Long-term Effects of Varying Intensities and Formats of Physical Activity on Participation Rates, Fitness, and Lipoproteins in Men and Women Aged 50 to 65 Years

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Background Although exercise parameters such as intensity and format have been shown to influence exercise participation rates and physiological outcomes in the short term, few data are available evaluating their longer-term effects. The study objective was to determine the 2-year effects of differing intensities and formats of endurance exercise on exercise participation rates, fitness, and plasma HDL cholesterol levels among healthy older adults.

Methods and Results Higher-intensity, group-based exercise training; higher-intensity, home-based exercise; and lower-intensity, home-based exercise were compared in a 2-year randomized trial. Participants were 149 men and 120 postmenopausal women 50 to 65 years of age who were sedentary and free of cardiovascular disease. Recruitment was achieved through a random digit-dial community telephone survey and media promotion. All exercise occurred in community settings. For higher-intensity exercise training, three 40-minute endurance training sessions per week were prescribed at 73% to 88% of peak treadmill heart rate. For lower-intensity exercise, five 30-minute endurance training sessions per week were prescribed at 60% to 73% of peak treadmill heart rate. Treadmill exercise performance, lipoprotein levels and other heart disease risk factors, and exercise adherence were evaluated at baseline and across the 2-year period. Treadmill exercise test performance improved for all three training conditions during year 1 and was successfully maintained during year 2, particularly for subjects in the higher-intensity, home-based condition. Subjects in that condition also showed the greatest year 2 exercise adherence rates ($P<.003$). Although no significant increases in HDL cholesterol were observed during year 1, by the end of year 2 subjects in the two home-based training conditions showed small but significant HDL cholesterol increases over baseline ($P<.01$). The increases were particularly pronounced for subjects in the lower-intensity condition, whose exercise prescription required more frequent exercise sessions per week. For all exercise conditions, increases in HDL cholesterol were associated with decreases in waist-to-hip ratio in both men and women ($P<.04$).

Conclusions While older adults can benefit from initiating a regular regimen of moderate-intensity exercise in terms of improved fitness levels and small improvements in HDL cholesterol levels, the time frame needed to achieve HDL cholesterol change (2 years) may be longer than that reported previously for younger populations. Frequency of participation may be particularly important for achieving such changes. Supervised home-based exercise regimens represent a safe, attractive alternative for achieving sustained participation. (***Circulation*. 1995;91:2596-2604.**)

Key Words • exercise • lipoproteins • cholesterol • aging • risk factors

Although the health effects of regular physical activity across a variety of chronic disease areas, including cardiovascular disease, are now well established,[1-3] identifying strategies for facilitating sustained exercise participation at a level sufficient to provide these health benefits remains a major public health challenge.[4] The modification of exercise parameters such as intensity and format (for example, class-based versus home-based) have been found to influence exercise participation rates in the short term (1 year or less).[4] However, few data are currently available evaluating the effects of such variables on longer-term participation rates in reasonably representative samples of adult men and women.

In addition, it is becoming increasingly apparent from epidemiological evidence that the quantity and intensity of physical activity required to obtain positive physiological changes such as increases in cardiorespiratory fitness may differ from that needed to have a positive impact on other aspects of cardiovascular disease risk.[1,2] For instance, it has been shown recently that more moderate levels of activity carried out for less than a year may improve the lipoprotein profile (that is, increase HDL cholesterol levels) of young adult women despite only modest increases in fitness.[5] Cross-sectional population-based investigations have indicated that exercise levels attainable by older men and women are associated with significantly greater HDL levels in older adults.[6] Few experimental data are available, however, to illuminate the time frame (1 year versus 2 years) as well as the frequency and intensity of physical activity required to achieve positive lipid changes in older (postmenopausal) women and men. In light of accumulating data indicating that HDL levels may be a particularly important

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determinant of ischemic heart disease starting in the sixth decade of life and beyond,[7,8] a clearer delineation of the general time course and "dose" of physical activity required to improve HDL levels in that population segment is especially warranted.

In an earlier report, results were presented across the initial 12-month study period for the three exercise training conditions under study as well as the 12-month wait-listed control condition.[9] The current study had two major goals: (1) to evaluate the effects of group-based versus supervised home-based endurance exercise training as well as higher-intensity versus lower-intensity training levels on 2-year exercise participation rates in this community-based sample of 269 healthy, initially sedentary women and men and (2) to compare the changes in cardiorespiratory fitness and HDL cholesterol levels achieved across a 2-year period through the three different training regimens under investigation.

Methods

Experimental Design

Eligibility criteria included currently residing in Sunnyvale, Calif, with no intention of moving from the community over a 2-year period; age between 50 and 65 years, free of cardiovascular disease or stroke (determined by medical history, clinical examination, and ECGs recorded at rest and exercise), sedentary, that is, no participation in a regular program of physical conditioning two or more times per week for at least 20 minutes per session or in a participative sport at least twice per week during the preceding 6 months; free of musculoskeletal problems that would prevent participation in moderate levels of physical activity, not currently taking medication for the treatment of hypertension or hyperlipidemia; for women, postmenopausal and not currently (for the previous 6-month period) taking postmenopausal hormone replacement, and willing to accept random assignment. The Stanford Medical School human use review board approved the project, and the procedures followed were in accordance with institutional guidelines. All subjects gave informed consent before participating in the study.

The 50- to 65-year-old age group was targeted in this study for several reasons: (1) incidence of a number of chronic diseases, including cardiovascular disease, begins to increase noticeably in both women and men in this age group[10] and (2) preventive activities, including physical activity, undertaken at this time in life can have important effects on future health status.[10,11] This is particularly the case in light of the number of years that many persons in the United States reaching this age have remaining to them.[10]

Individuals were recruited through a random digit-dial telephone survey of the community and citywide promotion (television, radio, and newspaper announcements). During the 1-week period before randomization, subjects underwent extensive medical and physical assessment. After stratification by sex and cigarette smoking status, subjects were randomly assigned to one of four conditions using a computerized version of the Efron procedure[12]: (1) higher-intensity, group-based exercise training, (2) higher-intensity, home-based exercise training, (3) lower-intensity, home-based exercise training, and (4) a 1-year delayed treatment control condition that received an exercise training program during the second year. Although the primary purpose of the second study year was to evaluate the maintenance of changes that had occurred during the first year in the three experimental conditions, it also provided a unique opportunity to assess longer-term effects of the three different exercise training regimens on variables such as lipoprotein levels that had not changed significantly during the first year.[9]

Higher-Intensity, Group-Based Exercise Training

These sessions were provided at a local community senior center and community college and were designed to simulate supervised exercise programs available in many communities. Exercise sessions were taught by two community exercise instructors with BA degrees in physical education who were certified to teach physical education in the California junior college system. Instructors met with project staff periodically throughout the 2-year period to ensure compliance with the study protocol. Sessions were conducted in the morning, late afternoon, and early evening 6 days per week. Each session lasted 60 minutes and included a 40-minute endurance training period. Subjects were encouraged to attend three classes per week throughout the 2 years. The major endurance activity during class was walking-jogging, with some use of stationary cycles and treadmills.

At baseline, each subject was provided an exercise prescription in which the exercise intensity was gradually increased over the initial 6-week period to 73% to 88% of the peak heart rate achieved during symptom-limited treadmill testing. This intensity range is comparable to 7 to 7.5 metabolic equivalents (METs). One MET is defined as the energy expended per minute while sitting quietly and is equivalent to 3.5 mL of oxygen uptake per kilogram of body weight per minute.[13] Class attendance was recorded throughout the 2 years to establish participation rates. Subjects also recorded their exercise heart rate and rating of perceived exertion[14] on the class attendance sheets at the end of each class period.

Higher-Intensity, Home-Based Training

Prescriptions were similar to those of subjects performing group-based training: three 60-minute training sessions per week, each containing a 40-minute endurance training period at 73% to 88% of peak treadmill heart rate. During a 30- to 40-minute introductory session, a project staff member provided instruction on monitoring pulse rate. Written information and activity logs were provided, and the staff member telephoned the subject at home the following week to check on progress. Telephone contact was made once per week for the first 4 weeks, biweekly for the following 4 weeks, and then once monthly through 12 months. Telephone contacts were used to monitor progress, answer questions, and provide individualized feedback. During the second year, subjects in this condition were encouraged to continue to self-monitor their physical activity on a regular (daily) basis[15] and were mailed self-assessment and informational materials related to relapse prevention on a monthly basis.[16] Staff-initiated telephone contact was reduced to an average of one contact per 2-month period.

Lower-Intensity, Home-Based Training

Prescriptions were based on a heart rate 60% to 73% of that achieved during symptom-limited treadmill testing. This intensity range is comparable to 4 to 4.5 METs. To ensure that the estimated total caloric expenditure per week was comparable across the three exercise conditions, these subjects were directed to complete five 30-minute exercise sessions per week. Instructions for exercise and telephone contacts were the same as for subjects in the higher-intensity, home-based training condition. Similar to the higher-intensity, home-based condition, subjects in this condition were encouraged during the second year to continue to self-monitor their physical activity regularly, were mailed self-assessment and informational materials related to relapse prevention on a monthly basis, and received staff-initiated telephone contacts on an average of once per 2-month period.

Inclusion of a higher-intensity, five-times-per-week, home-based exercise condition as well as a lower-intensity, five-times-per-week, group-based condition was considered originally. However, due to budgetary constraints as well as the large body of evidence demonstrating the difficulty of obtaining adequate adherence to higher-intensity exercise regimens as well as class-based regimens of less than five times per week,[17] these two alternatives were deemed impractical for this study.

1-Year, Delayed Treatment Control Condition

Subjects assigned to the 1-year, delayed treatment control condition were requested not to change their activity habits during the initial 12-month study period. This time period is substantially longer than that used in the vast majority of exercise training studies of this type.[17] Practical constraints prevented us from maintaining the wait-list control condition for longer than 1 year. Because they received a physical activity program of their choice during the second year and thus could no longer serve as control subjects, they will not be discussed further.

Measurement of Functional Capacity

At baseline and every 6 months subsequently across the 2-year period, all subjects performed a symptom-limited treadmill exercise test using a Balke-type protocol with workloads increasing by approximately 2 METs every 3 minutes.[18] Test completion was evaluated according to objective criteria (respiratory exchange ratio greater than 1.0 and plateauing of heart rate and/or oxygen uptake). A 12-lead ECG was recorded at rest and monitored continuously during the exercise test. Oxygen uptake during exercise was determined each minute using a semiautomatic computer-based system described previously.[19] Maximal oxygen uptake ($\dot{V}O_2max$) was defined as the highest value determined during the last 2 minutes of exercise.

Measurement of Other Heart Disease Risk Factors

Resting blood pressure, fasting plasma lipoprotein concentrations, body weight and composition, and smoking status were assessed at baseline, 12 months, and 24 months. Resting blood pressure was measured using a Hawksley random zero mercury sphygmomanometer. After a 5-minute period of rest, with the subject seated, blood pressure was measured three times using the right arm. The average of the second and third readings was used for analyses. Body weight was measured to the nearest one-tenth kilogram using a balance-beam scale with the subject in underclothing and without shoes. Body mass index (BMI) was calculated using the formula weight (kg)/height (meters)^2.

Subjects reported the average number of cigarettes smoked per day. Exposure to cigarette smoke was assessed by measuring expired air carbon monoxide and plasma thiocyanate concentrations.[20] Waist circumference, measured horizontally to the nearest centimeter at the level of the natural waist (the narrowest part of the torso as seen from the anterior aspect), and hip girth, measured at the largest horizontal circumference around the buttocks, were measured in the standing position (without clothing) in triplicate (average of three readings used in analysis) during two separate visits. The percentage of body fat was determined using hydrostatic weighing, as described previously.[9]

Venous blood was collected in the morning, after the subjects had abstained from all food and drink except water for 12 to 16 hours and from vigorous activity for at least 12 hours, for measurement of total plasma cholesterol, triglyceride, HDL, and LDL concentrations. It was immediately mixed with 1.5 mg of EDTA per milliliter and kept at 4°C until centrifugation, which occurred within 30 minutes. Plasma for lipid and lipoprotein analyses was stored at 4°C and assayed within 48 hours.

All lipid and lipoprotein measurements were made in the Biochemistry Laboratory at the Stanford Center for Research in Disease Prevention by laboratory staff blinded to subject assignment. Plasma levels of total cholesterol and triglyceride were measured by enzymatic procedures (ABA 200 instrument, Abbott Laboratories).[21,22] HDL cholesterol was measured by dextran sulfate–magnesium precipitation[23] followed by enzymatic determination of cholesterol.[21] The level of LDL cholesterol was calculated[24] as the level of total cholesterol minus the levels of HDL cholesterol and VLDL cholesterol. These measurements were consistently within specific limits as monitored by the Lipid Standardization Program of the Centers for Disease Control and Prevention and the National Heart, Lung, and Blood Institute during this period.

The entire baseline evaluation was repeated at 12 and 24 months. During the course of testing, clinic assessment staff were blind to the results of the subjects' previous visits and had limited involvement in other aspects of the study, including the intervention.

Assessment of Exercise Adherence

Exercise adherence rates were determined for all randomized subjects. Subjects in the two home-based exercise conditions were instructed to complete logs describing the exercise type, frequency, duration, exercise heart rate, and rating of perceived exertion for each training session. Logs were returned monthly by mail throughout the 24-month period. Timely return of the logs was achieved through a brief telephone reminder call before the end of the month. If a log was not returned, the subject was contacted by telephone to obtain adherence rates for that month. Average monthly adherence rates across the 24-month period were calculated as follows: number of exercise sessions reported as a percentage of exercise sessions prescribed for the month. Subjects in the higher-intensity, group-based condition completed in-class attendance sheets that included recording of exercise heart rate. Reports of class attendance were visually confirmed by the instructor.

Statistical Analyses

ANOVA procedures were used to evaluate between-group differences at baseline and with respect to exercise adherence. Repeated-measures ANCOVA procedures were used to assess changes across the 2-year period.[25] ANCOVA was chosen because, although we did not expect baseline differences between the conditions, given random assignment to study condition, the baseline values were likely to be highly correlated with the outcome measures in each condition. Using the baseline value as a covariate helps to increase the power of the statistical test by removing individual differences at baseline as a source of variance in the outcome measures. In analyzing change, main effects for group assignment, sex, and cigarette smoking status along with interactions of the latter two variables with group assignment were evaluated, with baseline levels of the dependent variables serving as covariates. Tukey's studentized range test was used to compare group means for all significant ANOVA effects, and the least squares means procedure[25] was used to compare group means for all significant ANCOVA effects. To evaluate correlates of change in HDL cholesterol across the 2-year study period, simultaneous multiple regression analysis was undertaken.[25] α was set at .05 using a two-tailed test of significance.

Results

Subjects

One hundred twenty women and 149 men were randomly assigned to one of the three exercise training conditions. As reported previously, the inclusion of a random digit-dial telephone survey to recruit participants achieved as representative a community sample as has been reported in a study of exercise training to date,[9] with over 20% of age-eligible and medically eligible subjects originally contacted randomized. As noted in an earlier report, demographic and health-related differences between those eligible subjects entering the study and those who refused study participation were minimal.[9] The study sample was similar to the target community in the 50- to 65-year age group on a range of demographic and health variables[9] including mean age (±SD) (women, 56.9±4.4 years; men, 55.8±4.0 years); ethnicity (percent white for women, 89.9%; men, 93.9%); years of formal education (women, 14.2±2.2 years; men, 16.2±2.6 years); employment status (percent currently employed for women, 64.7%; men, 87.8%); marital status (percent currently married for women,

Baseline Values and 24-Month Changes in Selected Risk Factors by Exercise Training Condition and Sex

	Higher-Intensity, Group-Based		Higher-Intensity, Home-Based		Lower-Intensity, Home-Based	
Variable	Men (n=37)	Women (n=32)	Men (n=40)	Women (n=34)	Men (n=37)	Women (n=27)
Cigarette smokers, No.	5	6	7	7	5	5
$\dot{V}O_2$max, mL/kg per min*						
Baseline	28.7±4.4	24.9±2.8	30.5±6.2	24.6±5.9	30.9±5.6	23.4±3.3
0-24 mo change	1.9±4.9	0.2±3.6	2.5±7.1	2.3±7.1	2.3±6.4	1.9±3.3
Treadmill duration, min*						
Baseline	11.9±2.7	9.4±2.2	12.5±3.1	10.0±3.8	13.5±3.4	8.8±2.1
0-24 mo change	2.1±3.2	1.1±2.4	2.3±3.6	1.9±4.2	1.8±4.1	1.3±1.8
Body mass index, kg/m^2						
Baseline	27.4±4.5	26.3±4.0	27.9±3.9	27.0±5.5	26.6±3.2	25.3±3.7
0-24 mo change	0.1±4.4	0.2±4.3	−0.1±3.8	0.1±5.7	−0.2±3.3	−0.4±3.8
LDL cholesterol, mmol/L‡						
Baseline	4.08±0.99	4.13±0.99	3.89±0.94	4.05±1.08	3.72±0.87	4.17±0.96
0-24 mo change	−0.35±0.95	−0.62±0.94	−0.28±0.90	0.34±1.02	−0.40±0.82	−0.34±0.82
HDL cholesterol, mmol/L†‡						
Baseline	1.30±0.33	1.55±0.40	1.13±0.32	1.55±0.45	1.18±0.23	1.43±0.37
0-24 mo change	0.01±0.32	0.06±0.42	0.05±0.32	0.07±0.45	0.11±0.24	0.10±0.37
Triglycerides, mmol/L§						
Baseline	1.41±0.68	1.13±0.52	1.39±0.75	1.23±0.90	1.44±0.81	1.04±0.43
0-24 mo change	−0.09±0.56	0.10±0.54	0.18±0.80	0.01±0.81	0.12±0.85	0.32±0.52

*Change over baseline for all three exercise training conditions (sexes combined) significant at $P<.01$.
†Change over baseline for two home-based exercise training conditions (sexes combined) significant at $P<.01$.
‡To convert values to mg/dL, multiply by 38.67.
§To convert values to mg/dL, multiply by 88.57.

53.3%; men, 83.9%); cigarette smoking status (women, 25.3%; men, 18.8%); and mean BMI (women, 26.6±4.8 kg/m^2; men, 27.6±4.0 kg/m^2). Subjects were comparable across the three exercise training conditions on all major variables of interest at baseline, substantiating the success of the randomization procedure.

At 2 years, subject retention rates across the three conditions equaled 89.2% (range for conditions, 87% to 90.8%), with comparable rates obtained for men (89.9%) and women (88.3%). Subject loss to follow-up was due primarily to relocation out of the area (n=10), medical contraindications to continuing in the study (n=8), and loss of interest (n=10) and was similar across the three exercise training conditions. Adherence rates for the prescribed exercise programs across the 2-year period were calculated for all subjects retained. Physiological data for all three time periods (baseline, 12 months, and 24 months) were successfully collected on 75.5% of this sample (comparable percentages across conditions).

Subjects without 2-year physiological data were compared with subjects with 2-year data at the baseline and 1-year time points. For each of the three training conditions, no statistically significant differences were observed for either men or women who had versus did not have 2-year data on major variables of interest (baseline and 1-year $\dot{V}O_2$max, percent body fat, BMI, or lipid concentrations; P values $>.10$; all means being compared were within a half a standard deviation of one another, suggesting that they were within the limits imposed by the measurement error of the tests).

Descriptive data (means, standard deviations), by exercise training condition and sex, are shown in the table for the physiological variables of interest across the 2-year study period. As noted earlier, there were no between-group differences on these variables at baseline.

Exercise Adherence Across the 2-Year Period

As described in a previous study,[9] reported adherence to each prescribed exercise frequency, intensity, and duration was successfully corroborated through a variety of methods during the trial, including treadmill exercise performance data, ambulatory heart rate and motion recordings (Vitalog), and exercise heart rates and ratings of perceived exertion recorded after each exercise session. As noted earlier, exercise adherence rates were calculated on all subjects available for follow-up during the 2-year period (89.2% of all originally randomized subjects).

As shown in Fig 1, during the first year, subjects in the higher- and lower-intensity, home-based exercise training programs, who did not differ significantly from one another in exercise adherence rates, reported significantly greater exercise adherence (mean±SD, 78.7±33.9% and 75.1±31.8%, respectively) than those assigned to higher-intensity, group-based exercise training (mean, 52.6±29.8%; $P<.0005$).[9] This pattern generally continued during year 2, with a notable variation. The higher-intensity, home-based training condition maintained an adherence level that was relatively high (mean, 67.8±46.0%) and significantly better than that for the higher-intensity, group-based condition (mean, 36.4±33.0%). However, the adherence rate for the lower-intensity, home-based condition (mean, 49.0±42.7%) dropped to a level that was more similar to that for the higher-intensity, group-based condition and significantly lower than that for the higher-intensity, home-based condition ($F=5.99$, $P<.0029$). Anecdotal reports from participants suggested that the year 2 decline in exercise adherence among the lower-intensity, home-based subjects may have been due primarily to the increasing difficulty of maintaining a five-times-per-week exercise schedule, particularly given the reduction in staff support that occurred in year 2.

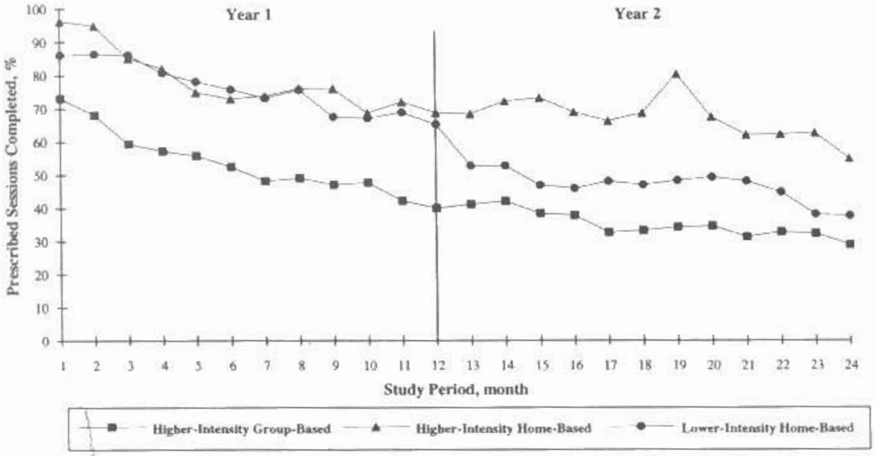

FIG 1. Line plot shows monthly adherence rates (% of prescribed exercise sessions completed) across the 2-year period by exercise training condition assignment. Note: During year 1, group-based training condition differed from the other two conditions at $P<.0005$. During year 2, higher-intensity, home-based training condition differed from the other two conditions at $P<.0029$.

Similar to what was observed during year 1,[9] smokers continued to have a lower level of exercise adherence relative to nonsmokers during year 2 (mean±SD, 37.1±37.0% and 54.0±40.7%, respectively; $P<.01$). There was no significant main effect for sex and no interaction effects for either smoking status or sex with group. In addition, there were no sex differences within any of the groups for exercise adherence.

Changes in Treadmill Performance From Baseline Through 2 Years

As reported previously, subjects in all three training conditions showed significantly greater improvements in $\dot{V}O_2$max and treadmill exercise test duration than control subjects across the initial 12-month period (P values $<.03$; Reference 9). As shown in Fig 2, these increases were reasonably well maintained across year 2 (differences between year 1 and year 2 nonsignificant for all conditions). The repeated-measures ANCOVA for $\dot{V}O_2$max indicated that there was also a time×group trend ($F=2.66$, $P<.07$), reflecting the somewhat larger increase in $\dot{V}O_2$max achieved during year 2 by the higher-intensity, home-based training condition relative to the other two training conditions. (This trend was confirmed when changes during year 2 alone were compared among the three conditions using ANOVA.)

The changes in $\dot{V}O_2$max and treadmill exercise test duration observed across the 2-year period are consistent with the exercise adherence levels reported by subjects in each of the three exercise training conditions during that time period, as reflected in Figs 1 and 2. Similarly, the higher levels of adherence evidenced by all three conditions in year 1 relative to year 2 (shown in Fig 1) correspond to the larger increases in $\dot{V}O_2$max achieved during the first year relative to the second year, providing additional evidence for the relation between exercise adherence and change in $\dot{V}O_2$max in the study sample.

There were no significant main or interaction effects with respect to sex or smoking status for either the $\dot{V}O_2$max or the treadmill exercise test duration variables.

Changes in Lipid Concentrations From Baseline to 2 Years

As reported previously,[9] changes in total cholesterol, HDL cholesterol, LDL cholesterol, and plasma triglycerides did not differ significantly between the three exercise training conditions versus the 1-year wait-listed control group at the end of year 1, nor did any of the three exercise training conditions show significant increases in HDL cholesterol levels over and above their baseline levels after the first year (no within-group differences during year 1).

The repeated-measures ANCOVA showed a significant time effect for HDL cholesterol changes occurring by the end of year 2 relative to year 1, with a general increase in HDL levels across the three training conditions in the second year ($F=5.19$, $P<.02$). Further inspection of the data using paired-comparison t tests

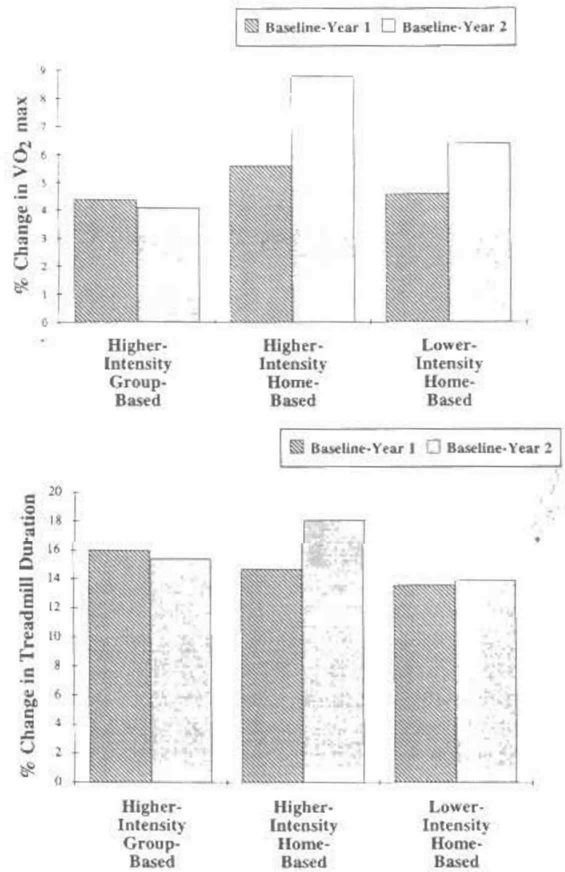

FIG 2. Bar graphs show percent change in treadmill exercise performance variables ($\dot{V}O_2$max, treadmill duration) across the first year and the entire 2-year period by exercise training condition assignment. Note: For $\dot{V}O_2$max change from baseline to 2 years, higher-intensity, home-based condition was greater than the other two conditions ($P<.07$).

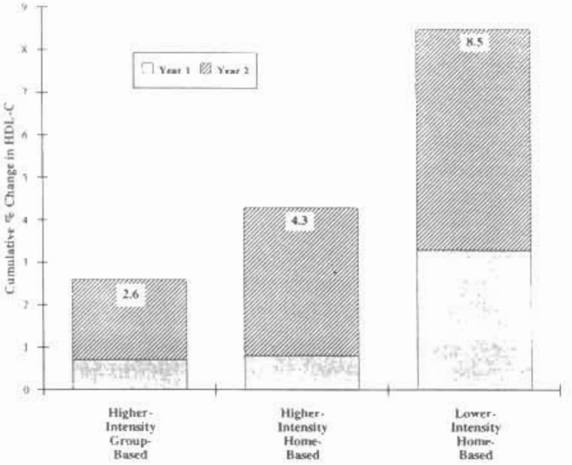

FIG 3. Bar graph shows cumulative percent change in HDL cholesterol at 2 years by exercise training condition assignment. Note: 2-year change from baseline is significant in the higher-intensity, home-based condition ($P<.01$) and in the lower-intensity, home-based condition ($P<.0002$).

showed that in contrast to similar analyses conducted between year 1 and baseline data as well as year 2 and year 1 data, the 2-year increases over baseline reached statistical significance in both the higher-intensity, home-based ($t=2.6$, $P<.01$) and lower-intensity, home-based ($t=4.0$, $P<.0002$) conditions but not in the higher-intensity, group-based condition ($P>.13$).

As shown in Fig 3, the HDL increases above baseline were especially pronounced for the lower-intensity, home-based training condition at 2 years. Despite a reduction in adherence in year 2 shown by this group with respect to its original five-sessions-per-week exercise prescription, subjects in the lower-intensity, home-based condition nonetheless averaged 2.4 exercise sessions per week during year 2, with an average of three exercise sessions per week across the entire 2-year period. In comparison, subjects in the higher-intensity, home-based condition averaged 2.0 exercise sessions per week during year 2 and 2.2 exercise sessions per week across the entire 2-year period, while the subjects in the higher-intensity, group-based condition averaged 1.1 exercise sessions per week during year 2 and 1.3 exercise sessions per week across the 2-year period. In contrast to the changes in treadmill test performance, these results suggest that the frequency of exercise may be important in producing metabolic changes related to increases in HDL cholesterol. In contrast, a higher-intensity exercise level did not appear to be essential in promoting HDL cholesterol increases in the sample.

To evaluate the influence of exercise frequency on HDL cholesterol further, each of the three exercise training conditions was subdivided into two groups: subjects who achieved a minimum of 2 days of exercise participation per week throughout the 2-year study period and subjects who achieved less than 2 days of exercise participation per week during the 2-year time period. Change in HDL cholesterol across the 2-year period was subsequently evaluated for these subgroups and is shown in Fig 4.

The similar pattern of differences shown across the three training regimens supports the concept that frequency of exercise participation across an extended time period rather than its intensity may be important in

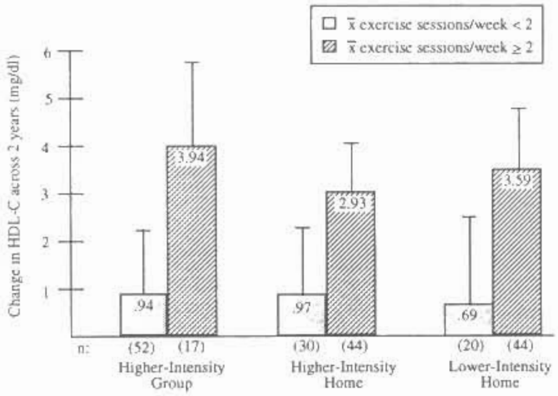

FIG 4. Bar graph shows mean change (with standard error bars) in HDL cholesterol based on the average number of exercise sessions per week completed across 2 years by exercise training condition.

influencing HDL cholesterol levels in this age group. Although differences within each training condition did not reach statistical significance (possibly due to the sample sizes of the resulting subgroups coupled with the relatively large standard errors observed for the HDL changes), the same session-based comparison undertaken when the three exercise training conditions were combined was significant ($P<.001$). Percentages of women and men were similar for the subgroups.

The clinical meaningfulness of the HDL cholesterol differences was evaluated more specifically by comparing the percentages of subjects within each exercise training condition who achieved a greater than 5 mg/dL (0.13 mmol/L) increase in HDL cholesterol across the 2-year study period—the average amount of change reported in exercise training studies of 12 weeks' duration or longer with younger adults.[26] As shown in Fig 5, over half (51.7%) of subjects in the lower-intensity, home-based condition had an increase of this magnitude or greater compared with a third or less in the higher-intensity, home-based and group-based conditions (35.2% and 32.0%, respectively; χ^2 test, 5.9; $P<.05$). Similar percentages of women and men achieved these changes for each of the three training conditions.

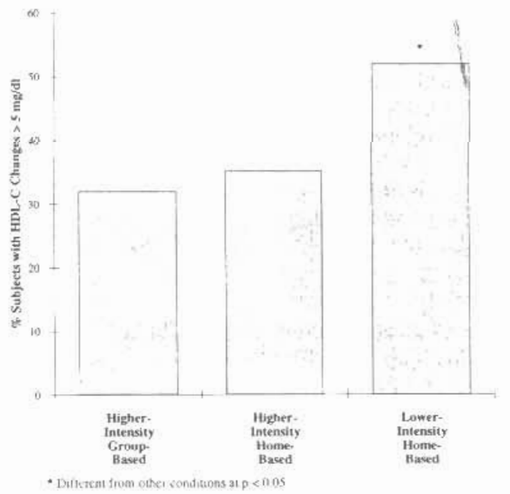

FIG 5. Bar graph shows percent of subjects in each exercise training condition achieving HDL cholesterol change of greater than 5 mg/dL (0.13 mmol/L) at 2 years. Note: Lower-intensity, home-based training condition was greater than the other two conditions ($P<.05$).

Total cholesterol, LDL cholesterol, and triglyceride levels did not change significantly within or between any of the exercise training conditions across the 2-year period (Table).

Changes in Other Health Variables From Baseline to 2 Years

There were no significant between-group or within-group changes in either BMI, waist-to-hip ratio, or body fat percentage for any of the three training conditions across the 2-year period (Table). Resting blood pressure levels also did not change in this initially normotensive sample, nor did self-reported alcohol intake, general dietary intake (assessed by the semiquantitative food frequency questionnaire[27] and a dietary habits questionnaire), smoking habits, or medication use change significantly for any of the three conditions during the study period. Exercise participation rates across the study period were found to have small but significant associations with increases in $\dot{V}O_2$max as well as decreases in BMI for men and women (r=.30 to .37, P<.05).

Correlates of Change in HDL Cholesterol Across the 2-Year Period

Potential correlates of HDL cholesterol changes across the 2-year period were evaluated using simultaneous multiple regression analysis. We were particularly interested in evaluating the relation between changes in body composition measures with changes in HDL cholesterol across the sample, since the presence of a significant inverse relation between such measures and HDL cholesterol would provide additional evidence supporting the reliability of the HDL cholesterol measurement across the 2-year period.[26,28]

For each sex separately, the following variables were included in the regression model: age, smoking status, exercise condition assignment, average number of sessions completed per week across the 2-year period, and 2-year changes in BMI and $\dot{V}O_2$max, along with alcohol use. This analysis was subsequently repeated with change in waist-to-hip ratio and change in body fat percentage substituted, in turn, for change in BMI.

For men, with BMI change in the model, reductions in BMI (standardized coefficient, −.30; P<.002) and greater age (standardized coefficient, .22; P<.02) were independently associated with increases in HDL cholesterol during the 2-year period. The model explained 22.8% of the variance in 2-year HDL cholesterol change. Similar results were obtained when change in percent body fat was substituted for BMI change (for reductions in percent body fat, P<.007; for greater age, P<.01; R^2=19.2%). When change in waist-to-hip ratio was substituted for BMI change, reduction in waist-to-hip ratio (standardized coefficient, −.20; P<.04), increases in $\dot{V}O_2$max (standardized coefficient, .28; P<.008), status as a nonsmoker (standardized coefficient, .19; P<.04), and greater age (standardized coefficient, .19; P<.05) were independently associated with increases in 2-year HDL cholesterol. The latter model explained 19% of the variance in 2-year HDL cholesterol change.

For women, the only variable that reached statistical significance was change in waist-to-hip ratio (standardized coefficient, −.29; P<.019), with decreases in waist-to-hip ratio associated with increases in HDL cholesterol across the 2-year period. The model explained 23.1% of the variance in 2-year HDL cholesterol change.

The lack of a significant independent association between exercise participation rate and HDL cholesterol change in the above models could be due to its relation, noted earlier, with changes in BMI in the sample.

Discussion

Participation over 2 years in any of three endurance exercise regimens by a reasonably representative sample of older, previously sedentary adults was found to be associated with significant gains in cardiorespiratory fitness and, in the two home-based exercise conditions, improvements in HDL cholesterol. The increase in $\dot{V}O_2$max achieved in this community-based study, while smaller than that reported in laboratory-based training studies, has been associated with significant improvements in health and functioning[29] and is likely to be more feasible to obtain across the population at large. In fact, the moderate-intensity programs undertaken in the current study are precisely the types of regimens currently being advocated by a range of national organizations to improve the nation's health.[30] Similar to recently reported studies in younger women,[5] we found that higher-intensity exercise levels were not essential in order to obtain significant increases in plasma HDL cholesterol concentrations. Rather, the results indicate that frequency of exercise may be particularly important in influencing HDL cholesterol levels in both men and women in the current age group. The potential importance of exercise frequency for improvement in HDL cholesterol has been noted in a study of 53 male college students who were assigned to run a specified distance each day, three days per week, in either one, two, or three blocks of time during the day.[31] While across a 10-week period all three training groups increased their maximal oxygen uptake significantly relative to the control group, only the group who ran three times per day showed significant improvement in HDL cholesterol. In contrast, while a study of middle-aged men (ages 30 to 47 years) did not find significant differences in serum lipid concentrations after participation in 16 weeks of endurance training (walking, jogging) of either 2 or 4 days per week,[32] the authors noted that most between-group differences in other variables of interest (for example, recovery heart rate) occurred only after 16 weeks of training, suggesting the importance of longer-term training for achieving optimal physiological changes.[32]

Of note in the current study was the greater length of time required to achieve increases in HDL cholesterol in our older age group relative to studies of younger individuals.[5,26] These increases did not become noticeable statistically until 2 years of regular exercise participation were achieved, which contrasts with the shorter time frames (6 to 12 months) that have been observed for younger adults.[26,33] As noted in a recent review,[34] such experimental data have been particularly lacking in postmenopausal women. Although it is tempting to conclude that frequency may be more important than intensity in influencing HDL cholesterol levels in this sample, the lack of a full factorial design (that is, the inclusion of a higher-intensity, 5-days-per-week exercise condition) places limits on such conclusions.

Although significant increases in HDL cholesterol over baseline levels were found among subjects assigned to the home-based exercise conditions, the absolute magnitude of the changes observed across the 2-year period was modest. This raises the question of the clinical significance of the results. The dose-response relation between increases in HDL cholesterol levels and important clinical end points such as coronary heart disease event rates has been evaluated systematically by Gordon and colleagues[35] across four major prospective American studies. They reported that a 1-mg/dL increment in HDL cholesterol was associated with a significant coronary heart disease risk decrement of 2% in men and 3% in women. In addition, a 1-mg/dL increment in HDL cholesterol was associated in the Lipid Research Clinics Prevalence Mortality Follow-up Study with significant 3.7% and 4.7% decrements in cardiovascular disease mortality rates in men and women, respectively.[35] The results from these studies suggest the potential public health utility of even reasonably modest increases in HDL cholesterol across a population. Of note in the current study, while the overall mean increases in HDL cholesterol across the three exercise training conditions were small, the majority of subjects in the higher-intensity (59%) and lower-intensity (68.8%), home-based exercise conditions were able to achieve mean increases of HDL cholesterol of approximately 3 mg/dL or greater. HDL changes of this magnitude are comparable to those reported by Duncan and colleagues[5] for several different walking programs undertaken by their younger women subjects. In addition, approximately 52% of subjects in the lower-intensity, home-based exercise condition were able to achieve 2-year HDL cholesterol increases of over 5 mg/dL which, based on the Gordon et al (1989) results,[35] translates into a reduction in coronary heart disease risk of approximately 10% or greater. While subjects in the lower-intensity, home-based exercise condition were able to achieve these increases by engaging in approximately 30 minutes of brisk walking about three times per week—levels of physical activity that should be quite feasible for the majority of the American public to attain—the fact that a 2-year period of such physical activity increases was required to achieve these HDL increments is sobering. The results underscore the continuing challenge of developing intervention strategies, applicable on a population-wide basis, for promoting long-term physical activity participation.

While our data indicate that the study sample provided a good representation of the healthy adults of advanced middle age residing in the target community,[9] the community being studied was largely white and well educated. Investigations in different populations are necessary to better determine the generalizability of these results.

Practical constraints prevented us from maintaining the wait-list control condition for longer than a 1-year period. Although, clearly, having a 2-year assessment-only condition would have been optimal, the daunting number of difficulties related to study recruitment and the adequate maintenance of persons in such a condition made it infeasible for the type of study being currently described.[17]

The lack of an assessment-only control group during the second year prevents us from making definitive conclusions concerning the cause of the increases in HDL cholesterol observed by the end of the 2-year period. It is possible, for instance, that laboratory drift could have resulted in overall increases in HDL cholesterol during year 2 relative to year 1. While we cannot definitely rule out this possibility, there are several reasons that make such an explanation less likely, including the facts that (1) HDL cholesterol measurements were performed in a specialized lipid research laboratory that remained standardized during the study period within the relatively narrow limits imposed by the National Heart, Lung, and Blood Institute and Centers for Disease Control Lipid Standardization programs; (2) the research laboratory was blinded to subject assignment; if there was laboratory drift, then one would expect it to affect all three conditions in a similar manner rather than creating the pattern of between-group and within-group differences in HDL cholesterol observed; in fact, laboratory coefficients of variation (cv) reported during this time period for HDL cholesterol were found to be quite satisfactory (intraday cv=2.0%; interday cv=4.0%); and (3) the significant associations found between changes in HDL cholesterol and reductions in body weight and composition measures, noted in other studies, support the reliability of the HDL measurement procedures.

The suggestion that a longer time frame and reasonable frequency of ongoing exercise participation may be required to achieve HDL cholesterol increases in older adults underscores the importance of physical activity regimens that are convenient and enjoyable enough to be adequately sustained over time. In the sample of adults under study, supervised home-based exercise training regimens afforded the additional flexibility and convenience not typically offered by class-based programs that may be required to achieve adequate long-term participation rates. As reported previously, such home-based regimens were found to be safe for persons in this age group and were initially preferred by a greater percentage of the community in the target age range relative to more typical class or group exercise programs.[9]

Although none of the three exercise training conditions resulted in significant decreases in group means for body weight or body composition measures across the 2-year period, the results from the multiple regressions suggest that the increases in HDL cholesterol observed were being mediated at least in part by reductions in overall body weight in men as well as changes in body composition in both men and women. It is possible that given the moderate amounts of exercise being undertaken by this older study sample, 2 years were required to achieve the amount of body composition changes required to begin to have noticeable effects on HDL cholesterol levels. Given subject reports indicating that dietary intake remained reasonably stable across the study period, it is likely that the relatively modest changes in body weight and composition being observed were attributable largely to the increased energy expenditure accompanying participation in the exercise training regimens. It is reasonable to assume that these positive benefits of physical exercise could be enhanced further through appropriate caloric restriction changes promoting increased weight loss, with larger increases in HDL cholesterol a possible result.[28]

We conclude that adults of advanced middle age can benefit from initiating a regular regimen of moderate-intensity endurance exercise in terms of cardiorespiratory fitness as well as some modification of lipoprotein levels. However, the time frame needed to achieve lipoprotein change may be longer than that reported for younger populations. It appears that exercise participation frequent enough to begin to induce changes in body composition and related variables may be particularly important for achieving such changes. Exercise regimens resulting in the greatest levels of ongoing participation are especially warranted. Supervised home-based exercise regimens represent one such alternative that merits further investigation as a means for expanding the programming options available to middle-aged and older adults. In addition, continued efforts to combine physical activity regimens with other hygienic measures that may positively influence HDL cholesterol levels, such as weight loss and smoking cessation,[35] are indicated.

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References

1. Leon AS, Connet J, Jacobs DR Jr, Rauramaa R. Leisure-time physical activity levels and risk of coronary heart disease and death: the Multiple Risk Factor Intervention Trial. *JAMA*. 1987;258:2388-2394.
2. Paffenbarger RS Jr, Hyde RT, Wing AL, Hsieh CC. Physical activity, all-cause mortality, and longevity of college alumni. *N Engl J Med*. 1986;314:605-613.
3. Powell KE, Thompson PD, Caspersen CJ, Kendrick JS. Physical activity and the incidence of coronary heart disease. *Annu Rev Public Health*. 1987;8:253-287.
4. King AC, Blair SN, Bild DE, Dishman RK, Dubbert PM, Marcus BH, Oldridge NB, Paffenbarger RS Jr, Powell KE, Yeager KK. Determinants of physical activity and interventions in adults. *Med Sci Sports Exerc*. 1992;24:S221-S236.
5. Duncan JJ, Gordon NF, Scott CB. Women walking for health and fitness: how much is enough? *JAMA*. 1991;266:3295-3299.
6. Reaven PD, McPhillips JB, Barrett-Connor EL, Criqui MH. Leisure time exercise and lipid and lipoprotein levels in an older population. *J Am Geriatr Soc*. 1990;38:847-854.
7. Abbott RD, Wilson PWF, Kannel WB, Castelli WP. High density lipoprotein cholesterol, total cholesterol screening, and myocardial infarction: the Framingham Study. *Arteriosclerosis*. 1988;8:207-211.
8. Brunner D, Weisbort J, Meshulam N. Relation of serum total cholesterol and high-density lipoprotein cholesterol percentage to the incidence of definite coronary events: twenty-year follow-up of the Donolo-Tel Aviv Prospective Coronary Artery Disease Study. *Am J Cardiol*. 1987;59:1271-1276.
9. King AC, Haskell WL, Taylor CB, Kraemer HC, DeBusk RF. Group- versus home-based exercise training in healthy older men and women: a community-based clinical trial. *JAMA*. 1991;266:1535-1542.
10. Institute of Medicine. *The Second 50 Years: Promoting Health and Preventing Disability*. Washington, DC: National Academy Press; 1990.
11. Centers for Disease Control. Surgeon General's Workshop on health promotion and aging: summary recommendations of the physical fitness and exercise working group. *Morb Mortal Wkly Rep*. 1989;38:700-707.
12. Efron B. Forcing a sequential experiment to be balanced. *Biometrika*. 1971;58:403-417.
13. Paffenbarger RS Jr, Hyde RT, Wing AL, Lee IM, Jung DL, Kampert JB. The association of changes in physical activity level and other lifestyle characteristics with mortality among men. *N Engl J Med*. 1993;328:538-545.
14. Borg G, Noble B. Perceived exertion. In: Wilmore JH, ed. *Exercise and Sports Science Reviews, II*. New York, NY: Academic Press Inc; 1974.
15. King AC, Taylor CB, Haskell WL, DeBusk RF. Strategies for increasing early adherence to and long-term maintenance of home-based exercise training in healthy middle-aged men and women. *Am J Cardiol*. 1988;61:628-632.
16. King AC, Frey-Hewitt B, Dreon D, Wood PD. Diet versus exercise in weight maintenance: the effects of minimal intervention strategies on long-term outcomes in men. *Arch Intern Med*. 1989;149:2741-2746.
17. Dishman RK. Increasing and maintaining exercise and physical activity. *Behav Ther*. 1991;22:345-378.
18. American College of Sports Medicine. *Guidelines for Exercise Testing and Prescription*. 3rd ed. Philadelphia, Pa: Lea & Febiger; 1986.
19. Gossard D, Haskell WL, Taylor CB, Mueller JK, Adams FR, Chandler M, Ahn DK, Miller NH, DeBusk RF. Effects of low- and high-intensity home-based exercise training on functional capacity in healthy middle-aged men. *Am J Cardiol*. 1986;57:446-449.
20. Fortmann SP, Rogers T, Vranizan K, Haskell WL, Solomon DS, Farquhar JW. Indirect measures of cigarette use: expired air carbon monoxide versus plasma thiocyanate. *Prev Med*. 1984;13:127-135.
21. Allain CC, Poon LS, Chan CS, Richmond W, Fu PC. Enzymatic determination of total serum cholesterol. *Clin Chem*. 1975;21:1983-1985.
22. Sampson EJ, Demers LM, Frieg AF. Faster enzymatic procedure for serum triglycerides. *Clin Chem*. 1975;21:1983-1985.
23. Warnick GR, Benderson J, Albers JJ. Dextran sulfate-Mg^{2+} precipitation procedure for quantitation of high-density-lipoprotein cholesterol. *Clin Chem*. 1982;28:1379-1388.
24. 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*. 1972;18:499-502.
25. Spector PC, Goodnight JH, Sall JP, Sarle WS. The GLM procedure. In: *SAS User's Guide: Statistics, Version 5*. Cary, NC: SAS Institute Inc; 1985:433-506.
26. Wood PD, Stefanick ML. Exercise, fitness, and atherosclerosis. In: Bouchard C, Shephard RJ, Stephens T, Sutton JR, McPherson BD, eds. *Exercise, Fitness, and Health: A Consensus of Current Knowledge*. Champaign, Ill: Human Kinetics Books; 1990:409-423.
27. Willett WC, Sampson L, Stampfer MJ, Rosner B, Bain C, Witschi J, Hennekens CH, Speizer FE. Reproducibility and validity of a semiquantitative food frequency questionnaire. *Am J Epidemiol*. 1985;122:51-65.
28. 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. Changes in plasma lipids and lipoproteins in overweight men during weight loss through dieting as compared with exercise. *N Engl J Med*. 1988;319:1173-1179.
29. Blair SN, Kohl HW, Paffenbarger RS Jr, Clark DG, Cooper KH, Biggons LW. Physical fitness and all-cause mortality: a prospective study of healthy men and women. *JAMA*. 1989;262:2395-2401.
30. US Centers for Disease Control and Prevention and American College of Sports Medicine. *Position Paper: Physical Activity and Public Health*. Atlanta, Ga: USCDCP; 1993.
31. Ebisu T. Splitting the distance of endurance running on cardiovascular endurance and blood lipids. *Jpn J Phys Ed*. 1985;30:37-43.
32. Pollock ML, Tiffany J, Gettmen L, Janeway R, Lofland HB. Effects of frequency of training on serum lipids, cardiovascular function and body composition. In: Franks BD, ed. *Exercise and Fitness*. New York, NY: Athletic Institute; 1969.
33. Taylor PA, Ward A. Women, high-density lipoprotein cholesterol, and exercise. *Arch Intern Med*. 1993;153:1178-1184.
34. Krummel D, Etherton TD, Peterson S, Kris-Etherton PM. Effects of exercise on plasma lipids and lipoproteins of women. *Proc Soc Exp Biol Med*. 1993;204:123-137.
35. Gordon DJ, Probstfield JL, Garrison RJ, Neaton JD, Castelli WP, Knoke JD, Jacobs DR Jr, Bangdiwala S, Tyroler A. High-density lipoprotein cholesterol and cardiovascular disease: four prospective American studies. *Circulation*. 1989;79:8-15.