Effects of Resistance Exercise and Body Mass Index on Lipoprotein–Lipid Patterns of Postmenopausal Women

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ABSTRACT

The purpose of this study was to examine the effects of a 16-week Dynaband resistance exercise program and body mass index (BMI) on the lipoprotein–lipid patterns of postmenopausal women aged 60–80 years. Eighteen female volunteers recruited from 3 senior nutrition sites in the Oklahoma City area completed the study. Subjects were tested for resting heart rate and blood pressure, skinfolds and circumferences, and fasting blood samples were obtained for the lipoprotein assays before and after the training program. The exercise program included a 10-minute warm up, followed by progressive resistance exercises (10–15 repetitions, 1–2 sets, 3×/week) utilizing Dynabands to train 7 muscle groups and concluded with a 5-minute cool-down. There were no significant changes in body weight, % body fat, or in waist-to-hip ratios resulting from the training program, and BMI did not appear to modulate the findings. Improvements in high-density lipoprotein cholesterol (HDL-C) concentrations and in the total cholesterol/HDL-C ratio were observed after training. In conclusion, the Dynaband resistance training program was associated with improvements in HDL-C that were not accounted for by weight loss.

Key Words: coronary heart disease, exercise, blood lipids, aging


Introduction

Coronary heart disease (CHD) is the leading cause of death for women over 65 years of age (27, 29). High blood levels of low-density lipoprotein cholesterol (LDL-C) and total cholesterol (TC) are associated with increased risk for coronary heart disease. Conversely, elevated high-density lipoprotein cholesterol (HDL-C) levels provide some protection against the development of atherosclerosis (9). After menopause, women exhibit a more atherogenic blood lipid profile which is one factor that could contribute to the increased rates of death from CHD in postmenopausal women (6, 27, 31, 34). It is important to examine the effects of interventions on the HDL-C levels of postmenopausal women as it appears to be a more potent CHD risk factor than LDL-C in this population (24).

Many studies have shown a beneficial effect of aerobic exercise on blood lipid profiles and cardiovascular health (11, 23). Cross-sectional studies in young and middle-aged women have shown that physically active women have serum lipid profiles associated with lower risk for CHD than sedentary women. Reaven et al. (33) reported higher HDL-C, but similar TC, LDL, and triglycerides (TG) in elderly women who self-reported as regular exercisers compared to those women who did not exercise. This relationship was further evidenced in highly endurance-trained elderly women who had significantly higher HDL-C and lower serum triglycerides (TG) than sedentary counterparts (30). Several prospective exercise intervention studies have demonstrated that endurance training programs in postmenopausal women were associated with decreases in TC and LDL-C, but HDL-C was not affected (4, 25). When HDL-C levels were elevated following aerobic training, the training interventions varied in length from 3 months to 2 years (19, 28). Although some investigators have reported that the training period needs to exceed 6 months for improvements in HDL-C to be noted (19) others have demonstrated that improvements can be detected with as little as 4 weeks of training (13).

Resistance training recently has become a form of exercise recommended for improving strength, balance, and bone mineral density in older populations (12); however, the effects of this type of exercise on blood lipid profiles are not clear. Resistance training interventions in subject populations of different genders or ages (i.e., young, middle-aged) have yielded variable results, with some studies reporting favorable
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Changes in blood lipids (17), whereas others found no effect (5, 22, 26). An early study by Hurley et al. (17) documented a significant increase in HDL-C and decrease in LDL-C in middle-aged men after 16 weeks of a traditional weight-training program. Interestingly, this positive alteration in the blood lipid profile occurred without concomitant changes in body weight or percent fat. These findings, however, have not been replicated in either men (22) or in middle-aged women (5, 26). The lack of response in these studies could be attributed to normal blood lipid profiles and/or to high HDL-C levels of the subjects at baseline that makes it more difficult to induce a training effect (35).

Potential mechanisms for exercise-induced alterations in blood lipids include loss of body weight, decreased adiposity, and changes in the enzymes that regulate lipoprotein metabolism (11, 37). There is a clear relationship between body weight and blood lipid changes with weight loss being associated with increases in HDL-C and decreases in total cholesterol and LDL-C (37). Changes in fat distribution also affect lipid profiles, as loss of abdominal fat and a decreased waist-to-hip ratio are related to increased HDL-C. Generally, exercise programs not associated with weight loss result in increased HDL-C but do not affect TC or LDL-C levels. This improvement in HDL-C with exercise training may be the result of increased activities of enzymes involved in the clearance of lipid from the blood or in the reverse transport of cholesterol (11, 14).

In addition to the effects of a community-based resistance program on neuromuscular function, we were also interested in whether a moderate intensity resistance exercise program would be associated with positive changes in blood lipid profiles of elderly women and whether or not these changes would be modified by body mass index (BMI) or body weight. The purpose of this study was to examine the effects of a 16-week Dynaband resistance exercise program on lipoprotein–lipid patterns of sedentary postmenopausal women. There are 2 unique aspects to this study. First, there is a paucity of data pertaining to the effects of resistance exercise programs on the blood lipids of elderly women. Second, the Dynaband program itself is a unique, nontraditional program that could be implemented in a senior center or in a home setting. We have already reported the results of this program on muscular strength and joint flexibility (3).

Methods

Subjects
Initially, 21 Caucasian women volunteered for the study; however, 1 subject dropped out of the program for a nonmedical reason and the phlebotomist was not able to obtain posttraining blood samples from 2 subjects. Thus, data from the remaining 18 women, ranging in age from 60 to 80 years (mean age = 72.9 ± 1.6 years) are reported in this paper. A power analysis determined that a sample size of 18 was still sufficient to detect exercise-induced changes in lipoprotein–lipid patterns based on previous studies (13). This was verified by our data analysis, which indicated that the power for the HDL-C trial effect in our study was 96%.

The subjects were recruited from 3 senior nutrition sites in the Oklahoma City (OKC) area. These nutrition sites are part of the community-based services provided by the Areawide Aging Agency, Division of Aging Services, Oklahoma Department of Human Services. The functions of the nutrition sites are (a) to provide a noon meal for seniors that provides one-third of their minimum dietary requirement; and (b) to organize activities that promote social interactions for this population. A randomized control trial design was not used as this program was sponsored by the Areawide Aging Agency for the purpose of providing an opportunity for social interaction for all interested seniors. All participants were asked to maintain their current level of activity outside of the exercise program.

Training Program
The 16-week (3×/week) resistance training program utilized Dynabands (The Hygenic Corporation, Akron, OH) that are a brand of commercially available elastic bands that can be used for resistance exercises. Subjects exercised 3 times per week with each training session supervised by both a trained senior volunteer and research assistants from the Neuromuscular Laboratory. Each session began with a 10-minute warm-up that consisted of walking and light stretching. Eight muscle groups were targeted for strengthening in the following order: chest, back, shoulder, biceps, triceps, quadriceps, hamstrings, and gastrocnemius. Each exercise was performed for 10–15 repetitions; the 45 minute exercise session concluded with a 5-minute cool-down. During each training session, subjects followed the examples of the trained group leader and were also able to watch a videotape of the exercise program.

The program was based on the progressive resistance exercise principle and was supervised by both a trained senior volunteer and laboratory staff. Each Dynaband was color coded in the following order of increasing resistance: pink, red, blue, green, and silver. Each subject began the training program with the pink Dynaband (approximately 7 lb of resistance at a stretched distance of about 24 in.). As each subject completed the 15 repetitions with the pink Dynaband, she then progressed to either the red Dynaband (approximately 10 lb of resistance at a stretched distance of about 24 in.) or doubled the resistance of the pink Dynaband by using 2 in parallel to each other. At the conclusion of the study, most subjects were using the silver Dynaband (approximately 25 lb of resistance at
a stretched distance of about 24 in.) for all the exercises. Adherence was excellent during the training program with all participants attending at least 95% of the exercise sessions.

**Body Composition**

Height, weight, skinfolds (tricep, suprailiac, thigh), and circumferences (waist, hip) were assessed using standardized procedures (16). The BMI was calculated as weight/height² (kg·m⁻²). Percent body fat (%BF) was estimated using the Jackson, Pollock, and Ward (18) equation. Body fat distribution was assessed by calculating the waist-to-hip ratios (WHR) by dividing the waist circumference by the hip circumference.

**Nutrition and Physical Activity Assessment**

Subjects recorded their 3-day dietary intakes at baseline and at the end of the training program. Subjects were shown food models to help visualize serving sizes and they were instructed on the best way to keep records. Dietary analyses were performed using DINE software (DINE Systems, Inc., Amherst, NY).

Subjects completed medical and menstrual history questionnaires prior to the study. Subjects were also asked to complete 3 questionnaires that could provide information pertaining to their activity patterns and current health status. The questionnaires included the Physical Activity Self Assessment Form, the Physical Activity Report Form, and the Short Form Health Survey-36 (36). The 2 physical activity questionnaires were developed in the Human Performance Lab at the University of Oklahoma and validated against the Harvard Alumni Health Questionnaire (32) and a questionnaire developed by Bouchard and associates (7).

**Blood Lipid Profiles**

Overnight fasting blood samples were obtained in the morning pre- and posttraining. The samples were allowed to clot and then were centrifuged to obtain the serum that was frozen at -20°C until the blood lipid assays were performed. The assays for TC, TG, LDL-C, very low-density lipoprotein cholesterol (VLDL-C), HDL-C, apolipoprotein C-III (apoC-III), and the distribution ratio (apoC-III ratio) of apoC-III in HDL-C to VLDL-C were conducted in the Lipid and Lipoprotein Laboratory directed by Dr. Petar Alaupovic (Oklahoma Medical Research Foundation, OKC). This research laboratory is certified by the Centers for Disease Control—National Heart, Lung, and Blood Institute Lipid Standardization Program. ApoC-III is an apolipoprotein synthesized by the liver involved in VLDL-C and HDL-C transport and it also functions to inhibit lipoprotein lipase activity (11). The ratio of apoC-III in HDL-C to apoC-III in VLDL-C indicates the efficiency of the degradation of the TG-rich lipoproteins (1). High apo-CIII levels and lower apoC-III ratios are associated with greater progression of atherosclerosis.

**Data Analyses**

Descriptive statistics were obtained for all variables. One-way analysis of variance (ANOVA) with repeated measures was used to determine the training effects on the body composition and blood lipid variables. Independent t-tests were used to determine whether the absolute changes in the blood lipids were significantly different from zero. Pearson correlation coefficients were computed to examine the relationships between the body composition and lipid variables. To investigate the influence of BMI and body weight on the variables of interest, subjects were divided into 2 subgroups based on BMI (above or below a BMI of 27 kg·m⁻²) and a 2-way repeated-measures ANOVA was performed. The probability level for statistical significance was set at p ≤ 0.05. A Bonferroni correction (α/number of t-tests) was used for the independent t-tests to control for inflated α levels.

**Results**

The subjects were late postmenopausal, having experienced their last menstrual period on average 33 ± 3 years (ranging from 20 to 53 years postmenopausal) before entering the study. The subjects also were sedentary and nonsmokers. Fourteen of the 18 women were not receiving any hormone replacement therapy while 4 were on estrogen replacement. The data were analyzed for the entire group of 18 subjects and again with the hormone replacement subjects removed. This procedure did not affect any statistical findings, therefore the entire group of 18 was used in all of the statistical procedures.

**Physical Characteristics**

Table 1 shows the pre- and posttraining means and standard errors for the physical characteristics and body composition variables for all of the subjects (n = 18). There were no significant changes in body weight, %BF, or in WHR as a result of the resistance training program. Although BMI decreased slightly (p = 0.046) from 28.6 to 28.3 kg·m⁻² it remained in the range for grade 1 obesity (2). Table 1 also displays the physical characteristics for those subjects below a BMI of 27 kg·m⁻² and with a lower body weight, approximately 66 kg, and those with a BMI above 27 kg·m⁻² and a higher body weight of about 78 kg.

**Strength**

As reported in Bemben et al. (3), the laboratory measures of strength improved for each of the muscle groups tested. The greatest improvements occurred for the biceps (25.2%) and quadriceps (12.7%) with smaller improvements for the hamstrings (1.5%) and triceps (5.7%).

**Activity and Dietary Profiles**

As mentioned earlier, all subjects were apparently healthy and sedentary. Scores on the Physical Activity
Table 1. Means ± SE for physical characteristics before and after resistance training.

<table>
<thead>
<tr>
<th>Variable</th>
<th>All subjects (n = 18)</th>
<th>BMI &lt;27 (n = 7)</th>
<th>BMI → 27 (n = 11)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pretraining</td>
<td>Posttraining</td>
<td>Pretraining</td>
</tr>
<tr>
<td>Age (years)</td>
<td>72.9 ± 1.6</td>
<td>73.5 ± 2.3</td>
<td>72.6 ± 2.2</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>161.0 ± 1.3</td>
<td>163.7 ± 1.7</td>
<td>159.5 ± 1.6</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>74.1 ± 2.2</td>
<td>73.6 ± 2.1</td>
<td>78.8 ± 2.5</td>
</tr>
<tr>
<td>% Body fat</td>
<td>30.7 ± 0.9</td>
<td>31.0 ± 0.5</td>
<td>32.4 ± 0.9</td>
</tr>
<tr>
<td>BMI (kg·m⁻²)*</td>
<td>28.6 ± 0.9</td>
<td>28.3 ± 0.9</td>
<td>31.0 ± 0.8</td>
</tr>
<tr>
<td>WHR</td>
<td>0.80 ± 0.01</td>
<td>0.78 ± 0.02</td>
<td>0.80 ± 0.02</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>143.0 ± 3.9</td>
<td>135.2 ± 4.2</td>
<td>140.2 ± 4.0</td>
</tr>
<tr>
<td>DBP (mmHg)*</td>
<td>79.1 ± 2.4</td>
<td>74.7 ± 2.6</td>
<td>80.6 ± 2.7</td>
</tr>
</tbody>
</table>

* p < 0.05. BMI = body mass index; WHR = waist-to-hip ratio; SBP = systolic blood pressure; DBP = diastolic blood pressure.

Table 2. Means ± SE for blood lipid profiles before and after resistance training.

<table>
<thead>
<tr>
<th>Variable</th>
<th>All subjects (n = 18)</th>
<th>BMI &lt; 27 (n = 7)</th>
<th>BMI &gt; 27 (n = 11)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pretraining</td>
<td>Posttraining</td>
<td>Pretraining</td>
</tr>
<tr>
<td>TC (mg·dl⁻¹)</td>
<td>273.7 ± 9.3</td>
<td>274.4 ± 10.8</td>
<td>280.3 ± 15.2</td>
</tr>
<tr>
<td>TG (mg·dl⁻¹)</td>
<td>183.8 ± 12.5</td>
<td>187.7 ± 16.7</td>
<td>191.3 ± 15.0</td>
</tr>
<tr>
<td>VLDL-C (mg·dl⁻¹)</td>
<td>36.8 ± 2.5</td>
<td>38.3 ± 3.5</td>
<td>38.3 ± 3.0</td>
</tr>
<tr>
<td>LDL-C (mg·dl⁻¹)</td>
<td>197.0 ± 9.6</td>
<td>190.0 ± 11.8</td>
<td>200.4 ± 17.8</td>
</tr>
<tr>
<td>HDL-C (mg·dl⁻¹)</td>
<td>40.2 ± 2.7</td>
<td>45.6 ± 2.8*</td>
<td>42.4 ± 3.4</td>
</tr>
<tr>
<td>ApoC-III (mg·dl⁻¹)</td>
<td>16.7 ± 1.7</td>
<td>13.9 ± 1.3</td>
<td>17.0 ± 2.4</td>
</tr>
<tr>
<td>ApoC-III ratio</td>
<td>0.98 ± 0.10</td>
<td>0.99 ± 0.10</td>
<td>1.13 ± 0.20</td>
</tr>
</tbody>
</table>

* p = 0.001 for training effect. TC = total cholesterol; TG = triglycerides; VLDL-C = very low-density lipoprotein-cholesterol; LDL-C = low-density lipoprotein-cholesterol; HDL-C = high-density lipoprotein-cholesterol; TC/HDL-C = total cholesterol to HDL ratio; apoC-III = apolipoprotein C-III; apoC-III ratio = distribution ratio of apoC-III in HDL to apoC-III in VLDL.

Self Assessment Form placed most individuals in the low (12–15 points) to moderate (7–11 points) categories for cardiovascular risk and most subjects indicated that their health was either good or very good based on the Short Form Health Survey (SF-36). The average caloric intake was 1,176 ± 115 kcal·d⁻¹, and the percent calories obtained from complex carbohydrates, fat, and protein were 52%, 28%, and 20%, respectively. There were no changes in dietary patterns following the training or for the 2 BMI subgroups.

**Blood Lipid Profiles**

Table 2 shows the pre- and posttraining blood lipid profiles for all the subjects (n = 18) as well as for the 2 groups based on BMI. HDL-C levels were significantly higher (p = 0.001) after the training. The only other significant effect was a decrease (p = 0.025) in the TC/HDL-C ratio. Absolute changes in the blood lipids are depicted in Figure 1. The 5.4 mg·dl⁻¹ increase in HDL-C was significantly different from zero (p = 0.001). TG, TC, VLDL-C, LDL-C, apoC-III, and apoC-III ratio were unchanged. Analysis of the data excluding the 4 subjects taking hormone replacement therapy yielded the same findings. Based on the TC/

HDLC ratios, 78% of the women were categorized as high risk (ratio >5). Subjects remained in the moderate to high risk ranges for CHD after training with 67% having TC/HDL-C ratios greater than 5.

Body composition variables generally were not significantly correlated with the blood lipid variables with the exception of posttraining WHR that negatively related to the corresponding HDL-C (r = −0.52; p = 0.03) and positively related to TC/HDL-C ratio (r
Because body weight has been shown to modulate blood lipid profiles (10) as well as the responses to an exercise intervention, the relationship between baseline body weight and changes in the lipoprotein–lipid profiles were examined. No significant correlations were found between baseline body weight and changes in TG, LDL-C, HDL-C, VLDL-C, TC, or apoC-III levels.

Because there was a large range in body weight (59.1–99.1 kg) and BMI (22.42–34.67 kg m⁻²), subjects were also partitioned into 2 groups based on weight and BMI. Therefore we also compared the lipoprotein–lipid responses to the exercise program for the lighter and BMI. Therefore we also compared the lipoprotein–lipid responses to the exercise program for the lighter group with a baseline BMI less than 27 kg m⁻² (mean = 25.11 ± 0.58 kg m⁻², range = 22.42–26.99 kg m⁻²) to a heavier group with a BMI greater than 27 kg m⁻² (mean = 31.22 ± 0.80 kg m⁻², range = 27.10–34.67 kg m⁻²). Table 2 provides the means and standard errors for the lipoprotein–lipid profiles for each group (all subjects, n = 18; subjects below a BMI of 27 kg m⁻², n = 7; and subjects above a BMI of 27 kg m⁻², n = 11). There was still no group or trial effect for any of the variables with the exception of HDL-C. HDL-C levels significantly increased for both subgroups from pre- to posttest sessions.

In general, it appeared that those subjects with a BMI less than 27 kg m⁻² had a somewhat more favorable response to the exercise program. This group experienced an 11% decline in TG (compared to an 11% increase for the above 27 kg m⁻² BMI group), a 6% decrease in VLDL-C (compared to a 10% increase for the above 27 kg m⁻² BMI group), and a 25% decrease in apoC-III (compared to a 10% decrease for the above 27 kg m⁻² BMI group). All other lipoprotein–lipid patterns were similar between the 2 groups.

**Discussion**

This resistance exercise program was a community-based project developed in conjunction with the Area-wide Aging Agency in Oklahoma for the purpose of enhancing the physical and social activities of elderly people who are served by the senior nutrition sites. Given this constraint, we were not able to utilize a randomized control design for this study. We previously reported that this program was associated with improvements in joint flexibility and muscular strength (3).

A new finding was the 13% increase in HDL-C serum levels after these elderly women participated in the Dynaband resistance exercise program. The magnitude of this change in response to resistance training is similar to that reported by Hurley et al. (17) in middle-aged men. There could be several explanations for this change in blood lipids found in our study. The subjects in our study had higher TC and lower HDL-C levels at baseline than in previous studies on women (5,26). This may partially explain the significant increase as changes in blood lipid levels have been reported to be correlated with the baseline levels, in that individuals with poor blood lipid profiles tend to show greater improvements with training (35). It also has been suggested that the threshold training volume required to increase HDL-C may be lower for hypercholesterolemic subjects (14).

Body composition, in particular fat distribution, affects lipoprotein patterns (11, 37); thus, exercise-induced reductions in body weight, percent BF, and abdominal adiposity could account for observed changes in blood lipids with exercise. For this reason, Kokkinos and Hurley (21) recommended that strength training studies should control for body composition changes experienced by the subjects. This factor should not have influenced our results as the resistance exercise program in this study was not associated with body weight or fat loss as measured by skinfolds or any changes in body weight as indicated by WHRs. BMI decreased slightly by approximately 1%. These findings were not surprising as the energy expenditure during resistance training usually is not sufficient to result in loss of BF without a concomitant decrease in body weight and/or BMI may have modulated any exercise response for the lipoprotein–lipid variables of interest, the lipid data also were analyzed with subjects that were placed into 2 groups based on BMI values. Unlike the recent findings of Klebanoff et al. (20), body weight had no statistical effect on the findings of this study.

A possible physiological mechanism for the increased HDL-C levels we observed is that training may have altered activities of the enzymes important for lipoprotein metabolism. Acute bouts of aerobic exercise have been reported to increase both HDL-C and lipoprotein lipase activity (14). Conversely, decreased activities of hepatic lipase were observed after acute exercise that would decrease the rate of HDL-C removal by the liver and result in higher circulating HDL-C levels. Although we did not measure lipoprotein lipase directly, we found that apoC-III, a lipoprotein lipase inhibitor, tended to decrease after training, particularly in the subjects whose BMI was <27. It could be speculated that lipoprotein lipase activity may have increased after training in these subjects. Further research needs to be conducted to investigate the existence of enzyme alterations in older postmenopausal women.

It is possible that the increase in HDL-C was the result of the seasonal variation in blood lipid profiles. Buxtorf et al. (8) examined blood lipid patterns in pre- and postmenopausal nuns for 1 year. TC and LDL-C were elevated in the autumn and spring, and they were lowest at the end of winter in both groups. In the postmenopausal group, HDL-C peaked in the win-
ter and then decreased approximately 14% over the next 6 months with the lowest values occurring in the summer. Similar seasonal variations in HDL-C in elderly women were reported by Woodhouse et al. (38), where its peak serum concentration occurred in March/April followed by a 9% decrease in July/August. Our study was conducted between late April and late August, corresponding to seasonal decreases in blood lipids according to those reports. The observed increase in HDL-C in our study, therefore, does not appear to be the result of seasonal variation.

Fiatarone et al. (15) reported that high-intensity resistance training resulted in gains in muscle size and strength and improvements in mobility in the frail elderly. There also was an increase in overall physical activity levels. It is possible that participation in our exercise program encouraged subjects to increase their physical activity levels. The subjects in our study were all able-bodied and living independently in the community. Some subjects reported anecdotally a positive effect of the training program in that they felt better and were able to do more around the house (i.e., painting the walls of a room). However, self-reported physical activity levels were similar before and after the training program.

In conclusion, this nontraditional resistance training program was associated with improvements in HDL-C. This effect did not appear to be related to changes in body weight or composition or to seasonal effects on blood lipids.

Practical Application

The advantages of this program include: (a) low-cost equipment, (b) ease of administration with no special facility needed, and (c) the moderate intensity was safe for this age group. It is recommended that future studies include a control group and a nutrition intervention with interviews and counseling.

References


Acknowledgments
The authors extend thanks to the Areawide Aging Agency and to Seibert and Associates for their cooperation and support of the study. The assistance of Dr. Petar Alapauvic and Mr. Jim Fessmire with the lipid assays is also greatly appreciated. This study was funded in part by a grant from National Academy of Sport and Physical Education.