the design and purpose of the study.

Diet Evaluation

Subjects in the training group were instructed to record their dietary intake for 3 days, including 1 weekend day, before and after the training period, with a questionnaire and interview methods by a nutritionist.

Determination of Exercise Intensity and Training Methods

The estimated maximal oxygen consumption ($\dot{V}O_2max$) was determined by the modified[21] method of Astrand and Ryming,[22] which measures the heart rate at three different submaximal workloads using an electric bicycle ergometer (ML-1400; Fukuda Electronic, Tokyo, Japan). The exercise intensity for each subject in the training group was set at 50% $\dot{V}O_2max$ from the estimated $\dot{V}O_2max$. Subjects in the training group exercised for 60 min/d two to four times per week for 5 months on the electric bicycle ergometer (FFS; Bridgestone Cycle, Tokyo, Japan). After every session of 30 bouts of exercise training, each subject underwent a submaximal exercise test to readjust the 50% $\dot{V}O_2max$ intensity level.

The total exercise duration per week mainly consisted of training on the bicycle ergometer (mean duration per week, 192 ± 32 minutes) under the supervision of either an exercise physiology specialist or a nurse and other regular supplementary low-intensity exercises (four men and three women; mean duration per week, 74 ± 47 minutes), including walking and social dancing, that corresponded to the metabolic rate at 50% $\dot{V}O_2$max. None of the subjects engaged in any heavy regular physical activity.

Blood Sampling and Morphological Measurements

Blood for lipid and lipoprotein measurements was collected in the early morning by venipuncture from an antecubital vein after at least 12 hours of fasting. The serum was recovered following centrifugation at 3,000 rpm for 15 minutes and then stored at 4°C. All analyses were completed within 48 hours. Total cholesterol and triglyceride concentrations were determined by the enzymatic method.[23] HDL-C was quantified by the heparin-manganese precipitation method.[24] HDL-C subfractions were separated by preparative ultracentrifugation.[25] The HDL_2-C subfraction was calculated as the difference between total HDL-C and HDL_3-C. Low-density lipoprotein cholesterol (LDL-C) was calculated according to the method of Friedewald et al.[26] Percent body fat was estimated based on the sum of triceps and subscapula skinfolds measured with a skinfold caliper[27] using the formula of Brozek et al.[28] The waist circumference was measured at the narrowest point between the rib cage and the iliac crest, and hip circumference was measured at the level of the greater trochanter. The waist to hip ratio (WHR) was used as an index of upper-body or abdominal obesity.

Statistical Analysis

We combined the data from both sexes, because lipoprotein levels at baseline and changes in these parameters with endurance training did not significantly differ between the sexes by analysis of covariance. All data were analyzed using JMP statistical software (SAS Institute, Cary, NC). An unpaired Student t test was used to evaluate group differences in baseline and endpoint measures. A two-factor repeated-measures ANOVA was used to determine the effect of exercise on the changes in outcome variables. When F ratios were significant, a Tukey multiple-comparison test was used to identify significantly different pairs of mean values. A simple linear regression analysis was used to determine the relationships among body weight, percent body fat reduction, total exercise duration per week (corresponding to 50% $\dot{V}O_2$max), and lipid metabolism. Statistical significance was set at a P level less than .05. The data are presented as the mean ± SD.

RESULTS

Table 1 lists the physical features of subjects in both groups. No significant differences were found for any characteristics between the training and control groups before the training period. The mean total exercise duration (corresponding to 50% $\dot{V}O_2$max) in the training group was 218 ± 57 min/wk. In the training group, body weight and percent body fat did not change significantly. A significant increase was found for the $\dot{V}O_2$max ($P < .01$) in the training group. There was no change in the blood pressure and WHR in the training group, and no significant changes were found for any of these parameters in the control group. Total energy consumption (1,828 ± 316 to 1,775 ± 73 kcal/d) and protein (64.6 ± 12.1 to 66.8 ± 13.9 g/d), fat (40.6 ± 12.6 to 46.4 ± 21.7 g/d), and carbohydrate (278.7 ± 61.3 to 247.1 ± 39.5 g/d) intake were not significantly different at baseline versus the endpoint of training in the training group.

Serum lipid and lipoprotein concentrations and the atherogenic index in the training and control groups before and after the training period are shown in Table 2. There was a significant increase in HDL-C, HDL_2-C, and the HDL_2-C/HDL_3-C ratio ($P < .01$) and a significant decrease in HDL_3-C ($P < .05$) for the training group after 5 months. The mean changes were 9.3% for HDL-C, 21.6% for HDL_2-C, and 39.3% for the HDL_2-C/HDL_3-C ratio. The training group showed a significantly higher HDL-C, HDL_2-C, and HDL_2-C/HDL_3-C ratio ($P < .05$) compared with the control group after 5 months. No significant change was observed for any other parameters in the training group or control group.

The total exercise duration per week correlated positively with the change in HDL_2-C ($r = .57$, $P < .01$) and the HDL_2-C/HDL_3-C ratio ($r = .63$, $P < .01$) in the training group following the 5-month training period (Fig 1). The changes in body weight, percent body fat, and the $\dot{V}O_2$max were not significantly correlated with any lipid parameters in the training group (data not shown).

The total exercise duration per week also showed a significantly positive relationship with HDL-C ($r = .75$, $P < .01$) and HDL_2-C ($r = .81$, $P < .01$) levels and the HDL_2-C/HDL_3-C

Table 1. Body Characteristics, Blood Pressure, and $\dot{V}O_2$max Before and After Training

Parameter	Training Group (n = 20) Before	Training Group (n = 20) After	Control Group (n = 20) Before	Control Group (n = 20) After
Body weight (kg)	53.3 ± 6.1	52.9 ± 6.0	55.1 ± 7.7	55.0 ± 6.8
BMI (kg/m²)	22.0 ± 2.3	21.8 ± 2.0	22.7 ± 2.8	22.5 ± 2.4
Body fat (%)	20.7 ± 9.0	19.8 ± 6.7	21 4 ± 9.2	20.4 ± 7.4
WHR	0.86 ± 0.07	0.89 ± 0.07	0.89 ± 0.06	0.91 ± 0.06
SBP (mm Hg)	142 ± 22	140 ± 19	145 ± 24	138 ± 19
DBP (mm Hg)	83 ± 11	81 ± 11	83 ± 12	79 ± 9
$\dot{V}O_2$max (mL/kg/min)	29.8 ± 5.7	31.9 ± 5.4*	30.5 ± 7.8	30.0 ± 6.3

NOTE. Values are the mean ± SD.

Abbreviations: SBP, systolic blood pressure; DBP, diastolic blood pressure.

*$P < .01$, before v after

Table 2. Lipid and Lipoprotein Concentrations Before and After Training

Parameter	Training Group (n = 20) Before	Training Group (n = 20) After	Control Group (n = 20) Before	Control Group (n = 20) After
TC (mg/dL)	203.7 ± 21.5	212.2 ± 24.9	207.1 ± 31.2	213.6 ± 37.4
LDL-C (mg/dL)	133.2 ± 21.9	138.4 ± 18.7	134.9 ± 28.8	142.0 ± 33.4
HDL-C (mg/dL)	51.3 ± 11.3	56.2 ± 13.9†	49.7 ± 10.8	48.1 ± 11.1‡
HDL_2-C (mg/dL)	32.9 ± 9.5	40.0 ± 12.7†	31.5 ± 9.5	32.0 ± 10.0‡
HDL_3-C (mg/dL)	18.4 ± 4.0	16.2 ± 3.4*	18.3 ± 2.9	17 5 ± 3.0
TG (mg/dL)	84 8 ± 27.7	87.7 ± 30.0	108.0 ± 44.0	111.7 ± 54.1
TC/HDL-C ratio	4.17 ± 1.11	3.94 ± 0.78	4.22 ± 0.96	4.48 ± 0.91
LDL-C/HDL-C ratio	2.76 ± 0.95	2.60 ± 0.67	2.78 ± 0.85	2.99 ± 0.79
HDL_2-C/HDL_3-C ratio	1.83 ± 0.63	2.55 ± 1.03†	1.74 ± 0.51	1.83 ± 0.63‡

NOTE. Values are the mean ± SD.

Abbreviations. TC, total cholesterol; TG, triglycerides.

*$P < .05$, before v after.

†$P < .01$, before v after.

‡$P < .05$, training group v control group during the same period.

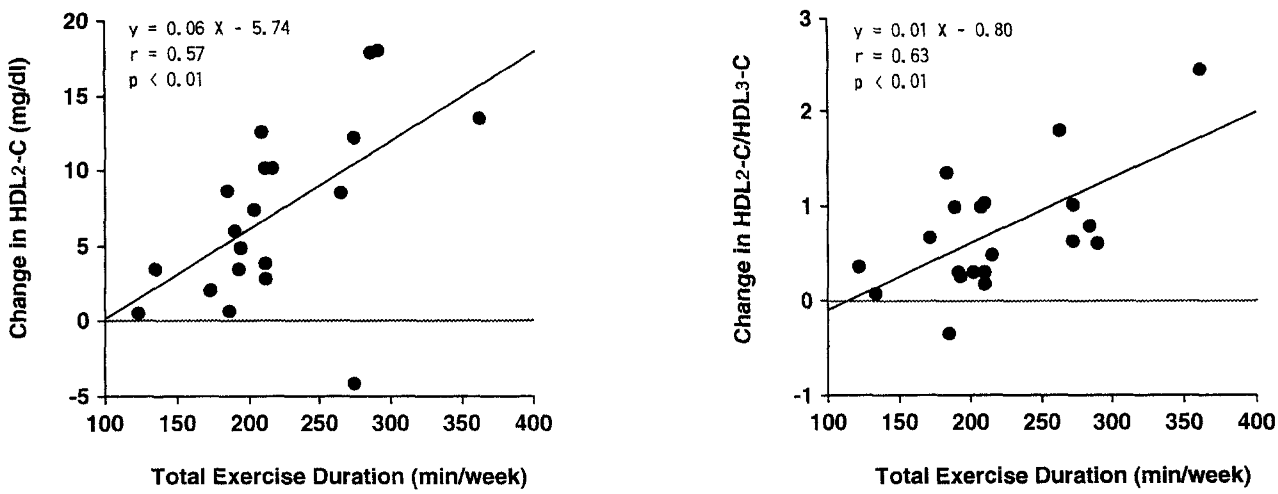

Fig 1. Relationship between the changes in HDL_2-C and the HDL_2-C/HDL_3-C ratio and the total exercise duration per week in the training group following 5 months of training.

ratio ($r = .71$, $P < .01$) (Fig 2), while a negative relationship was observed for the LDL-C/HDL-C ratio ($r = .51$, $P < .05$) in the training group after the training period. No significant relationship was observed between the body weight or percent body fat reduction and the level of any lipid parameter in the training group after the training period (data not shown).

DISCUSSION

Five months of supervised low-grade training at an intensity of 50% $\dot{V}O_2$max by healthy elderly subjects significantly increased HDL-C and HDL_2-C levels and the HDL_2-C/HDL_3-C ratio. The changes in HDL_2-C ($r = .57$, $P < .01$) and the HDL_2-C/HDL_3-C ratio ($r = .63$, $P < .01$) were positively associated with an increase in the total exercise duration per week. These findings thus suggest that elderly subjects show a clear improvement in HDL-C subfractions after low-intensity endurance training.

Several longitudinal studies have reported a significant increase in HDL-C after endurance training in elderly subjects,[19,20,29-32] but others have not.[19,33-35] The reason for this

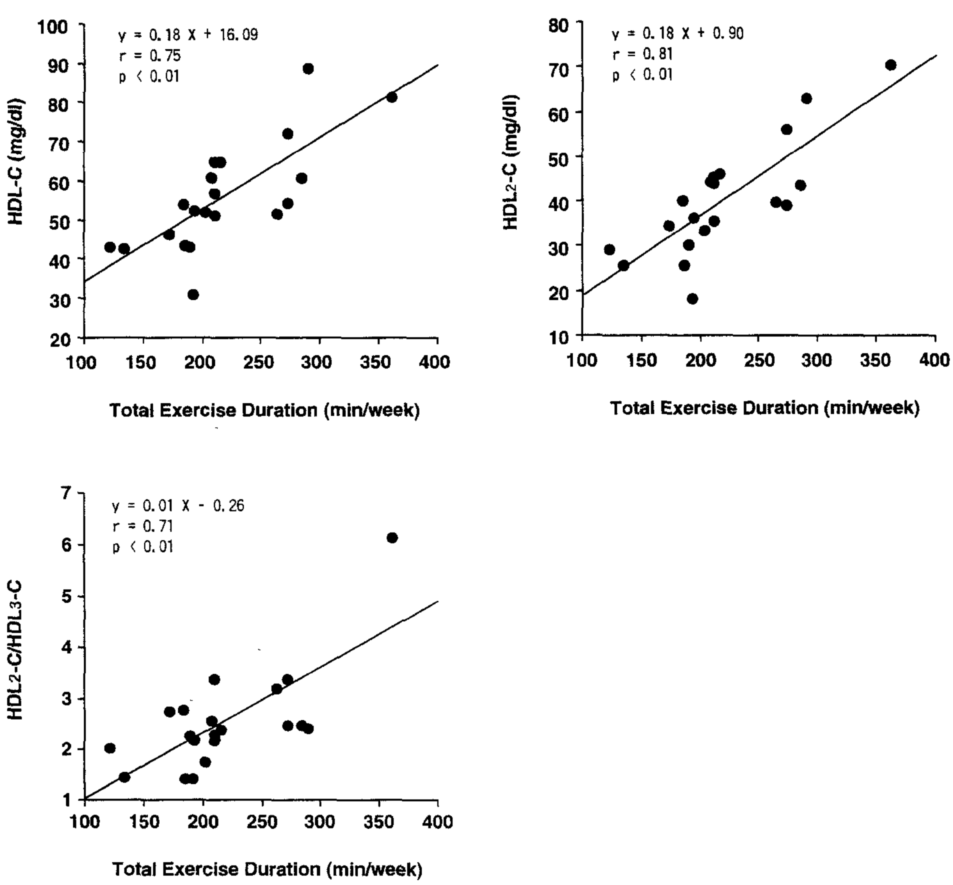

Fig 2. Relationship between HDL-C, HDL_2-C, and the HDL_2-C/HDL_3-C ratio and the total exercise duration per week in the training group after the training period.

discrepancy is most likely related to the exercise intensity or duration, changes in body weight, and pretraining HDL-C levels. Previous studies implied that vigorous exercise leads to a more favorable effect on serum lipid and lipoprotein concentrations. We previously observed a significant increase in HDL-C after 9 months of exercise for 30 min/d three to six times per week at low-intensity aerobic training without a weight reduction in elderly patients.[29] These studies suggested that if the exercise duration per week during the training period is longer, then HDL-C may even be increased by low-intensity training in elderly subjects. The present study thus confirmed the hypothesis that low-intensity training can induce an increase in HDL_2-C in healthy elderly subjects. All elderly subjects in the training group completely and continuously performed exercise for 60 minutes per session, since the training intensity was low. Usually, they enjoyed watching television and talking during exercise. We believe that this volume of exercise is feasible in elderly subjects. In fact, most of the subjects continue to perform a similar volume of exercise after this experiment. In the study reported by Sasaki et al[16] in which low-intensity exercise at the lactate threshold was prescribed for middle-aged patients with essential hypertension, a significant increase in plasma HDL_2-C, but not total HDL-C, was observed as a result of training on a bicycle ergometer for 60 min/d three times per week for 10 weeks. Nye et al[13] showed a significant increase in HDL_2-C and decrease in HDL_3-C after moderate exercise training in previously sedentary men. Ballantyne et al[11] showed that the increase in HDL-C is mainly attributable to an increase in the HDL_2 subfraction by moderate physical exercise. Despres et al[15] studied exercise training in obese women and found a significant increase in HDL_2-C and the HDL_2-C/HDL_3-C ratio and a decrease in HDL_3-C, but no change in total HDL-C, with exercise at less than 55% $\dot{V}O_2$max four to five times per week for 14 months. These data are analogous to the results of the present study in elderly subjects.

It is well known that the improvement in lipid and lipoprotein profiles with endurance training is normally associated with a significant body weight reduction.[15,34,36-39] However, the previous studies that demonstrated an improvement in lipid and lipoprotein profiles with a significant reduction in body weight were mostly based on obese subjects (body mass index [BMI] > 29 kg/m^2 and/or body fat > 30%). Nicklas et al[40] showed that endurance exercise training without a weight loss increases HDL-C and HDL_2-C levels in lean (BMI, 25 ± 1 kg/m^2) and moderately obese (BMI, 29 ± 1 kg/m^2) middle-aged and older men, but not in obese (BMI, 33 ± 2 kg/m^2) men. Thompson et al[17] reported that exercise training without a weight loss increased serum HDL-C and HDL_2-C in overweight men (BMI, 28.1 ± 2.5 kg/m^2). In non-obese subjects, improvement in lipid and lipoprotein profiles, especially the HDL_2-C subfraction, has also been observed in the absence of either a body weight or percent body fat reduction.[10,13,16] In the present study, favorable changes in HDL-C and HDL_2-C levels and the HDL_2-C/HDL_3-C ratio were observed without a reduction in either body weight or percent body fat in elderly subjects following low-intensity training for 5 months. Moreover, no significant relationship was observed between the reduction in body weight and/or percent body fat and the change in any lipid or lipoprotein parameters.

The total exercise duration per week correlated positively with the changes in HDL_2-C and the HDL_2-C/HDL_3-C ratio, while the changes in body weight, percent body fat, and the $\dot{V}O_2$max were not significantly correlated with any lipid parameters. It seems that the total exercise duration per week may thus better reflect favorable changes in the lipid and lipoprotein profiles in non-obese elderly subjects. Furthermore, in the present study, a significantly positive relationship was observed between the total exercise duration per week and total HDL-C, HDL_2-C, and the HDL_2-C/HDL_3-C ratio after the training period. Our results thus agree with the finding of a positive relationship between the running distance per week and plasma HDL-C and/or HDL_2-C concentrations in previous studies.[41-45] Kokkinos et al[45] reported a dose-response relationship between HDL-C levels and running miles per week at mild to moderate intensity in middle-aged men, and Williams[44] showed that HDL-C levels increased significantly in relation to the number of running kilometers per week in premenopausal female recreational runners. Our results therefore strongly support the proposition that increased physical activity improves total HDL-C and the HDL-C subfractions.

Several of the physiological mechanisms by which exercise training improves the HDL_2-C subfraction have been described in previous reports. Lecithin cholesterol acyltransferase (LCAT) and lipoprotein lipase (LPL) are important for converting HDL_3-C to HDL_2-C, and hepatic triglyceride lipase (HTGL) is involved in converting HDL_2-C to HDL_3-C.[46] Since LCAT and LPL activity have been shown to increase while HTGL activity decreases with exercise training,[47,48] the same phenomenon most likely occurred in our elderly subjects.

The findings of the present study thus suggest that low-intensity aerobic training improves serum lipid and lipoprotein concentration profiles, especially the HDL-C subfraction profile, in healthy elderly subjects. Moreover, the total exercise duration per week was also identified as an important factor for improving HDL-C and HDL_2-C levels.

ACKNOWLEDGMENT

The authors are grateful for the product support provided by Bridgestone Cycle Co and Fukuda Electronic Co, for the excellent conducting assistance of Miyoko Yamauchi and Yoshiko Hosoya, and for the constructive criticism of the manuscript of Dr Shuzo Kumagai in the Kyusyu University School of Health Science.

REFERENCES

1. Zimetbaum P, Frishman WH, Ooi WL, et al: Plasma lipids and lipoproteins and the incidence of cardiovascular disease in the very elderly. The Bronx Aging Study. Arterioscler Thromb 12:416-423, 1992

2. Wilson PW, Abbott RD, Castelli WP: High density lipoprotein cholesterol and mortality. The Framingham Heart Study. Arteriosclerosis 8:737-741, 1988

3 Musliner TA, Krauss RM: Lipoprotein subspecies and risk of coronary disease. Clin Chem 34:B78-B83, 1988

4. Miller NE, Hammett F, Saltissi S, et al: Relation of angiographically defined coronary artery disease to plasma lipoprotein subfractions and apolipoproteins. BMJ Clin Res Ed 282:1741-1744, 1981

5. Wood PD, Haskell WL: The effect of exercise on plasma high density lipoproteins. Lipids 14·417-427, 1979

6. Durstine JL, Pate RR, Sparling PB, et al: Lipid, lipoprotein, and iron status of elite women distance runners. Int J Sports Med 2:119-123, 1987

7. Sasaki J, Tanabe Y, Tanaka H, et al: Elevated levels of HDL2-cholesterol and apo A-I in national class Japanese male marathon runners. Atherosclerosis 70:175-177, 1988

8. Wood PD: Physical activity, diet, and health: Independent and interactive effects. Med Sci Sports Exerc 26:838-843, 1994

9. Owens JF, Matthews KA, Wing RR, et al: Physical activity and cardiovascular risk: A cross-sectional study of middle-aged premenopausal women. Prev Med 19:147-157, 1990

10. Raz I, Rosenblit H, Kark JD: Effect of moderate exercise on serum lipids in young men with low high density lipoprotein cholesterol. Arteriosclerosis 8:245-251, 1988

11. Ballantyne FC, Clark RS, Simpson HS, et al: The effect of moderate physical exercise on the plasma lipoprotein subfractions of male survivors of myocardial infarction. Circulation 65:913-918, 1982

12. Schwartz RS: The independent effects of dietary weight loss and aerobic training on high density lipoproteins and apolipoprotein A-I concentrations in obese men. Metabolism 36:165-171, 1987

13. Nye ER, Carlson K, Kirstein P, et al: Changes in high density lipoprotein subfractions and other lipoproteins by exercise. Clin Chim Acta 113:51-57, 1981

14. Hardman AE, Hudson A: Brisk walking and serum lipid and lipoprotein variables in previously sedentary women. Br J Sports Med 28:261-266, 1994

15. Despres JP, Pouliot MC, Moorjani S, et al: Loss of abdominal fat and metabolic response to exercise training in obese women. Am J Physiol 261:E159-E167, 1991

16. Sasaki J, Urata H, Tanabe Y, et al: Mild exercise therapy increases serum high density lipoprotein2 cholesterol levels in patients with essential hypertension. Am J Med Sci 297:220-223, 1989

17. Thompson PD, Yurgalevitch SM, Flynn MM, et al: Effect of prolonged exercise training without weight loss on high-density lipoprotein metabolism in overweight men. Metabolism 46:217-223, 1997

18. Crouse SF, O'Brien BC, Grandjean PW, et al: Training intensity, blood lipids, and apolipoproteins in men with high cholesterol. J Appl Physiol 82:270-277, 1997

19. Schwartz RS: Effects of exercise training on high density lipoproteins and apolipoprotein A-I in old and young men. Metabolism 37:1128-1133, 1988

20. Schwartz RS, Cain KC, Shuman WP, et al: Effect of intensive endurance training on lipoprotein profiles in young and older men. Metabolism 41:649-654, 1992

21. Shindo M, Tanaka H, Kitashima H, et al: Ergometry-stress testing by aerobic exercise. Rinsho Byori 28:12-18, 1980

22. Astrand PO, Ryming I: A nomogram for calculation of aerobic capacity (physical fitness) from pulse rate during submaximal work. J Appl Physiol 7:218-221, 1954

23. Allain CC, Poon LS, Chan CS, et al: Enzymatic determination of total serum cholesterol. Clin Chem 20:470-475, 1974

24. Warnick GR, Albers JJ: A comprehensive evaluation of the heparin-manganese precipitation procedure for estimating high density lipoprotein cholesterol. J Lipid Res 19:65-76, 1978

25. Havel RJ, Edger HA, Bragdon JH: The distribution and chemical composition of ultracentrifugally separated lipoproteins in human serum. J Clin Invest 34:1345-1353, 1955

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

27. Nagamine S, Suzuki S: Anthropometry and body composition of Japanese young men and women. Hum Biol 36:8-15, 1964

28. Brozek J, Grande F, Anderson JT, et al: Densitometric analysis of body composition: Revision of some quantitative assumptions. Ann NY Acad Sci 110:113-140, 1963

29. Motoyama M, Sunami Y, Kinoshita F, et al: The effects of long-term low intensity aerobic training and detraining on serum lipid and lipoprotein concentrations in elderly men and women. Eur J Appl Physiol 70:126-131, 1995

30. Seals DR, Hagberg JM, Hurley BF, et al: Effects of endurance training on glucose tolerance and plasma lipid levels in older men and women. JAMA 252:645-649, 1984

31. Koro T: Physical training in the aged person. Jpn Circ J 54:1465-1470, 1990

32. Whitehurst M, Menendez E: Endurance training in older women. Phys Sports Med 19:95-104, 1991

33. Foster VL, Hume GJ, Byrnes WC, et al: Endurance training for elderly women: Moderate vs low intensity. J Gerontol 44:M184-M188, 1989

34. Coon PJ, Bleecker ER, Drinkwater DT, et al: Effects of body composition and exercise capacity on glucose tolerance, insulin, and lipoprotein lipids in healthy older men: A cross-sectional and longitudinal intervention study. Metabolism 38:1201-1209, 1989

35. Fonong T, Toth MJ, Ades PA, et al: Relationship between physical activity and HDL-cholesterol in healthy older men and women: A cross-sectional and exercise intervention study. Atherosclerosis 127:177-183, 1996

36. Wood PD, Stefanick ML, Dreon DM, et al: 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, 1988

37. Williams PT, Krauss RM, Vranizan KM, et al: Changes in lipoprotein subfractions during diet-induced and exercise-induced weight loss in moderately overweight men. Circulation 81:1293-1304, 1990

38. Lamarche B, Despres JP, Pouliot MC, et al: Is body fat loss a determinant factor in the improvement of carbohydrate and lipid metabolism following aerobic exercise training in obese women? Metabolism 41:1249-1256, 1992

39. Katzel LI, Bleecker ER, Rogus EM, et al: Sequential effects of aerobic exercise training and weight loss on risk factors for coronary disease in healthy, obese middle-aged and older men. Metabolism 46:1441-1447, 1997

40. Nicklas BJ, Katzel LI, Busby Whitehead J, et al: Increases in high-density lipoprotein cholesterol with endurance exercise training are blunted in obese compared with lean men. Metabolism 46:556-561, 1997

41. Lehtonen A, Viikari J: Serum triglycerides and cholesterol and serum high-density lipoprotein cholesterol in highly physically active men. Acta Med Scand 204:111-114, 1978

42. Wood PD, Haskell WL, Blair SN, et al: Increased exercise level and plasma lipoprotein concentrations: A one-year, randomized, controlled study in sedentary, middle-aged men. Metabolism 32:31-39, 1983

43. Williams PT, Wood PD, Haskell WL, et al: The effects of running mileage and duration on plasma lipoprotein levels. JAMA 247:2674-2679, 1982

44. Williams PT: High-density lipoprotein cholesterol and other risk factors for coronary heart disease in female runners. N Engl J Med 334:1298-1303, 1996

45. Kokkinos PF, Holland JC, Narayan P, et al: Miles run per week and high-density lipoprotein cholesterol levels in healthy, middle-aged men. A dose-response relationship. Arch Intern Med 155:415-420, 1995

46. Eisenberg S: High density lipoprotein metabolism. J Lipid Res 25:1017-1058, 1984

47. Haskell WL: Exercise-induced changes in plasma lipids and lipoproteins. Prev Med 13:23-36, 1984

48. Urata H, Sasaki J, Tanabe Y, et al: Effect of mild aerobic exercise on serum lipids and apolipoproteins in patients with coronary artery disease. Jpn Heart J 28:27-34, 1987