Effects of Exercise Training on Cardiorespiratory Function in Men and Women >60 Years of Age

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This study reports the physiologic effects of up to 14 months of aerobic exercise in 101 older (>60 years) men and women. After an extensive baseline physiologic assessment (Time 1), in which aerobic capacity and blood lipids were measured, subjects were randomized to an aerobic exercise condition (cycle ergometry, 3 times per week for 1 hour), nonaerobic yoga (2 times per week for 1 hour), or a waiting list nonexercise control group for 4 months, and then underwent a second (Time 2) assessment. At the completion of the second assessment, all remaining subjects completed 4 months of aerobic exercise and were reevaluated (Time 3). Subjects were given the option of participating in 6 additional months of supervised aerobic exercise, and all available subjects completed a fourth assessment (Time 4) 14 months after their initial baseline evaluation. Results indicated that subjects generally exhibited a 10 to 15% improvement in peak oxygen consumption after 4 months of aerobic exercise training, and a 1 to 6% improvement in aerobic power with additional aerobic exercise training. On the other hand, subjects, especially men, continued to have improvements in submaximal exercise performance (i.e., anaerobic threshold). In addition, aerobic exercise was associated with an improved lipid profile; subjects participating in aerobic exercise for up to 14 months exhibited increased levels of high-density lipoprotein cholesterol. Maintenance of regular aerobic exercise for an extended time interval is associated with greater cardiovascular benefits among older adults than has been reported previously.

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Previous studies suggest that exercise training in older persons may improve cardiovascular function.[1-4] However, there has been wide variation in the magnitude of the training effects, with gains in aerobic power ranging from 0%[5] to 38%.[6] These discrepant findings may be attributable to differences in the mode, frequency and duration of exercise training, as well as to other factors, such as gender, initial fitness level of subjects, and procedural differences. Some programs set the intensity of exercise based upon age-predicted maximal heart rate,[6-8] whereas others used measures of oxygen consumption ($\dot{V}O_2$).[2,9] Similarly, some studies required subjects to exercise continuously for 30 minutes,[3,10-12] whereas others had subjects exercise continuously for <5 minutes.[6] Many investigations have studied only men,[5,6] and training studies have lasted 5 to 52 weeks. Methodologic problems that may have contributed to inconsistencies in results include small sample sizes, lack of adequate control groups, systematic bias (e.g., only reporting data on subjects who demonstrate the greatest gains), and inclusion of subjects with concomitant medical problems.

In an initial pilot study,[10] we demonstrated that a 12-week exercise program was associated with a 10% improvement in functional work capacity. However, we did not measure $\dot{V}O_2$ and had no control group. Subsequently, we improved upon the pilot study by including a larger sample, screening for concomitant medical illness, randomizing subjects to nonexercise control groups, and measuring $\dot{V}O_2$. In our initial report,[13] we described the results of the first 4 months. The purpose of the present investigation was to assess the feasibility of a long-term structured exercise program for older adults, and to document the cardiovascular adaptations in this more recent subject sample, with up to 14 months of aerobic exercise.

METHODS

The methods of our longitudinal study are described in detail elsewhere.[13] In brief, 101 healthy subjects (51 women, 50 men) were studied over a 14-month period. Subjects ranged in age from 60 to 83 years (mean ± standard deviation 67.0 ± 4.9). All subjects were in good health but were not engaged in habitual exercise before study entry. Subjects underwent a baseline evaluation (Time 1) and subsequent evaluations at 4 months (Time 2), 8 months (Time 3) and 14 months (Time 4). The study protocol was approved by the Duke Medical

Center institutional review board, and informed consent was obtained from each subject.

Procedures: The Duke Aging and Exercise Study was conducted between 1985 and 1987. Subjects were randomly assigned to an aerobic exercise group (n = 33), a yoga-flexibility control group (n = 34), or a waiting list control group (n = 34) after the completion of an extensive psychologic and physiologic assessment battery.

Subjects in the aerobic group attended 3 supervised exercise sessions per week for 4 consecutive months. During the first 2 weeks, subjects were assigned 6-beat training ranges equivalent to 50% of their maximal heart rate (HR) reserve [(HR max − HR rest) 0.50 + HR rest][14] during an initial bicycle exercise test. At the start of the third week, the exercise prescription intensity was increased to 60% of maximal heart rate reserve. During the fourth week, training ranges equivalent to 70% of maximal heart rate reserve were assigned. This training range was maintained for the remainder of the training regimen. In addition to the progressive increase in intensity, the duration of cycle ergometry started at 8 minutes at the first session, and increased by 2 minutes each subsequent session. By the fourth week, all subjects were cycling for 30 minutes continuously at an intensity equivalent to 70% of maximal heart rate reserve. The subjects then engaged in brisk walking/jogging and arm ergometry at their prescribed training range for 15 minutes. Each aerobic exercise session began with a 10-minute warm-up exercise period and concluded with 5 minutes of cool-down exercises. Heart rates were monitored via radial pulses and were recorded, along with ratings of perceived exertion,[15] 3 times during each exercise session.

Subjects in the yoga group participated in 60 minutes of yoga exercises ≥2 times per week for 4 months. The supervised yoga classes provided a control group for the effects of social stimulation and attention from trainers, without producing an aerobic training stimulus.

Subjects randomized to the waiting list control group did not receive any form of treatment between Time 1 and Time 2 evaluations. They were instructed to maintain their usual physical activity habits and to refrain from initiating an exercise program for the 4-month period. Subjects in all 3 groups were told to maintain their regular dietary habits until completion of the study.

After the first 4 months, all subjects participated in 4 months of aerobic exercise using the aforementioned exercise protocol and underwent a third (Time 3) assessment. Although this study was originally intended to last for 8 months, many subjects requested that it be extended. Consequently, we provided subjects with the option of participating in 6 additional months of supervised aerobic exercise and all available subjects (regardless of whether they stopped after 8 or 14 months) underwent an assessment at Time 4.

Assessments: Blood pressure measurements were obtained by standard cuff sphygmomanometry while the subject was in the sitting position. Body weight was obtained by a standard balance scale. Levels of plasma triglycerides, total serum cholesterol, and low- and high-density lipoprotein cholesterol were determined from blood samples drawn between 0700 and 0900 hours after a 14-hour fast.

Cardiorespiratory fitness was measured by a maximal cycle ergometry test after a practice test (Fitron cycle ergometer, model no. F1000750, Cybex Lumex Inc.). The protocol, with a pedaling rate of 60 rpm, started at 150 $kpm \cdot min^{-1}$ and increased by 150 $kpm \cdot min^{-1}$ every 3 minutes. A 12-lead electrocardiogram (Hewlett Packard, model no. 1517A) was monitored continuously and heart rate recorded every minute. Blood pressure was measured by cuff sphygmomanometry at 3-minute intervals. Respiratory and oxygen consumption measurements were obtained with a System 4400 metabolic instrument (Alpha Technologies, Inc., Laguna Hills, California). Measurements of $\dot{V}O_2$, carbon dioxide consumption, expired ventilation and end-tidal gas concentrations were measured breath-by-breath and recorded every 15 seconds. In addition, anaerobic threshold was derived from the respiratory and oxygen consumption data, and was determined by a single, blinded investigator (MBH) unaware of the training status of the subjects by procedures described previously.[16]

Statistical analysis: Data were analyzed by a 3 (group) × 2 (gender) × 2 (time) repeated measures multivariate analysis of variance. Group and gender served as between-subject factors and time served as a within-subject factor. For the comparison between Times 3 and 4 (the optional 6-month extension), subjects were grouped according to status (whether or not they participated in the 6-month supervised aerobic exercise program) rather than by their initial group assignment.

RESULTS

Compliance: Of the original 101 subjects, 97 completed their assessments at Time 2. All remaining subjects participated in aerobic exercise between Times 2 and 3 and completed an average of ≥44 sessions, maintaining their heart rates within the prescribed training range ≥70% of the time. Only 8 subjects dropped out before completing their Time 3 assessments, for an 8-month dropout rate of 11%. Fifty subjects participated in an additional 6 months of aerobic exercise, 49 of whom completed the 6-month extended exercise program.

All available participants, regardless of compliance with the exercise program, were asked to return for a fourth assessment 14 months after the initial baseline evaluations. Eighty-four subjects returned, for an overall follow-up rate of 84% at 14 months. Compliance with the program is summarized in Table I.

Weight and blood pressure: A series of analyses of variance were performed to assess changes in body weight, and systolic and diastolic blood pressure between Times 2 and 3 and 3 and 4. Because the results

TABLE I Exercise Compliance

	Time 1 to Time 2			Time 2 to Time 3			Time 3 to Time 4		
	Aerobic	Yoga	Waiting List	Aerobic	Yoga	Waiting List	Aerobic	Yoga	Waiting List
Mean number ± SD of sessions attended	46 ± 2	32 ± 3	—	44 ± 4	45 ± 2	44 ± 3	52 ± 16	56 ± 7	53 ± 1
Percentage of time in training range	88	—	—	85	70	75	81	59	82
Mean RPE ± SD	13.5 ± 1.8	—	—	13.0 ± 2.2	13.9 ± 1.8	13.5 ± 2.3	13.1 ± 1.9	14.3 ± 2.5	13.5 ± 3.1
Dropouts / Total no. of pts.	2/33	0/34	2/34	3/31	3/34	1/32	0/23	0/12	1/15

49 subjects completed the aerobic exercise program at Time 4, but 84 of the original cohort of 101 subjects returned for follow-up evaluation.
RPE = ratings of perceived exertion; SD = standard deviation.

between Times 1 and 2 have been described previously, they will not be reported in detail. For body weight, there were significant gender main effects at Times 2 to 3 ($p < 0.0001$) and Times 3 to 4 ($p < 0.0001$). Overall, men weighed more than women (80.3 ± 9.6 vs 63.1 ± 10.4 kg). There also were significant time-related main effects between Times 2 and 3 ($p < 0.003$), but not between Times 3 and 4. All subjects tended to lose a slight amount of weight (<1.5 kg) between Times 1 and 4.

Between Times 1 and 2, men tended to exhibit a greater reduction in diastolic blood pressure than women. Systolic blood pressure did not change significantly. The analysis of variance between Times 2 and 3 revealed a time main effect, with all subjects exhibiting a reduction in diastolic blood pressure from 76 ± 9 to 73 ± 10 mm Hg ($p < 0.03$). Between Times 3 and 4, there was only a significant gender main effect for systolic blood pressure, with men having lower levels (124 ± 15) than women (129 ± 16) ($p < 0.03$). Comparison of blood pressures between Times 1 and 4 revealed significant time main effects for systolic ($p < 0.003$) and diastolic blood pressure ($p < 0.006$). Thus, there was a tendency for blood pressure to be lower at the conclusion of the study, independent of exercise status.

Cardiorespiratory function: Separate, repeated measures multivariate analysis of variance were performed between Times 2 and 3 and 3 and 4. Between Times 1 and 2, we reported that participants in the aerobic group achieved an average 11.6% improvement in peak $\dot{V}O_2$ (relative) and 9.1% improvement in anaerobic threshold, whereas results of subjects in the 2 other groups did not change. Thus, the different treatment programs produced differential improvements in cardiorespiratory fitness among the 3 groups.

Because all subjects participated in aerobic exercise between Times 2 and 3, the repeated measures multivariate analysis of variance for the Time 2 to 3 data assessed the effects of an additional 4 months of aerobic exercise for the aerobic group and of an initial 4 months of aerobic exercise for the yoga and waiting list control groups. The results of the multivariate analysis of variance yielded significant multivariate main effects for group ($p < 0.002$), gender ($p < 0.0001$) and time ($p < 0.0001$), and significant group × gender ($p < 0.02$), gender × time ($p < 0.06$) and group × time ($p < 0.0006$) interactions. Significant univariate group × time effects were observed for heart rate at submaximal work loads ($p < 0.04$), time on the bicycle ($p < 0.0001$), and peak $\dot{V}O_2$ ($p < 0.002$). Between Times 2 and 3, the yoga and wait list groups significantly increased their cardiorespiratory fitness, whereas the aerobic group merely maintained their previous improvements from Times 1 and 2 (Table II). Examination of the mean change in peak $\dot{V}O_2$ (relative) from Time 2 to 3 revealed that the yoga group achieved an average 10.5% improvement and the waiting list group an average improvement of 15%. Subjects in all 3 groups achieved a significant increase in anaerobic threshold ($p < 0.005$).

Because not all subjects elected to continue with 6 months of supervised exercise, exercise status was substituted for group in the multivariate analysis of variance as a between-subjects factor between Times 3 and 4. Table III lists the changes as a function of status. Results revealed a significant multivariate main effect for gender ($p < 0.0001$), which reflects the consistent advantage in aerobic capacity for men throughout the duration of the study, and a multivariate time × status interaction ($p < 0.002$). Men achieved higher peak $\dot{V}O_2$ than women (25.0 ± 8.2 vs 17.3 ± 2.8 ml/kg/min), had lower heart rates at rest (70 ± 14 vs 74 ± 11 beats/min) and at 300 kpm·min^{-1} (87 ± 12 vs 108 ± 16 beats/min), and achieved longer times on the bicycle (14.5 ± 5.0 vs 8.9 ± 1.4 min). Men also had greater anaerobic thresholds than women (13.4 ± 2.5 vs 10.6 ± 1.5 ml/kg/min). Examination of the univariate time × status interactions revealed that subjects who continued with the program exhibited lower submaximal heart rates ($p < 0.03$) and achieved longer bicycle times ($p < 0.005$) than subjects who discontinued the supervised exercise (Table III).

Interestingly, between Times 1 and 4 there was a significant time × status interaction ($p < 0.02$), as well as a significant time × status × gender interaction for anaerobic threshold ($p < 0.05$). Subjects who maintained their exercise increased their anaerobic threshold from 746 ± 240 to 940 ± 317 ml/min, whereas the subjects who did not continue only increased their thresholds from 749 ± 212 to 815 ± 243 ml/min. This pattern was especially true for the men who continued

TABLE II Mean Change ± Standard Deviation in Cardiorespiratory Function over Time by Group

Times	Aerobic 1	Aerobic 2	Aerobic 3	Aerobic 4	Yoga 1	Yoga 2	Yoga 3	Yoga 4	Waiting List 1	Waiting List 2	Waiting List 3	Waiting List 4
	(n = 32)	(n = 31)	(n = 28)	(n = 28)	(n = 34)	(n = 34)	(n = 31)	(n = 27)	(n = 34)	(n = 31)	(n = 31)	(n = 26)
HR at rest (beats/min)	74 ± 11.3	70 ± 13.4	72 ± 10.8	72 ± 9.0	75 ± 11.9	73 ± 10.0	70 ± 9.5	72 ± 10.6	70 ± 13.7	68 ± 14.2	69 ± 14.0	71 ± 12.6
Submaximal HR (beats/min)	104 ± 17.7	98 ± 14.2	98 ± 16.2	95 ± 14.9	105 ± 16.0	103 ± 15.9	96 ± 16.0	98 ± 16.1	103 ± 23.4	104 ± 24.7	98 ± 20.5	99 ± 22.7
Maximal HR (beats/min)	150 ± 16.6	150 ± 18.8	150 ± 17.5	144 ± 19.2	148 ± 16.9	146 ± 17.1	142 ± 14.0	140 ± 14.5	148 ± 20.5	144 ± 19.5	142 ± 16.1	138 ± 24.3
Bicycle time (min)	11.3 ± 3.4	12.1 ± 3.3	12.5 ± 3.7	12.2 ± 3.9	11.0 ± 2.8	10.1 ± 2.2	11.1 ± 2.5	10.6 ± 2.3	10.6 ± 2.7	9.8 ± 2.7	11.1 ± 3.2	10.6 ± 3.2
AT (ml/min)	770 ± 242	840 ± 303	901 ± 298	983 ± 318	736 ± 228	729 ± 219	766 ± 209	808 ± 240	742 ± 210	740 ± 224	818 ± 226	865 ± 299
Peak VO_2 (ml/kg/min)	19.5 ± 5.2	21.4 ± 5.8	21.6 ± 6.0	22.7 ± 6.0	18.8 ± 4.5	18.7 ± 4.8	19.8 ± 4.9	20.0 ± 4.7	18.4 ± 3.9	17.9 ± 4.2	20.4 ± 5.1	20.6 ± 5.4
Peak VO_2 (ml/min)	1,452 ± 540	1,570 ± 564	1,600 ± 624	1,656 ± 610	1,354 ± 438	1,327 ± 433	1,390 ± 444	1,433 ± 481	1,345 ± 436	1,311 ± 478	1,450 ± 527	1,495 ± 578
AT/$\dot{V}O_2$	0.55 ± 0.09	0.55 ± 0.07	0.58 ± 0.09	0.60 ± 0.09	0.55 ± 0.06	0.55 ± 0.08	0.56 ± 0.09	0.59 ± 0.15	0.56 ± 0.10	0.58 ± 0.06	0.56 ± 0.09	0.60 ± 0.09

AT = anaerobic threshold; HR = heart rate; $\dot{V}O_2$ = peak oxygen consumption.
Time 1 and Time 2 data have been reported previously.[13]

to exercise. The men who participated in the exercise program increased their thresholds from 914 ± 209 to 1,223 ± 190 ml/min ($p = 0.0001$), whereas the thresholds of the men who discontinued remained relatively unchanged (894 ± 192 to 965 ± 275 ml/min) (difference not significant). Corresponding values were 570 ± 106 to 618 ± 118 and 601 ± 90 to 684 ± 135 ml/min for women who continued and discontinued the program, respectively. Of the original 33 subjects assigned to the aerobic group, 23 participated in the full 14-month exercise program. This subgroup of subjects increased their aerobic power by 18% at the conclusion of the study.

Lipids: To assess changes in lipids, low- and high-density lipoprotein cholesterol, total cholesterol and triglycerides were considered together in a multivariate analysis of variance. The mean lipid values for the 4 testing sessions are listed in Table IV. In our previous report,[13] we noted that women had higher high-density lipoprotein levels (60.5 ± 14.3 mg%) than men (44.3 ± 8.9 mg%) ($p < 0.0001$), and that only the aerobic group had a significant reduction in total ($p < 0.002$) and low-density lipoprotein cholesterol ($p < 0.003$). The 3 groups had a significant reduction in triglycerides over time ($p < 0.009$).

Between Times 2 and 3, there were significant multivariate main effects for gender ($p < 0.0001$) and time ($p < 0.0001$). Both total ($p < 0.0001$) and low-density lipoprotein cholesterol ($p < 0.0001$) increased slightly from Time 2 to 3 in all groups. Once again, women had higher high-density lipoprotein cholesterol levels than men.

The multivariate analysis of variance between Times 3 and 4 revealed a marginally significant time × status interaction ($p < 0.06$), as well as significant main effects for time ($p < 0.0003$), gender ($p < 0.0001$) and status ($p < 0.05$). Examination of the univariate time × status interactions indicated that only the subjects who continued in the exercise program significantly increased their levels of high-density lipoprotein cholesterol (54.3 ± 14.7 to 58.0 ± 14.7 mg%; $p < 0.05$) (Table IV). No other univariate interactions were statistically significant.

DISCUSSION

The results of this study demonstrate that a program of regular aerobic exercise is associated with significant improvement in functional capacity in a group of older men and women. Men and women had comparable improvements of 10 to 15% in cardiorespiratory fitness after 4 months of aerobic exercise. An additional 4 months of exercise produced a more gradual improvement of 1 to 6% in peak aerobic power. Subjects in the aerobic group who maintained their exercise for the full 14 months achieved an average increase in peak $\dot{V}O_2$ of 18%, relative to their baseline assessments. It should be emphasized that these data reflect the average improvement among highly motivated older persons who initiate an exercise program, rather than the potential physiologic responses to exercise training. Indeed, 1 subject achieved a 68% improvement in aerobic power. Even

TABLE III Mean Physiologic Measures ± Standard Deviation by Status (Discontinued or Continued for 6-Month Extension) for Time 1 (Baseline), Time 3 (8 Months) and Time 4 (14 Months)

	Discontinued			Continued		
Times	1	3	4	1	3	4
Cardiovascular						
HR at rest (beats/min)	74.2 ± 12.6	70.9 ± 11.3	74.6 ± 11.4	73.1 ± 12.3	70.7 ± 11.9	70.2 ± 9.8
Submaximal HR (beats/min)	104.7 ± 18.6	99.5 ± 18.4	103.5 ± 17.8	104.7 ± 19.7	97.0 ± 17.0	93.9 ± 17.3
Bicycle time (min)	11.0 ± 2.7	11.3 ± 2.9	10.3 ± 2.5	10.8 ± 3.3	11.8 ± 3.4	11.7 ± 3.6
Peak $\dot{V}O_2$ (ml/kg/min)	19.0 ± 4.2	19.9 ± 4.8	19.9 ± 4.6	18.6 ± 5.0	21.1 ± 5.7	22.0 ± 5.9
Peak $\dot{V}O_2$ (ml/min)	1,376.6 ± 424.9	1,400.3 ± 454.7	1,425.6 ± 491.6	1,373.3 ± 524.8	1,537.3 ± 589.0	1,602.1 ± 598.6
AT (ml/min)	748.7 ± 211.8	772.4 ± 224.2	814.5 ± 242.8	745.7 ± 239.7	865.8 ± 260.6	940.4 ± 317.3
Total cholesterol (mg%)	236.4 ± 36.5	254.4 ± 31.2	253.3 ± 38.0	233.5 ± 35.0	241.9 ± 38.8	235.1 ± 35.9
HDL cholesterol (mg%)	49.0 ± 13.9	52.3 ± 12.5	53.0 ± 14.8	54.8 ± 14.7	54.3 ± 14.7	58.0 ± 14.7
LDL cholesterol (mg%)	154.7 ± 35.1	173.2 ± 33.8	170.8 ± 39.9	152.3 ± 36.0	163.9 ± 35.6	155.6 ± 34.8
Triglycerides (mg%)	163.4 ± 62.3	144.7 ± 79.0	147.8 ± 69.8	131.8 ± 52.8	118.6 ± 61.6	107.4 ± 42.0

HDL = high-density lipoprotein; LDL = low-density lipoprotein; other abbreviations as in Table II.

greater improvements may be possible in some subjects with more intense training.

The magnitude of change in peak $\dot{V}O_2$ is generally consistent with other studies. Cunningham et al,[9] for example, reported an 11% improvement after 12 months in a randomized clinical trial of 224 men aged 55 to 65 years. Niinimaa and Shephard[17] observed a 10% improvement in maximal $\dot{V}O_2$ in 19 men and women aged 60 to 76 years. However, other studies have reported higher values. Sidney and Shephard[12] studied 14 men and 28 women for a period of up to 1 year of exercise training. Although they reported an overall 24% improvement in maximal $\dot{V}O_2$, only 22 of the 42 subjects actually completed the protocol. Because an additional 20% of the potential subjects were rejected at study entry, the authors noted that the improvement in aerobic capacity may not have been representative of the older population in general. Seals et al[2] reported a 25 to 30% increase in maximal $\dot{V}O_2$ after 12 months of training. However, they used a different exercise modality (jogging and walking vs biking) at a higher intensity training stimulus (85% for 45 vs 70% for 30 minutes), and reported data from only the 11 subjects who completed the exercise training protocol. Similarly, Barry et al[6] noted a 38% increase in maximal $\dot{V}O_2$ after 3 months of exercise training in only 8 subjects aged 55 to 78 years. Inclusion of subjects <60 years old in the sample, reporting data only for those subjects who completed the exercise training protocol, and apparent premature termination of several initial tests may have influenced the magnitude of the training effect. In contrast, our data were analyzed following the "intention to treat" principle, under the assumption that it is more clinically relevant to assess the likely extent of improvement in aerobic power in healthy older persons than the potential degree of improvement.

Few previous studies examine the effects of exercise training on anaerobic threshold in older subjects. Seals et al[18] demonstrated a decrease in lactate levels at submaximal work loads after a 6-month exercise training program, and this effect was enhanced when a more intensive exercise regimen was continued for 6 additional months. Our study is unique in that it demonstrates progressive improvements in submaximal exercise performance with prolonged training at the same intensity level.

It is also of interest to note that continued exercise training appeared to increase anaerobic threshold more than peak $\dot{V}O_2$. Examination of the ratio of anaerobic threshold to peak $\dot{V}O_2$ revealed an increase from 54% at Time 1 to 60% at Time 4 among participants who continued to exercise for the 14 months. These data are consistent with data from studies of middle-aged sedentary persons, which showed that the anaerobic threshold occurs at 50 to 60% of maximal $\dot{V}O_2$.[19] In addition, the change in the ratio of anaerobic threshold to $\dot{V}O_2$ suggests that increases in anaerobic threshold and peak $\dot{V}O_2$ initially occur in parallel but then dissociate with prolonged training. For example, the correlation of the change in anaerobic threshold and change in peak $\dot{V}O_2$ among aerobic participants was significantly greater between Times 1 and 2 ($r = +0.65$, $p < 0.001$) than for aerobic participants who maintained their aerobic exercise between Times 3 and 4 ($r = +0.26$, difference not significant). The observation of a dissociation between increases in anaerobic threshold and peak $\dot{V}O_2$ among the elderly has been noted previously in young and middle-aged subjects.[20,21] Peripheral adaptations that promote increased submaximal exercise performance may include increased capillarization or increased aerobic enzyme content in skeletal muscle.[22] Thus, maintenance of regular aerobic exercise is associated with significant

TABLE IV Mean Lipid Values ± Standard Deviation

Times	Aerobic				Yoga				Waiting List			
	1	2	3	4	1	2	3	4	1	2	3	4
	(n = 32)	(n = 31)	(n = 28)	(n = 27)	(n = 34)	(n = 34)	(n = 30)	(n = 30)	(n = 34)	(n = 32)	(n = 31)	(n = 27)
TC (mg%)	235 ± 38.6	224 ± 39.4	247 ± 36.9	238 ± 33.4	233 ± 29.5	242 ± 33.2	250 ± 28.2	248 ± 30.7	236 ± 38.2	232 ± 43.7	246 ± 42.2	242 ± 48.0
HDL-C (mg%)	52.7 ± 15.4	52.3 ± 14.3	55.2 ± 13.6	56.7 ± 15.5	49.5 ± 12.3	52.2 ± 13.1	51.2 ± 14.2	52.4 ± 13.9	53.4 ± 16.0	54.5 ± 15.6	53.8 ± 13.4	58.9 ± 14.9
LDL-C (mg%)	151 ± 39.1	144 ± 38.9	166 ± 39.9	156 ± 34.1	155 ± 28.4	165 ± 32.2	173 ± 27.5	171 ± 30.0	153 ± 39.0	150 ± 41.0	165 ± 37.1	158 ± 47.2
TRIG (mg%)	153 ± 71.7	139 ± 83.2	126 ± 73.9	123 ± 71.6	143 ± 55.5	125 ± 61.2	129 ± 67.3	126 ± 52.8	144 ± 49.1	138 ± 60.4	136 ± 73.1	124 ± 51.5

TC = total cholesterol; TRIG = triglycerides; other abbreviations as in Table III.
Data at Time 1 and Time 2 have been reported previously.[13] Only 12 women (5 aerobic, 2 yoga, 5 waiting list) were receiving hormone-replacement therapy. Removal of these women from analysis did not alter the results.

improvements in aerobic power and, perhaps more importantly, with increased ability to exercise at submaximal work loads.

We also noted significant changes in lipid profiles associated with the exercise training program. We observed that subjects who participated in aerobic exercise had a reduction in total and low-density lipoprotein cholesterol between Times 1 and 2. Moreover, subjects who continued for 14 months of exercise also had a significant increase in high-density lipoprotein cholesterol. Our data are generally consistent with cross-sectional[23,24] and longitudinal studies[25,26] among younger adults, although studies have not always found lipid changes.[27,28] Our data are consistent with those of Brownell et al,[29] who reported that women tended to have lower total and low-density lipoprotein cholesterol values and higher high-density lipoprotein cholesterol values than men. Although Brownell et al noted a trend for men to have larger decreases in low-density lipoprotein cholesterol and larger increases in high-density lipoprotein cholesterol, relative to women, after 10 weeks of exercise, we did not observe a similar trend in our data. In the absence of any gender interactions with group or time, it would appear that, in our sample of older men and women, the lipid changes in response to exercise were comparable. Thus, aerobic exercise is associated with significant and meaningful improvements in aerobic capacity, submaximal exercise performance, and lipid patterns, particularly when habitually maintained.

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