

Effects of Endurance Training and Resistance Training on Plasma Lipoprotein Profiles in Elderly Women

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It has been shown that high levels of high-density lipoprotein (HDL) cholesterol and low levels of low-density lipoprotein (LDL) cholesterol are associated with health maintenance in older women, but the few studies that have examined the relationship between exercise and plasma lipoprotein levels in this elderly population have been equivocal. In addition, there are no studies that examine the plasma lipoprotein response of two different types of exercise in a group of active but nonexercising women. Thus, the effects of exercise training on plasma lipoprotein levels in elderly women remain unclear. The purpose of this research was to examine the effects of endurance and resistance exercise on plasma lipoprotein levels in elderly women who were active but nonexercising prior to the study. A total of 45 healthy, active women, aged 70–87 years, were randomly assigned to either an aerobic training (AT, 76 ± 5 years, $n = 15$), resistance training (RT, 73 ± 3 years, $n = 15$), or control (C, 74 ± 5 years, $n = 15$) group. The AT group walked 3 days a week at 70% heart rate reserve. The duration on day 1 was 20 minutes, and it was increased by 5 minutes each day until subjects were walking for 50 minutes (week 3). The exercise training session for the RT group consisted of one to three sets of eight repetitions of eight different exercises at an eight repetition maximum; the C group maintained normal activity. Weight and diet were unchanged across groups. The exercise interventions lasted 10 weeks. Blood samples were obtained from all subjects at week 0 and week 11. Training resulted in a significant decrease in 1-mile walk times and heart rate at completion of the walk for the AT group and a significant increase in eight repetition maximum of all RT exercises. Both AT and RT groups experienced increased HDL cholesterol and decreased triglycerides at week 11 compared with week 0. There were no positive changes in control lipoproteins. Both triglycerides and the total cholesterol to HDL ratio increased significantly while total cholesterol, HDL cholesterol, and LDL cholesterol remained unchanged. The RT group also had significantly lower LDL cholesterol and total cholesterol compared with controls at week 11. Both RT and endurance training resulted in favorable changes to plasma lipoprotein levels for elderly women in only 10 weeks. The fact that this occurred without concurrent changes in weight or diet is an indication that high-intensity exercise alone can be used to modify lipoproteins in populations of healthy elderly women.

A significant amount of effort has been invested in improving the quality of life for the elderly population. This is important, and particularly so for elderly women, because they outlive men by an average of 7 years (1,2). Much of this attention has focused on the value of exercise in maintaining health and improving functional capacity. Resistance exercise has been shown to attenuate muscle wasting, retard the development of disability (3), increase muscle strength and mass (4–6), increase bone density (7), and improve functional capacity and balance (8). Endurance exercise prevents or delays the development of high blood pressure, reduces blood pressure in hypertensive people (9),

improves physical functioning and health perceptions, and increases the capacity for activities of daily living (10). Synergistically, endurance exercise and improved cardiorespiratory fitness decrease the risk of cardiovascular disease, the leading cause of death in the United States, in a dose-response fashion.

One well-known risk factor for cardiovascular disease is hypercholesterolemia. Although some research indicates that exercise has a positive effect on plasma lipoprotein profiles in younger subjects (11–14), the effects of exercise on this risk factor in the elderly population is unclear. Three observational studies have reported that elderly subjects

who are physically active have higher levels of the protective factor, high-density lipoprotein (HDL), than their non-active counterparts (15–17). This is important because it has been shown that high levels of HDL cholesterol and low-levels of low-density lipoprotein (LDL) cholesterol are associated with the maintenance of health in older women (18). In contrast, the few intervention studies that have examined the relationship between exercise and plasma lipoprotein levels in the elderly population show inconclusive results. Fonong and colleagues, Schuit and colleagues, and Shigematsu and colleagues all conducted studies that showed no change in plasma lipoprotein levels after exercise conditioning (19–21). Motoyama and colleagues, Woolf-May and colleagues, and Sunami and colleagues report favorable plasma lipoprotein changes after exercise interventions (22–24). To our knowledge there are no studies that examine the plasma lipoprotein response of two different types of exercise in a group of active but nonexercising elderly women. Thus, the effects of exercise training on plasma lipoprotein levels in the elderly population remain unclear. The purpose of this research was to examine the effect of endurance and resistance exercise on plasma lipoprotein levels in elderly women who were active but nonexercising prior to the study.

METHODS

Subjects

Independently living subjects were recruited from two large cities in the Midwest by advertisements placed in newspapers, local magazines, and church bulletins. Two separate studies were conducted, each with their own control group. There were no significant differences in any parameters for the control groups, so they were combined in the final analysis. The protocols for both studies were identical except for the exercise intervention.

Screening and Exclusion Criteria

Potential subjects completed a preliminary medical history, exercise questionnaire, and written informed consent. After the preliminary medical screening, each potential subject was examined by a physician specializing in family practice and sports medicine, and a complete medical history was obtained prior to participation. Subjects were screened for dementia by using the Mini-Mental State Examination (25) and were excluded from participation if dementia was present. In addition, subjects meeting the exclusion criteria of the American College of Sports Medicine (26), including recent myocardial infarction, resting electrocardiogram changes indicative of acute cardiac event, unstable angina, uncontrolled ventricular or atrial arrhythmia, third degree heart block, severe aortic stenosis, dissecting aneurysm, or recent embolus were not allowed to participate. Other exclusion criteria included the following: the presence of activity-limiting arthritis; being bedridden within 3 months of the study; the presence of central or peripheral nervous system disorders, stroke, acute or chronic infection, major affective disorder, human immunodeficiency virus infection or autoimmune disorders, or metabolic disorders (type I diabetes mellitus); being a smoker or smokeless tobacco user; participating in regular aerobic or resistance

training within the previous 3 months; using oral steroids or medications known to have an effect on blood lipids except hormone replacement therapy; having surgery within the previous 3 months; and consuming caffeine in excess of the equivalent of 4 cups of coffee per day. Six potential subjects were taking a continuous daily dose of 0.625 mg conjugated estrogen and 2.5 mg medroxyprogesterone (PremPro, Wyeth Ayerst, Radnor, PA) orally. Three subjects had been taking the drug for 5 years, and they were randomized one to each group. The other three subjects were uncertain as to how long they had been taking hormone replacement therapy but reported it as “more than 10 years” and were each randomized to a different group.

Prior to the study, a lower extremity musculoskeletal exam was performed to identify musculoskeletal or flexibility limitations that would interfere with the completion of the training protocol. Each subject was also asked to perform a “Get Up and Go” test (27). Subjects who were unable to complete this task were excluded from participation.

Cardiac Screening and Testing

Following the physical exam, subjects were required to perform a submaximal treadmill test with blood pressure and 12-lead electrocardiogram monitoring. After a 3-minute warm-up at 2 mph, the workload was increased by one metabolic equivalent every 2 minutes until the subjects’ heart rates reached 85% of age-predicted maximal heart rate (28). In addition, endurance training subjects completed the 1-mile walk test on a separate day, which enabled estimates of $\dot{V}O_{2\max}$ (29). This test was completed again at week 11. Bazzano and colleagues (30) have determined that this is a suitable field testing procedure for elderly women. Women in the resistance training group completed a baseline one repetition maximum (1RM) for leg extension, leg curl, and plantar flexion and a baseline eight repetition maximum (8RM) for all exercises.

Subjects who were cleared for participation were randomly assigned to either the aerobic training (AT) group or the control (C) group for the first study. Ten weeks later, the second set of subjects was assigned to either the resistance training (RT) or C group. All groups completed a questionnaire for classification into categories of high, medium, and low physical activity, and all participants scored “high” on the Physical Activity Questionnaire (31) prior to training. Although retired and nonexercising, the subjects were a highly active, high functioning group of women.

Diet Analysis

Diet intake was assessed before and after intervention by using the Food Frequency Questionnaire (National Cancer Institute-Block Healthy Habits and History Questionnaire) (32). As a way to increase the accuracy of information, a registered dietitian and a graduate student trained by the dietitian reviewed the procedures to complete the instrument. Subjects were instructed not to alter their diets during training. They were told to report any dietary changes (self-imposed or recommended by medical provider) to the researchers.

Aerobic Training Program

Subjects in the AT group ($n = 15$) completed 10 weeks of endurance training (compliance > 95%). Controls were

asked to maintain their normal activity level for 10 weeks. As a way to determine resting heart rate reserve (HRR), subjects wore Polar Heart Rate monitors (Polar USA, Inc., Woodbury, NY) while they slept on five successive nights, and they recorded their heart rate upon waking. HRR was determined by taking the mean of five early morning heart rates. All AT sessions were preceded by 5–10 minutes of light stretching. On Monday, Wednesday, and Friday, subjects walked at 70% HRR. The duration on day 1 was 20 minutes, and it was increased by 5 minutes each day until subjects were walking for 50 minutes (week 3). It remained at 50 minutes for the duration of the study. Subjects used Polar Heart Rate monitors to help them maintain target heart rates. Heart rates were monitored and recorded by researchers at 10-minute intervals during the training to ensure compliance.

Resistance Training Program

Subjects and controls completed a 1-week period of acclimation on three alternate days. RT was preceded by a 5-minute warm-up on either a treadmill or bicycle ergometer followed by a period of stretching. Subjects were taught proper lifting techniques and safety precautions for the leg extension, leg curl, hip flexion, hip extension, hip adduction, hip abduction, and plantar/dorsi flexion exercises. Following the instruction, subjects performed two sets of eight repetitions of each exercise at a light weight to acclimate to the technique and become acquainted with the equipment. Forty-eight hours later, and after the same warm-up, a 1RM for leg extension, leg curl, and plantar flexion was completed by each subject. A 1RM was defined as the weight that can be lifted no more than one time with "acceptable form." Acceptable form was defined as performing the exercise primarily with the specified major muscle group for that exercise, and through the entire range of motion, without the assistance of momentum or changes in body position. The 1RM tests were followed by 8RM testing for each exercise. An 8RM was defined as the weight that can be lifted no more than eight times with acceptable form. To determine the 8RM, the subject started with 70% of 1RM on leg extension, leg curl, and plantar flexion. For the exercises for which 1RM was not tested, subjects began with a weight assigned by the investigator based on day 1 of acclimation. Subjects completed up to 10 repetitions and were asked to stop. After a 2-minute rest, the weight was increased by 5 lb (~2.26 kg). This procedure continued until 8RM was determined. The third day of acclimation consisted of two sets of eight repetitions at 8RM.

After acclimation, subjects assigned to the RT group ($n = 15$) completed 10 weeks of RT, 3 days per week (compliance > 95%) while controls ($n = 15$) were instructed to maintain their normal activity level. The exercise training session consisted of three sets of eight repetitions of leg extension, leg curl, plantar flexion, and dorsi flexion; two sets of hip flexion and hip extension; and one set of hip adduction and hip abduction. All sets were at 8RM and a 2-minute rest was given between sets. Every Friday, subjects exercised to volitional fatigue during the last set; every Monday, the weight was adjusted to maintain the 8RM workload. After 10 weeks of training, subjects and controls were again

tested for 1RM on leg extension, leg curl, and plantar flexion and for 8RM on all exercises.

Pretraining and Posttraining Responses to Exercise

The pretraining experimental trials were conducted on either Monday or Wednesday the week before the training began. The posttraining experimental trials were conducted on either Monday or Wednesday the week following the completion of the training period. Equal numbers of controls were tested at the same times and on the same day.

Blood Collection Schedule

After a 12-hour to 14-hour fast, a blood sample was obtained between 6 AM and 7 AM from an antecubital vein by a trained phlebotomist, and it was evacuated into a tube containing no preservative. Samples were placed on ice, allowed to clot, and then transported to the laboratory for analysis. They were immediately spun and serum was collected and frozen at -70°C for analysis at a later date.

Plasma Lipoprotein Analysis

Total cholesterol (TC) and triglycerides (TRI) were analyzed by using a standard kit purchased from Sigma Diagnostics Corporation (St. Louis, MO). HDL cholesterol was measured in plasma after precipitation of apolipoprotein B-containing lipoproteins by dextran sulfate and magnesium chloride (33). The samples were run in triplicate and read on the Milton-Roy 501 spectrophotometer. The coefficient of variation was 4.7% for TC, 3.3% for HDL cholesterol, and 5.2% for TRI. LDL cholesterol was calculated by using the following formula (34): $\text{LDL cholesterol} = (\text{TC}) - (\text{HDL cholesterol}) - (\text{TRI}/5)$.

Statistical Analysis

For plasma lipoprotein outcome variables, food frequency questionnaires, mile walk times, estimated $\dot{V}\text{O}_2\text{max}$, and heart rate after 1 mile, a two-factor (Group \times Time) analysis of variance was used. For RT variables, a series of repeated measures analyses of variance were run. When a significant f ratio was found ($p \leq .05$), a Tukey post hoc was performed to determine differences between pairs of means. For before to after differences, a paired sample t test was used, the appropriate Bonferroni correction factor was applied, and the significance level was set at $p \leq .005$.

RESULTS

Subjects

The descriptive data and the results of the food frequency questionnaire can be found in Table 1. There were no significant differences between groups and no significant differences within groups after the training.

1-Mile Walk Time

The 1-mile walk time significantly decreased for all AT participants ($F(1,14) = 5.95$, $p = .029$). In addition, subjects' heart rates significantly decreased after the walk ($F(1,14) = 7.79$, $p = .014$). The combination of decreased time and decreased heart rate resulted in a significant increase in estimated $\dot{V}\text{O}_2\text{max}$ ($F(1,14) = 15.97$, $p = .002$).

Table 1. Subject Characteristics for AT, RT, and C Groups

Parameter	AT (n = 15)		RT (n = 15)		C (n = 15)	
	Before	After	Before	After	Before	After
Age	76 ± 5	76 ± 5	73 ± 3	73 ± 3	74 ± 5	74 ± 5
Weight (kg)	65 ± 9	64 ± 9	60 ± 10	60 ± 10	65 ± 6	65 ± 6
Height (cm)	159 ± 10	159 ± 10	155 ± 7	156 ± 7	158 ± 5	157 ± 5
BMI (kg m ⁻²)	26 ± 5	25 ± 5	26 ± 5	26 ± 5	26 ± 2	27 ± 2
kcal/day	1320 ± 90	1376 ± 85	1296 ± 78	1342 ± 73	1372 ± 125	1302 ± 89
Carbo (g/day)	154 ± 8	160 ± 5	173 ± 12	187 ± 14	175 ± 9	176 ± 8
Protein (g/day)	57 ± 2	59 ± 3	61 ± 3	64 ± 3	53 ± 3	52 ± 3
Fat (g/day)	52 ± 4	54 ± 3	50 ± 2	55 ± 5	54 ± 4	55 ± 3

Notes: AT = aerobic training; RT = resistance training; C = control; BMI = body mass index. Numbers are mean ± standard deviation. There were no significant differences ($p > .05$).

There were no significant changes in time and heart rate for the C group (Table 2).

Resistance Training

There were significant training effects in the 1RM for leg extension (+53%; $t(27) = 7.4, p = .000$), leg curl (+98%; $t(27) = 7.34, p = .000$), and plantar flexion (+93%; $t(27) = 7.61, p = .000$) (Table 3). The 8RM for leg extension (+78%; $F(3,42) = 80.3, p = .000$), leg curl (+152%; $F(3,42) = 66.4, p = .000$), plantar flexion (+147%; $F(3,42) = 125, p = .000$), hip extension (+152%; $F(3,42) = 145.7, p = .000$), hip flexion (+157%; $F(3,42) = 191.9, p = .000$), abduction (+102%; $F(3,42) = 126.3, p = .000$), adduction (+155%; $F(3,42) = 124.3, p = .000$), and dorsi flexion (+179%; $F(3,42) = 52.2, p = .000$) are shown in Table 4. All times (week 0, week 3, week 6, and week 10) were significantly different from each other. There was no difference in 8RMs for controls between week 0 and week 10.

Plasma Lipoprotein Levels

There were significant group effects for TC ($F(2,43) = 104.7, p = .043$), LDL cholesterol ($F(2,43) = 691.5, p = .000$), HDL cholesterol ($F(2,43) = 879.8, p = .015$), TRI ($F(2,43) = 285.8, p = .000$), and TC to HDL cholesterol ratio ($F(2,43) = 19.77, p = .000$). There were significant training effects for HDL cholesterol, the TC to HDL cholesterol ratio, and triglycerides. These differences are shown in Tables 5 and 6.

DISCUSSION

To our knowledge, the present study is the first randomized, controlled study that investigates the possible effects

of two different types of exercise on healthy, active, but previously nonexercising elderly women. The most important finding of this study is that both RT and endurance training resulted in favorable changes to plasma lipoprotein levels for elderly women in only 10 weeks. The fact that this occurred without concurrent changes in weight or diet is an indication that high-intensity exercise alone can be used to modify lipoproteins in healthy elderly populations.

Very few well-controlled studies have been published examining the relationship between exercise and blood lipids in the elderly population, and those that have been published report disparate results. In a recent review, Leon and Sanchez examined the relationship between endurance exercise and lipoproteins, and only 5 out of 51 studies included female subjects over the age of 70 (35). The study by Motoyama and colleagues in which elderly subjects were exercised at 60% maximal heart rate (HR_{max}) for 30 minutes, 3–6 times per week for 9 months (22) and the study by Sunami and colleagues in which elderly subjects were exercised at 50% maximal oxygen consumption 2–4 times per week for 5 months (24) yielded results consistent with those of the present study. In both cases the training groups experienced significant increases in HDL cholesterol and significant reductions in the TC:HDL cholesterol ratio by week 12. Three other studies report different results. Lindheim and colleagues (36) saw no change in HDL cholesterol levels but favorable changes in TC, LDL cholesterol, and TRI after 6 months of aerobic exercise at 70% HR_{max} . Fonong and colleagues reported no significant changes after 8 weeks of AT (19), and Schuit and colleagues (20) reported no change in any variable except TRI after 6 months

Table 2. Results of the 1-Mile Walk Test

Characteristic	Aerobic Trained (n = 15)			Controls (n = 15)		
	Before	After	p	Before	After	p
Time (min)	20 ± 2	17 ± 1*	0.002	21 ± 1	20 ± 2	0.605
Heart rate (bpm)	108 ± 3	98 ± 3*	0.004	110 ± 5	110 ± 2	0.842
Estimated $\dot{V}O_{2max}$ (ml/kg)	19 ± 2	26 ± 3*†	0.000	18 ± 2	18 ± 3†	0.887

Note: Results are mean ± standard deviation.

*Indicates posttraining scores are significantly different from pretraining scores.

†Indicates exercisers are significantly different from controls ($p < .05$).

Table 3. 1RM Leg Strength for RT and C Groups

Characteristic	RT (n = 15)			C (n = 15)		
	Before	After	p	Before	After	p
Leg extension (kg)	16.2 ± 0.9	25 ± 1.0*†	0.000	23 ± 1.0†	20 ± 1.9	0.552
Leg curl (kg)	9.7 ± 0.8	19 ± 1.0*	0.000	11 ± 1.0	10 ± 1.2	0.219
Plantar flexion (kg)	18.0 ± 2.0	36 ± 2.0*	0.000	20 ± 2.0	20 ± 1.5	0.713

Notes: 1RM = one repetition maximum; RT = resistance training; C = control. Numbers are mean ± standard deviation.

*Indicates posttraining scores are significantly different from pretraining scores.

†Indicates exercisers are significantly different from controls ($p < .05$).

Table 4. 8RM Leg Strength Across Times for the Exercise Group

Exercise (n = 15)	Week 0	Week 3	Week 6	Week 10	p
Leg extens. (kg)	12.0 ± 1.0	15.0 ± 1.0	18.0 ± 1.0	21.0 ± 1.0	0.000
Leg curl (kg)	6.8 ± 0.3	9.6 ± 0.8	12.0 ± 1.0	16.0 ± 1.0	0.000
Plantar flex. (kg)	13.0 ± 1.0	19.0 ± 2.0	25.0 ± 2.0	31.0 ± 2.0	0.000
Hip flex. (kg)	5.2 ± 0.4	6.7 ± 0.5	8.9 ± 0.6	13.4 ± 0.6	0.000
Hip extens. (kg)	6.2 ± 0.5	9.0 ± 0.5	11.1 ± 0.6	15.7 ± 0.7	0.000
Abduction (kg)	6.5 ± 0.6	8.1 ± 0.5	9.9 ± 0.6	13.2 ± 0.7	0.000
Adduction (kg)	8.0 ± 0.5	11.1 ± 1.0	14.3 ± 0.7	20.4 ± 0.9	0.000
Dorsi flex. (kg)	11.0 ± 2.0	20.0 ± 2.0	26.0 ± 2.0	32.0 ± 2.0	0.000

Notes: All weeks are statistically different from all other weeks for resistance training ($p < .05$). Numbers are mean ± standard deviation. 8RM = eight repetition maximum.

Table 6. Percent Change in Plasma Lipoprotein Profiles

Parameter	AT	RT	C	p
TC	+2.2 ± 2.1	-5.1 ± 5.4	+7.5 ± 3.9	0.098
LDL	-3.6 ± 7.4	-23.2 ± 10.2	+10.8 ± 6.9	0.593
HDL	+25.3 ± 6.9 ^a	+7.7 ± 8.2 ^b	-7.6 ± 8.2 ^{a,b}	0.009
TRI	-38.6 ± 19.9 ^{c,d}	-10.9 ± 12.4 ^c	+26.5 ± 8.9 ^d	0.009
TC:HDL	-14.5 ± 5.6 ^e	-22.5 ± 6.2 ^f	+10.8 ± 12.4 ^{e,f}	0.000

Notes: Profiles are mean ± standard error of the mean. TC = total cholesterol; LDL = low-density lipoprotein; HDL = high-density lipoprotein; TRI = triglycerides; AT = aerobic training; RT = resistance training; C = control. Like letters indicate significant differences ($p < .05$).

of AT. The reason for the discrepancies in the literature is unclear but may be related to the exercise intervention itself. There is some evidence that suggests that a reduction in cardiovascular risk is associated with both the intensity and the amount of endurance exercise (11). The exercise intensity used in the present study was higher than that used previously with elderly women. The present study exercised elderly women for 50 minutes at 70% HRR. A recent study by Kohrt and colleagues (37) indicated that using HRR for prescribing exercise intensity would likely result in an exercise session that is performed at a higher than expected percentage of $\dot{V}O_2\text{max}$ in elderly subjects. Thus, in the present study it may be reasonably assumed that the women exercised at a higher intensity than in previous studies. Many elderly women are unable to exercise at a high intensity, and because increased intensity is also related to increased risk of injury, future research should focus on finding the minimum intensity necessary for favorable change.

There is a dearth of information available examining the relationship of RT to lipoprotein levels, particularly for elderly populations. In younger populations, RT has been reported to both improve the lipoprotein profile (38) and result in no change (39,40). However, because septuagenarian and sexagenarian endurance athletes have been shown to differ from younger populations in HDL cholesterol, LDL cholesterol, and TRI, caution has to be used when results are extrapolated from younger populations to older ones (11).

The results of the present study demonstrate a favorable response of plasma lipoproteins to RT. After 10 weeks of high-intensity RT, subjects experienced an increase in HDL cholesterol and a decrease in TRI. They were also significantly lower than the C group in TC and LDL cholesterol. These results are in disagreement with those of Lyndon and

colleagues (41), who reported a decrease in HDL cholesterol and consequently the TC:HDL cholesterol ratio after 12 weeks of progressive RT twice weekly. Although both studies exercised subjects at the same intensity, the present study used three more exercises and increased the frequency by 1 day per week. If, as previously noted, improvements in the plasma lipoprotein profile are associated with both the intensity and the amount of endurance exercise (11), this may hold true for resistance exercise as well.

In the present study, the women in each training group increased their HDL cholesterol by at least 9 mg/dl, whereas the women in the C group decreased their HDL cholesterol by almost 5 mg/dl. Gordon and colleagues (42) estimated that a 1 mg/dl increment in HDL cholesterol is associated with a 4.7% decrement in cardiovascular disease rates. Based on those estimates, the exercising women decreased their risk of cardiovascular disease by almost 47% whereas the nonexercisers increased their risk by 21%. In addition, exercise can positively affect other risk factors for cardiovascular disease such as blood pressure, insulin resistance, and obesity (43). The combination of the protective factors related to exercise and lipoprotein profiles is likely to significantly reduce the risk of cardiovascular disease in these women.

Many previous studies have been criticized for flaws in the methodology that failed to provide a C group, randomize the groups, or control for extraneous factors including the possible interaction of acute exercise on lipoprotein levels and subjects' diet (16,44). Subsequent research has controlled for these factors and the results are still inconsistent (16,19,22,24,44). What seems apparent is that there is no ideal exercise prescription for improving blood lipid profiles in both sexes and across age groups, exercise levels, and body mass indices. Therefore, it is important to study

Table 5. Plasma Lipoprotein Profiles

Parameter	AT		RT		C	
	Before	After	Before	After	Before	After
TC (mg/dl)	178.9 ± 7.5	182.6 ± 8.4	172.2 ± 9.5	162.2 ± 7.0 ^b	184.5 ± 7.6	196.7 ± 8.2 ^a
LDL (mg/dl)	113.4 ± 6.0	106.6 ± 6.7	107.3 ± 11.2	89.0 ± 11.2 ^b	122.5 ± 7.5	132.1 ± 8.5 ^b
HDL (mg/dl)	45.4 ± 3.5 ^c	54.4 ± 2.9 ^{c,e}	47.1 ± 3.3 ^d	57.4 ± 2.0 ^{d,f}	43.1 ± 3.4	38.6 ± 3.6 ^{e,f}
TRI (mg/dl)	149.8 ± 10.9 ^{g,h}	128.9 ± 15.2 ^{g,i}	113.5 ± 12.9 ^{h,k}	84.6 ± 12.9 ^{h,k}	105.7 ± 12.7 ^j	142.0 ± 16.8 ^j
TC:HDL (ratio)	4.2 ± 0.3 ^m	3.4 ± 0.2 ^{m,n}	3.9 ± 0.4 ^o	2.9 ± 0.3 ^{o,p}	4.5 ± 0.3 ^p	5.6 ± 0.4 ^{o,p}

Notes: Profiles are mean ± standard error of the mean. TC = total cholesterol; LDL = low-density lipoprotein; HDL = high-density lipoprotein; TRI = triglycerides; AT = aerobic training; RT = resistance training; C = control. Like letters indicate significant differences ($p < .05$).

each group as a separate entity. Despite the fact that over 90% of women who die of cardiovascular disease are over the age of 65 (45) and that survival rates are linked to blood lipids (46), elderly women represent an understudied population. It is not possible to randomize a population-based study that requires subjects to participate in an exercise intervention. Therefore, the voluntary nature of the participation in the present study is a limitation. Caution has to be exercised before the results are extrapolated to the general population of elderly women, especially those who are neither motivated nor physically able to participate in an exercise program. Despite limitations, the present study demonstrates that healthy, motivated elderly women are capable of tolerating a level of exercise necessary to bring about favorable changes in the lipoprotein profile. Future studies are needed to determine the minimum amount and intensity of exercise necessary to bring about favorable changes in frail elderly populations.

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