Cardiovascular and Behavioral Effects of Aerobic Exercise Training in Healthy Older Men and Women

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The cardiovascular and behavioral adaptations associated with a 4-month program of aerobic exercise training were examined in 101 older men and women (mean age = 67 years). Subjects were randomly assigned to an Aerobic Exercise group, a Yoga and Flexibility control group, or a Walking List control group. Prior to and following the 4-month program, subjects underwent comprehensive physiological and psychological evaluations. Physiological measures included measurement of blood pressure, lipids, bone density, and cardiorespiratory fitness including direct measurements of peak oxygen consumption ($\text{VO}_2\text{max}$) and anaerobic threshold. Psychological measures included measures of mood, psychiatric symptoms, and neuropsychological functioning. This study demonstrated that 4 months of aerobic exercise training produced an overall 11.6% improvement in peak $\text{VO}_2$ and a 13% increase in anaerobic threshold. In contrast, the Yoga and Waiting List control groups experienced no change in cardiorespiratory fitness. Other favorable physiological changes observed among aerobic exercise participants included lower cholesterol levels, diastolic blood pressure levels, and for subjects at risk for bone fracture, a trend toward an increase in bone mineral content. Although few significant psychological changes could be attributed to aerobic exercise training, participants in the two active treatment groups perceived themselves as improving on a number of psychological and behavioral dimensions.

Physical exercise has become increasingly popular as a method of health enhancement. Epidemiologic and laboratory studies have shown that increased levels of physical activity are associated with longevity and reduced risk for cardiovascular disease (1-3). Lack of activity, on the other hand, has been shown to be associated with decreased exercise capacity, cardiovascular deconditioning, and muscle atrophy (4,5). Most research on exercise has focused on young and middle-aged male subjects, however. In an editorial appearing in the journal of the American College of Sports Medicine, Holloszy (6) noted that the positive attention that exercise has received is based "largely on emotional reactions and on wishful thinking." In particular, he cited the paucity of data on older persons and stated that "such a recommendation [to exercise] cannot be made lightly in view of the potential hazards of unsupervised exercise for older individuals" and noted "the unresolved questions regarding the effect of exercise on the aging process" (p. 2).

It is especially important to evaluate the effects of exercise on elderly persons because aging is associated with declines in physical and mental functioning that may be modifiable by exercise. Previous studies have documented impaired cardiovascular performance for older individuals as compared to younger persons in terms of maximum oxygen consumption ($\text{VO}_2\text{max}$), heart rate, cardiac output, and left ventricular ejection fraction during exercise (7-10). Furthermore, these changes are not due simply to the increased prevalence of specific cardiovascular disease states in the elderly, but also occur in elderly individuals without overt disease (10).

The decline in cardiovascular performance that is typically associated with aging is attributable to both in peripheral circulation and intrinsic myocardial systolic and diastolic function (11,12). However, the degree to which these decrements represent the inevitable biologic sequelae of normal aging or represent changes that may be potentially modifiable with exercise training has not been systematically studied in a large sample of older men and women.

There is considerable support for the hypothesis that habitual rigorous physical exercise may enhance cardiovascular functioning in elderly persons. First, sociocultural features of modern industrial society have resulted in declining levels of habitual physical activity among adults, suggesting that physical deconditioning, which is potentially reversible, could contribute to a decline in cardiovascular function (13). Second, with the exception of peak heart rate, all the parameters of cardiovascular function that have been observed to decline with advancing age are known to be favorably modified by aerobic exercise training in young populations (14,15). Several studies have suggested that similar effects occur in the elderly (16-18), although results have been inconsistent (19-21) and are plagued by methodological limitations. These limitations have included cross-sectional comparisons that are potentially confounded by genetic differences between sedentary and active groups as well as by selection bias; exercise programs of insufficient duration and intensity to assess adequately the effects of exercise training; non-random comparison groups; and small sample sizes.

In addition to decrements in cardiovascular function, declines in psychological function including decreased cog...
nitive efficiency and increased prevalence of psychiatric symptoms have been found among older adults (22,23). In traditional tests of cognitive function, for example, there are age-related impairments in the acquisition and manipulation of unfamiliar material (24), and declines in some forms of memory performance (25). Disturbances of mood are also prevalent among the elderly population (26). A number of studies in younger and middle-aged subjects have shown that aerobic exercise may improve mood (27–29) and may improve performance on various cognitive tasks (30,31). Recently these observations have been extended to the elderly (32–34), although methodological problems and inconsistent results have made it difficult to draw any firm conclusions for older people (35–37).

The purpose of this study was to provide a comprehensive assessment of the cardiovascular, psychological, and behavioral effects of aerobic exercise training in a group of healthy older (greater than 60 years) men and women. The study was designed to improve upon the methodological shortcomings of previous research by (a) using a longitudinal design in which a large cohort of subjects undergo intensive exercise training; (b) precisely measuring changes in aerobic fitness using measures of direct oxygen consumption; (c) including randomized control groups to identify nonspecific factors (e.g., attention, expectations, enhanced self-efficacy, etc.) that may contribute to changes in physical and psychological functioning; and (d) evaluating concurrent changes in behavioral and psychological characteristics, as well as changes in cardiovascular function among study participants.

**METHOD**

One hundred thirteen men and women were initially recruited as subjects for the study through television, radio, and newspaper advertisements. Twelve subjects were subsequently excluded because of positive ECG during exercise testing (n = 5), moving from the area (n = 2), evidence of coronary artery disease (n = 1), asthma (n = 1), previous pneumonectomy (n = 1), uncontrolled hypertension (n = 1), or concurrent beta-blocker therapy (n = 1). All remaining 101 subjects (51 women, 50 men) were judged to be free of clinical manifestations of coronary disease by medical history, physical examination, and bicycle ergometry exercise testing performed under continuous electrocardiographic monitoring. The subjects ranged in age from 60 to 83 years (mean = 67.0 ± 4.9 years). All subjects had at least a high school education, and 96% were white.

**Procedures.** — Subjects were randomly assigned to an Aerobic Exercise (AE) group (n = 33), a Yoga and Flexibility (YO) control group (n = 34), or a Waiting List (WL) control group (n = 34) following the completion of an extensive assessment battery. Subjects in the AE group attended three supervised exercise sessions per week for 16 consecutive weeks. Based on maximum heart rate achieved during the bicycle exercise test, subjects were assigned six-seat training ranges equivalent to 70% maximum heart rate reserve (38). Each aerobic exercise session began with a 10-minute warm-up exercise period followed by 30 minutes of continuous bicycle ergometry at an intensity that would maintain heart rate within the assigned training range. The subjects then engaged in brisk walking/jogging and arm ergometry for 15 minutes. The exercise session concluded with 5 minutes of cool-down exercises. Heart rates were monitored via radial pulses and were recorded, along with ratings of perceived exertion (39), three times during each exercise session.

Subjects in the YO group participated in 60 minutes of yoga exercises at least two times a week for 16 weeks. The supervised yoga classes provided a control for the effects of social stimulation and attention from trainers, without producing an aerobic training stimulus.

Subjects randomized to the WL control group did not receive any form of treatment between Time 1 and Time 2 evaluations. They were instructed not to change their physical activity habits and specifically not to engage in any aerobic exercise for the 4-month period. Subjects in all three groups were told to maintain their regular dietary habits until completion of the study. No suggestions for dietary modification were offered to any subjects.

**Assessment Procedures**

All participants underwent comprehensive physiological and psychological evaluations that were conducted prior to the beginning of the exercise program (Time 1) and after four months (Time 2).

**Physiological measures.** — Blood pressure was obtained by standard cuff sphygmomanometry with the subject in a sitting position. Body weight was obtained by a standard balance scale. Plasma triglycerides, total serum cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C) were determined from blood samples drawn between 0700 and 0900 hours following a 14-hour fast. Blood was withdrawn by a one-syringe, 15 cc vacutainer tube, anticoagulated with 3.5% sodium citrate, and centrifuged at 6000 × g for 15 minutes prior to analysis by a commercial laboratory. Although assays from commercial laboratories may be variable (40), the quality control data from Smith Klein Laboratories (Atlanta, GA) between January 1986 and June 1987 were excellent (r > .90).

Measurement of bone density by single photon absorptiometry with L-125 was performed using a Bone Densitometer (Norland Corporation, Fort Atkinson, WI). The bone mineral content (mg/cm²) was obtained from the distal radius of the non-dominant arm by locating the position at which the radius and ulna were separated by 5 mm. This site has been demonstrated to contain 50% trabecular bone (41). The subject was seated and the arm studied in slight pronation (1–10 degrees).

In order to measure cardiorespiratory fitness, subjects underwent bicycle ergometry testing. Each subject performed two maximum effort exercise tests following an initial practice test on a Fitron cycle ergometer (Cybex Lumex, No. F1000750). The graded exercise protocol consisted of 3-minute stages starting at 150 kpm and increasing 150 kpm at each stage. Subjects maintained a pedaling rate of 50 rpm. Subjects exercised until exhaustion or standard clinical endpoints. A 12-lead EKG (Hewlett Packard, No. 1517A) was employed to provide continuous electrocardio-
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Psychological measures. — A comprehensive psychological test battery including measures of mood, psychiatric symptoms, and neuropsychological functioning was administered before and after the exercise program.

Anxiety, depression, and overall mood were assessed by questionnaires. Anxiety was assessed by the State-Trait Anxiety Inventory (43), a 40-item questionnaire that measures levels of anxiety at the time of the assessment (state) and in general (trait). Depression was measured by the Center for Epidemiological Studies Depression Scale (44), which is a 20-item scale that assesses how many days in the past week the subject experienced symptoms associated with depression. The Affect Balance Scale (45), a 10-item mood survey, was used to measure global positive and negative emotional states. Life satisfaction was assessed by the 20-item Life Satisfaction Index (46), and a 10-item Self-Esteem Scale (47) was used to measure perceived self-confidence.

Psychiatric symptoms were assessed from the Hopkins Symptom Checklist (SCL-90-R) (48), a 90-item questionnaire designed to assess the degree of emotional distress and psychopathology. For the purposes of this study, five scales were selected to measure psychiatric symptoms including the Somatization, Obsessive Compulsive, Phobic Anxiety, Paranoid Ideation, and Psychoticism scales.

Neuropsychological functioning was assessed in several behavioral areas. Two tests were used to assess strength and motor function:

- The Finger Tapping Test (49) requires the subject to tap the index finger of each hand as quickly as possible for two 30-second trials alternating between dominant and non-dominant hands.
- The Strength of Grip Test (49) requires the subject to squeeze a hand dynamometer (Smedley Inc., Chicago) for four trials. The first and third trials were performed with the dominant hand, and the second and fourth trials were performed with the non-dominant hand.

Four procedures were used to assess memory function:

- The Short Story Module of the Randt Memory Test (50) requires subjects to recall the details of a short story immediately after it has been read to them and after a 30-minute delay.
- The Digit Span Subtest of the WAIS-R (51) requires subjects to repeat a series of digits that have been orally presented to them both forward and, in an independent test, in reverse order.
- The Benton Revised Visual Retention Test (52) requires subjects to draw from memory a series of geometric shapes following a 10-second exposure.
- The Selective Reminding Test (53) requires subjects to read a list of words and then to recall as many as possible.

Three procedures were used to assess psychomotor function:

- The Digit Symbol Subtest of the WAIS-R (51) is a paper-and-pencil task that requires subjects to reproduce, within 90 seconds, as many coded symbols as possible in blank boxes beneath randomly generated digits, according to a coding scheme for pairing digits with symbols.
- The Trail Making Test (Part B) (49) requires subjects to connect, by drawing a line, a series of numbers and letters in sequence (i.e., 1-A-2-B, etc.) as quickly as possible.
- The 2 & 7 Test (54) is a timed visual scanning task in which subjects must identify "target" stimuli (the digits 2 and 7) from an array of visually presented distractors.

Several other tests were also included as general measures of psychomotor function:

- The Nonverbal Fluency Test (55) requires subjects to draw as many original, nonrepetitive designs as possible in a five-dot matrix within a two-minute time limit.
- The Verbal Fluency Test (56) includes two one-minute trials in which subjects are asked to generate as many words as possible that begin with a given letter.
- The Stroop Color-Word Test (57) measures the ease with which subjects can shift their perceptual set by accurately naming the color of the ink that the words red, blue, or green are printed in. Each word is printed in a different color ink than the color it represents.

A Perceived Change Questionnaire was administered at Time 2 only, and was designed to measure subjects' self-ratings of perceived change in mood, personality, physical and social functioning. Nineteen dimensions were included, and each was rated on a 7-point Likert-type scale, from "much worse" to "much improved."

Data Analyses

The principal mode of data analysis was a repeated measures multivariate analysis of variance (MANOVA). Group (AE, YO, or WL) and Sex (Male or Female) served as between-subject factors, while Time (Time 1 and Time 2 or Pre- and Post-Treatment) served as a within-subject factor. In order to control for the numerous instruments that were used, variables were clustered into various conceptual units (e.g., exercise performance, lipids, mood, psychiatric symptoms, strength and motor function, memory, etc.) whenever possible. Univariate analyses were examined when significant multivariate effects were observed. In cases where data could not be clustered (e.g., body weight), data were analyzed by ANOVA.

RESULTS

Comparability of groups. — Table 1 shows the characteristics of the subjects in the three groups. Among the 101 subjects who completed the Time 1 baseline assessments,
Table 1. Baseline Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Aerobic</th>
<th>Yoga</th>
<th>Wait List</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n = 33)</td>
<td>(n = 34)</td>
<td>(n = 34)</td>
<td>(n = 101)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>66.5 ± 4.3</td>
<td>67.8 ± 5.9</td>
<td>66.8 ± 4.3</td>
<td>67.0 ± 4.9</td>
</tr>
<tr>
<td>Sex (M/F)</td>
<td>M = 17 F = 16</td>
<td>M = 17 F = 17</td>
<td>M = 16 F = 18</td>
<td>M = 50 F = 51</td>
</tr>
<tr>
<td>Education (years)</td>
<td>15.2 ± 2.0</td>
<td>15.6 ± 2.6</td>
<td>14.6 ± 2.6</td>
<td>15.2 ± 2.4</td>
</tr>
<tr>
<td>(\text{VO}_{2}\text{max} (\text{ml/min}))</td>
<td>1454.9 ± 538.0</td>
<td>1354.2 ± 438.9</td>
<td>1345.6 ± 436.2</td>
<td>1376.6 ± 471.6</td>
</tr>
<tr>
<td>SCL-GSI</td>
<td>51.1 ± 3.6</td>
<td>52.1 ± 4.7</td>
<td>53.7 ± 6.6</td>
<td>52.3 ± 5.2</td>
</tr>
<tr>
<td>Vocabulary</td>
<td>60.3 ± 6.9</td>
<td>59.7 ± 8.1</td>
<td>57.7 ± 8.2</td>
<td>59.2 ± 7.8</td>
</tr>
</tbody>
</table>

Note: Values are means ± SD

there were no significant group differences in demographic, physiological, or psychological characteristics.

The subjects in this study population were characterized by educational levels above those in the United States population as a whole. The incidence of psychopathology was low and the level of intellectual functioning (inferred from the Vocabulary subsets of the WAIS-R) was above average as compared to published normative data (51).

Adherence to randomization procedure. — Of the 101 subjects who entered the study, 97 completed both Time 1 and Time 2 testing. Only four subjects failed to complete their respective programs and were not available for the Time 2 assessments. Of the four subjects who dropped out of the study before the Time 2 assessments, two subjects dropped out of the AE group because they moved from the area, and two subjects dropped out of the WL group because of family illness. This left a sample of 48 men and 49 women for an overall adherence rate of 96%.

Assessment of subject participation indicated that the AE and YO participants were highly compliant with their respective programs. Subjects assigned to the AE group exercised for a mean (± SD) total of 46 ± 2 exercise sessions (out of a possible 48) while the YO group attended 32 ± 3 exercise sessions (out of a suggested 32) during the 16-week period. Review of the daily exercise logs indicated that the AE group subjects were within or above their prescribed HR training range 88% of the time. Perceived exertion ratings (RPE) during the aerobic exercise classes were in the “moderate” range (13.4 ± 1.8).

Changes in cardiorespiratory fitness. — Heart rate at rest and submaximal (300 kpm) workload, duration of exercise on the bicycle ergometer, and peak VO₂ were all considered together in a MANOVA. The MANOVA for the measures of cardiorespiratory fitness revealed significant multivariate main effects for time, \(F(3,86) = 10.25, p < .001\), and sex, \(F(3,86) = 66.83, p < .001\), and a significant multivariate Group × Time interaction, \(F(6,172) = 7.69, p < .001\).

Comparison of peak VO₂ data revealed that men had higher initial fitness levels (21.7 ± 4.2 ml/kg/min) than women (16.0 ± 2.9 ml/kg/min). However, both men and women in the AE group experienced comparable improvements in aerobic capacity. Univariate analysis of the peak VO₂ revealed a significant Time × Group interaction, \(F(2,90) = 6.89, p < .01\). Figure 1 shows that subjects in the AE group experienced an overall 11.6% increase in peak VO₂. Men achieved a 14.4% improvement in peak VO₂ and women achieved an 8.6% improvement. AE participants increased from 19.4 ± 5.3 to 21.4 ± 5.8 ml/kg/min. The respiratory exchange ratios (RER) at Time 1 (1.30) and Time 2 (1.33) were not significantly different, suggesting that exercise tests at Time 1 and Time 2 were comparable. In contrast, subjects in the YO and WL groups experienced a nonsignificant 1–2% reduction in aerobic capacity (Yoga: 18.8 ± 4.7 to 18.7 ± 4.8 ml/kg/min; Wait List: 18.5 ± 4.0 to 17.9 ± 4.2 ml/kg/min). The success of the AE intervention in inducing a cardiovascular training effect is also reflected by their lower heart rates at rest and at submaximal exercise workloads (i.e., 300 kpm) and by the longer exercise times during ergometry testing for the AE group only (see Figure 1).

Anaerobic threshold (AT) was considered separately in an ANOVA as an index of submaximal exercise performance. The ANOVA revealed a significant sex main effect, \(F(1,76) = 123.71, p < .001\), with men having significantly higher ATs (955 ± 217 ml/min) than women (579 ± 93 ml/min). There was also a significant Time × Group interaction, \(F(7,79) = 3.23, p < .04\). Figure 2 shows that the anaerobic threshold increased 13% for the AE group, \(F(1,28) = 7.64, p < .01\), but did not change for the YO and WL control groups.

Changes in lipids. — A MANOVA for the lipid values revealed a significant multivariate sex main effect, \(F(4,89) = 15.26, p < .001\). Univariate analyses indicated that women had higher HDL-cholesterol levels (60.6 ± 14.3 mg%) than men (44.5 ± 8.7 mg%). There were no sex differences for total cholesterol or triglycerides, however. The MANOVA also revealed a marginally significant multivariate effect for Time, \(F(4,89) = 2.34, p < .07\) and a significant multivariate Time × Group interaction, \(F(8,178) = 2.29, p < .03\).

The univariate Time × Group interaction was significant for total cholesterol, \(F(2,92) = 6.95, p < .002\), and for LDL-cholesterol, \(F(2,92) = 6.37, p < .01\). Figure 3 shows that cholesterol levels for the AE group were reduced after training, \(F(1,30) = 5.38, p < .05\), while the cholesterol levels for the YO group increased and the cholesterol levels for the WL group remained unchanged.

Changes in weight and blood pressure. — An ANOVA for body weight revealed significant main effects for sex, \(F(1,87) = 67.9, p < .001\) and time, \(F(1,87) = 4.30, p < .05\), and a Time × Sex interaction, \(F(1,87) = 7.87, p < .01\). Subjects in all three groups, particularly the men, lost a
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Figure 1. Mean (± SE) values of cardiorespiratory training effects.

Figure 2. Mean (± SE) values for anaerobic threshold (AT) obtained during bicycle ergometry studies.

Figure 3. Mean (± SE) values for blood lipid levels.

small but statistically significant amount of weight (Aerobic: 0.4 kg; Yoga: 0.6 kg; Wait List: 0.2 kg).

A MANOVA for blood pressure (systolic and diastolic) revealed a significant time main effect, $F(2,91) = 5.61, p < .01$. The ANOVA for diastolic blood pressure (DBP) revealed a significant time main effect, $F(1,92) = 11.23, p < .01$, with all three groups showing a reduction of 2-4 mm Hg in DBP (Aerobic: 79-75; Yoga: 79-77; Wait List: 79-75 mm Hg). There was not a significant univariate time main effect for systolic blood pressure.

Changes in bone density. — An ANOVA for bone mineral content revealed significant main effects for time, $F(3,85) = 3.09, p < .05$, and sex, $F(3,85) = 18.91, p < .001$. Figure 4 shows that the sex main effect was observed because women had lower mineral content values than men. The time main effect was a result of the lower overall mineral content values at Time 2 compared to Time 1 for all subjects.

Previous studies have used a ratio of bone mineral content to bone width, and have found that women with a ratio < .325 tend to be at risk for subsequent bone fracture (58). Consequently, the sample was partitioned into High and Low risk group categories based upon the suggested .325 cutoff. A 3 (Treatment group) × 2 (Risk group) × 2 (Time) ANOVA revealed a marginally significant 3-way interaction $F(2,85) = 2.32, p < .10$. The high-risk subjects who participated in the AE group experienced an increase in bone mineral content (0.47 ± 0.20 to 0.56 ± 0.18), while the high-risk subjects in the YO and WL group experienced no change.

Changes in mood. — The State-Trait Anxiety Inventory (STAI), CES-Depression Scale, and Affect Balance Scale were considered together in a MANOVA. Results revealed a significant Time × Group × Sex interaction, multivariate $F(8,170) = 2.00, p < .05$. Examination of the univariate effects revealed a significant Time × Group × Sex interaction for the CES-Depression Scale, univariate $F(2,88) = 5.39, p < .01$. Examination of the right panel of Figure 5 reveals that the men in the AE group experienced a significant reduction in their depression scores, $F(1,115) = 8.69, p < .01$. The women in the AE group, however, did not experience a statistically significant change in their depression scores and neither men nor women in the control groups changed significantly between assessments.

The univariate ANOVA for trait anxiety revealed a marginally significant Time × Group × Sex interaction, $F(2,88) = 2.42, p < .09$. Examination of Figure 6 revealed that men in the AE group tended to achieve lower trait anxiety scores at Time 2 compared to the men in the other groups, and women in the AE group tended to achieve lower state anxiety scores than women in the other groups. The ANOVA for the Life Satisfaction and Self-esteem scales revealed no significant main effects or interactions.

Changes in psychiatric symptoms. — Five scales from the SCL-90 were considered in a MANOVA for psychiatric symptoms including Somatization, Obsessive-Compulsive, Phobic Anxiety, Paranoid Ideation, and Psychoticism (see Table 2). The results of this MANOVA revealed a multivariate time main effect, $F(5,86) = 3.56, p < .006$. Significant
univariate time main effects were observed for obsessive-compulsive, $F(1,90) = 6.36, p < .01$ and psychoticism, $F(1,90) = 4.15, p < .05$, with subjects in all three groups reporting fewer symptoms. No other significant multivariate main effects or interactions were observed.

Changes in strength and motor functioning. — Strength and motor function were assessed by tapping speed and grip strength. Results of the MANOVA revealed a significant time main effect, multivariate $F(4,86) = 10.78, p < .001$ and a sex main effect, multivariate $F(4,86) = 48.85, p < .001$. Examination of Table 3 shows that men accomplished more total taps for both the dominant hand, $F(1,89) = 30.94, p < .001$ and nondominant hand, $F(1,89) = 22.28, p < .001$, than women. Similarly, men achieved greater grip strength for the dominant hand, $F(1,89) = 200.39, p < .001$ and nondominant hand, $F(1,89) = 156.42, p < .001$, than women. Table 3 also shows that both men and women tended to display decreased grip strength at Time 2 relative to Time 1.
Changes in memory. — Memory function was assessed by the Digit Span Subtest of the WAIS-R, Benton Visual Retention Test, the Randt Short Story Subtest, and the Selective Reminding Test. Results of the MANOVA revealed significant multivariate main effects for sex, $F(7,84) = 2.55, p < .02$, and time, $F(7,84) = 2.57, p < .02$. Examination of the scores in Table 4 indicates that men scored higher on Digit Span than women, $F(1,90) = 7.82, p < .01$, whereas women achieved higher scores than men on the Selective Reminding Test, $F(1,90) = 5.09, p < .03$. Significant univariate time main effects were found only for two summary scores from the Selective Reminding Test, greater long-term cumulative recall, $F(1,90) = 4.17, p < .05$, and number of intrusions, $F(1,90) = 4.47, p < .04$.

Psychomotor function. — Psychomotor functioning was assessed with the 2 and 7 Test, Trail Making Test (Part B), and Digit Symbol Subtest from the WAIS-R. Results of the MANOVA revealed a significant multivariate main effect for time, $F(4,87) = 3.97, p < .01$. Univariate analyses indicated a significant time main effect for Digit Symbol, $F(1,90) = 15.11, p < .001$. Table 5 shows that all subjects performed better at Time 2 compared to Time 1.

Additional procedures included the Stroop Test and the Nonverbal Fluency and Verbal Fluency tests. These data were analyzed by a MANOVA that revealed significant multivariate main effects for sex, $F(4,87) = 3.21, p < .02$, and time, $F(4,87) = 12.71, p < .001$. Results are displayed in Table 6. The univariate ANOVAs for Nonverbal Fluency revealed a significant time main effect, $F(1,90) = 46.55, p < .001$. In addition, there was a significant sex main effect, with men achieving higher scores than women, $(1,90) = 8.39, p < .01$. Subjects in all three groups achieved a significant increase in mean total productions at Time 2 relative to

---

**Table 4. Memory Function**

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<tr>
<th>Measures</th>
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*Note. Values are means ± SD.*

**Table 5. Psychomotor Function**

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*Note. Values are means ± SD.*
Table 6. Additional Psychomotor Tests

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<td>± 11.2</td>
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<tr>
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<td>± 6.8</td>
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Note. Values are means ± SD.

Table 7. Perceived Changes (in %) Among Study Subjects

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<th>YO</th>
<th>WL</th>
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<td>26</td>
<td>92</td>
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Time 1. There were no significant main effects for Verbal Fluency, however. Examination of the univariate time main effects for the Stroop test revealed that performance improved both in terms of color performance, $F(1.90) = 4.65$, $p < .04$, and interference scores, $F(1.90) = 5.08$, $p < .03$, for all three groups.

Perceived change in quality of life. — Examination of Table 7 reveals that both the AE and YO groups reported comparable changes in social, personal, and physical functioning. In contrast, the WL showed little perceived change on any of the measures. The active treatment groups reported more positive changes (chi square $p < .001$) than the waiting list group on 17 of 19 variables.

DISCUSSION
The results of this study indicate that four months of aerobic exercise training elicited significant increases in cardiorespiratory functioning in healthy older men and women. A moderate intensity aerobic exercise program of 60 minutes three times a week was associated with an overall 11.6% improvement in directly measured peak VO2 and a 13% increase in anaerobic threshold. This level of improvement of cardiorespiratory fitness is generally consistent with previous studies of older subjects that reported increases of VO2 max from 5–20% (59). For example, these data are consistent with the recent 1-year trial of exercise among retired men reported by Cunningham et al. (18). Moreover, the present results indicate that women participating in aerobic exercise are able to achieve similar levels of improvement in cardiorespiratory fitness. Posner et al. (60) also reported recently a comparable improvement in VO2 max and maximal work rate in their sample of 28 elderly men and women participating in four months of aerobic exercise. Schocken et al. (61) also reported a 10% improvement in functional capacity, although VO2 was not measured directly. It should be noted that reports by Seals et al. (21) and Dustman et al. (33) found a two- to threefold larger improvement in aerobic capacity, however. These latter two studies differ from ours in several important respects: their samples were considerably smaller, subjects in their study included more men, and samples included subjects who were less fit initially than subjects in the present study. DeVries (62) also reported a 15.8% improvement in physical work capacity after 42 weeks of exercise but reported data on only eight of an initial group of 112 male subjects aged 52 to 88. Dustman et al. (33) reported a 27% improvement in VO2 max in 13 study subjects. Although our 4-month exercise training protocol was similar to that of the Dustman et al. study, subjects in the present study experienced less than 50% of the improvement in VO2 max reported by Dustman et al. However, the Dustman sample was younger than the present sample (60 vs 67 years) and predominantly male (9 of 14 subjects vs 50 of 101 subjects). Furthermore, our use of ergometry testing rather than treadmill testing may have limited our VO2 values, since bicycle values may be 5–10% lower than treadmill values (63,64). The significant 13% improvement in AT is also noteworthy. Changes in AT may be more meaningful than improvements in VO2 max, as subjects’ daily activities seldom require maximum effort (65). Our data indicate that subjects in the AE group were able to perform more work before exercise-limiting ventilatory and metabolic changes occurred and suggest greater submaximal, as well as peak, work capacity.
In addition to aerobic fitness, other favorable physiological changes were observed among aerobic exercise participants including lower cholesterol levels and, for subjects at risk for bone fracture, an increase in bone mineral content. Previous studies have associated increased levels of physical activity with higher bone mineral content (66–71). Talmage and colleagues (71), for example, reported that the most active women in a cohort of over 1,200 subjects had greater bone mass than the sedentary women. In another cross-sectional study, Jacobsen et al. (70) concluded that regular exercise may reduce bone loss accompanying aging, especially post-menopausally. These cross-sectional studies contain inherent biases, however (72). Our longitudinal data indicate that four months of aerobic exercise may increase bone mineral content in individuals who have low bone density and who are apparently at risk for fracture. Although the mechanisms for this observation are unknown, radial measurements may reflect overall skeletal status in healthy adults (73), and suggest that exercise may actually increase bone density.

Although the relationship between exercise and serum lipid levels has not been definitively established, decreases in the total cholesterol and LDL-cholesterol and increases in HDL-cholesterol have been reported (74). Our data are consistent with recent reviews that suggest that reductions in total cholesterol may be likely especially accompanying weight loss (75). In the present study, weight loss was small and consistent across the three groups, suggesting that reductions in cholesterol may have been induced by the specific effects of the aerobic exercise. Although lipid assays performed by commercial laboratories have been suspect (40), our lipid assays were performed by the same commercial laboratory throughout the duration of the study, and we are unaware of any systematic source of bias that may have selectively reduced the cholesterol levels in the aerobic exercise group.

The representativeness of our study sample is also important to consider in interpreting our data. For example, it has been noted that 85% of all older persons have at least one co-existing chronic medical condition. Our sample was healthy with no concomitant illness. In addition, our subjects were highly motivated to participate in our study, hence a 96% compliance rate, and had a higher than average education. The general lack of significant change using standard psychological instruments may be due to the relatively high level of functioning of our program participants. For example, Himmelfarb and Murrell (76) reported a mean CES-D score of 10.11 in their sample of 279 community elderly aged 54–100 and 36.43 on the STAI trait anxiety scale. The mean scores for our sample were 5.3 and 31.3 respectively. Similarly, our subjects performed at a relatively high level on the neuropsychological procedures and may have had little room for improvement.

There were few psychological changes that could be clearly attributed to a specific treatment condition. There was a tendency for aerobic exercise to be associated with improved mood, in that men experienced reduced depression scores and tended to have lower trait anxiety scores, and women tended to have lower state anxiety scores. However, the improved performance on the various neuropsychological tests was not unique to a particular group, and changes were probably the result of practice and increased familiarity with the tasks.

Two final points are worth noting. Despite the absence of objective changes on the majority of the psychological measures, subjects in the aerobic exercise and yoga groups perceived themselves as changing on a number of important psychological, social, and physical dimensions. In the physical area, subjects felt in better health, felt that they looked better, and that they had more energy, endurance, flexibility, and better sleep; socially, subjects reported improved family relations, better sex life, less loneliness, and a better social life; psychologically, subjects reported improved mood, self-confidence and life satisfaction, and that they had better memory and concentration. In contrast, the wait list control group perceived relatively little change over four months. These differences may be due to the demand characteristics of the study and may simply reflect the fact that subjects in the two active treatment groups expected to feel better. However, it is also possible that subjects’ own self-perceptions may be more sensitive to change (on at least some measures) than the standard psychometric instruments. Both active treatment groups may have experienced an increased sense of self-efficacy which, along with social support, may have served to enhance their feelings of self-confidence and self-esteem.

Second, it should be emphasized that these results represent changes in physical and psychological functioning after only four months of treatment. It is possible that a longer exercise program may be needed for significant psychological changes to occur. We are currently investigating this possibility in follow-up studies of this cohort.

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