Summer 1997

Effect of Resistance Training on Lipid Profile and Body Composition in Premenopausal Women

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EFFECT OF RESISTANCE TRAINING ON LIPID PROFILE AND BODY COMPOSITION IN PREMENOPAUSAL WOMEN

by

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A Thesis submitted to the faculty of
Old Dominion University in Partial Fulfillment of the
Requirement for the Degree of

Master of Science in Education with
Emphasis in Exercise Science and Wellness

Department of Exercise Science, Physical Education, and Recreation
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August, 1997

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ABSTRACT

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This study examined the effects of 14 weeks of resistance training on lipid levels and body fat percentage (BF%) in healthy, sedentary premenopausal women. Twenty four women (mean±SD: age:27±6.5 yrs, weight 66.2±12.3 kg) participated in the study. The subjects were randomly placed in either a control (CON) group or in an exercise (EXER) group. The EXER group participated in a supervised 45-50 minute resistance training session (85% of 1-RM) for 14 weeks, 3 times per week on non-consecutive days. The CON group did not participate in any physical activity. The subjects were asked not to alter their diet. The training program resulted in significant increases ($p<0.05$) in strength as evidenced by 1-RM strength tests. There was a 9% decrease in the concentration of total cholesterol (T-CHOL) (179.8±11.8 vs 163.7±8.7 $mg \cdot dl^{-1}$, $p<0.05$), 14% decrease in the concentration of low density lipoprotein cholesterol (LDL-C) (114.9 ±11.1 vs 98.8±7.7 $mg \cdot dl^{-1}$, $p<0.05$), 14.3% decrease in total cholesterol to high density lipoprotein cholesterol (T-CHOL/HDL-C) ratio (4.2±0.4 vs 3.6±0.4, $p<0.05$), and a 5% reduction (i.e. 1.4% in body fat units) in percent body fat (BF%) (27.9±2.1%

vs 26.5 ± 2.2%, $p < 0.05$) and a strong trend towards a significant decrease in LDL-C/HDL-C ratio ($p = 0.057$) in the EXER group compared to their baseline values. The concentration of plasma triglycerides (TG) and HDL-C were not altered by training. These changes were observed despite no change in body weight. No changes were observed in any of the measured variables in the control group. These findings indicate that resistance training has a favorable effect on lipid profile and body composition in healthy, sedentary premenopausal women.

ACKNOWLEDGMENTS

There are many people who deserve credit for their assistance in seeing this research study come to completion. I would like to thank my advisor Dr. Elizabeth Dowling for being my thesis committee chairperson.

I would like to thank Dr. David Branch immensely for helping me in several ways to complete my research study, especially in the statistical analysis of the results. Many thanks to my committee members, Dr. David Swain, and Dr. Brian Leutholtz for setting aside time from their busy schedule to provide guidance.

Many thanks to my friend Jim Schoffstall, without whose help this study would not have been possible.

Many thanks to Mr. Yoshifumi Yamanaka, Benefactor, Yamanaka Fund, for providing financial assistance without which this study would have been very difficult to conduct.

I would like to thank my husband Dr. Ram Prabhakaran, who has always encouraged me to study and has helped me in several ways to complete my degree program. Many thanks to my son Kartik and my daughter Ranjani for their love and support. Last but not least, I would like to thank my father Krishnamurthy and my mother Jayalakshmi, who have always encouraged me to do my very best.

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CHAPTER 1

Introduction

Exercise training has numerous effects on lipid metabolism. Exercise-trained and physically active individuals generally exhibit lower plasma concentrations of triglycerides (TG) and higher levels of high density lipoprotein cholesterol (HDL-C) than their untrained, sedentary counterparts. Several epidemiological studies have shown that low concentrations of total cholesterol (T-CHOL), low density lipoprotein cholesterol (LDL-C) and high levels of high density lipoprotein cholesterol (HDL-C), and low percentage of body fat (BF%) are associated with a decreased prevalence of coronary heart disease (Castelli 1984, Despres et al., 1989, Lamarche et al., 1992, Frick et al. 1987).

Regular physical activity improves lipid and glucose metabolism that is manifested by enhanced insulin sensitivity, improved glucose tolerance, increased concentration of HDL-C levels and decreased concentration of LDL-C levels. Physical activity is also known to reduce blood pressure (Goldberg, 1989; Hurley et al., 1988). Physical exercise acutely increases HDL-C and lipoprotein lipase activity in both trained and untrained men (Kantor et al., 1987). Therefore, the therapeutic effects of physical exercise have become a widely used strategy to reduce the risk for coronary heart disease.

Several studies have shown that endurance-trained athletes usually have lower plasma concentrations of triglycerides and LDL-C and higher levels of HDL-C than untrained individuals (Adner and Castelli 1980; Despres et al., 1989, Lamarche et al., 1992,).

Some studies have indicated that resistive training may also have favorable effects on lipid profiles (Goldberg et al., 1984; Boyden et al., 1993; Hurley et al., 1988). Goldberg et al. (1984) reported that weight training exercise performed at 84% of 1-RM resulted in favorable changes in lipid and lipoprotein levels in previously sedentary men (n=6) and women (n=8). However, they did not see any significant change in HDL-C in both men and women. Boyden et al. (1993) also reported reduction in the concentrations of T-CHOL and LDL-C in premenopausal women (n=46) following five months of resistive training performed at 70% of 1-RM. No changes in body composition or HDL-C concentration were reported. Whereas, Hurley et al. (1988) showed that resistive training resulted in an increase in the concentrations of HDL-C and reduction in T-CHOL, and LDL-C in middle-aged male subjects despite no changes in body weight, VO_{2max}, or percent body fat.

Statement of the problem

In contrast to the extensive research on the effects of aerobic-type exercise, well-controlled research showing the effects of resistance exercise training on lipid levels and body composition is meager. The purpose of this investigation is to study the effects of a 14-week supervised, intensive resistance exercise training on lipid profile and body composition in healthy, sedentary premenopausal women.

Null Hypothesis

There will be no significant differences between the control and exercising groups either in lipid profile or in body composition following 14 weeks of high intensity resistance training exercises in healthy, sedentary, nonsmoking premenopausal women.

Independent variable: Resistance training exercise

Dependent Variables: T-CHOL, LDL-C, HDL-C, TG, LDL-C/HDL-C ratio, T-CHOL/HDL-C ratio, Body fat percentage, and 1-RM.

Significance of the study

Improvement in lipid profile will lower the risk for coronary heart disease which is the leading cause of death in women in this country (Thom, 1987). This study will add further insight into the favorable effects of resistance training exercise on lipid profile in healthy, sedentary premenopausal women.

Delimitations

This investigation was conducted within the following parameters:

1. Thirty female subjects between the ages of 18 and 40 participated in the study.
2. Subjects were healthy with no history of cardiovascular disease or thyroid problems.
3. Subjects were eumenorrheic having 10-12 menstrual cycles per year.
4. Subjects were sedentary for at least 9 months.
5. Subjects were nonsmokers.

Limitations

Characteristics of the subject population may limit the application of conclusions to healthy, sedentary, eumenorrheic, nonsmoking premenopausal women.

Definitions of Key Terms

1. **Resistance Training**: or weight training- is an exercise program as a means to increase muscle strength and/or lean body mass by lifting weights.

2. **Lipid Profile**: The concentrations of high density lipoprotein cholesterol (HDL-C), low density lipoprotein cholesterol (LDL-C), Total Cholesterol (T-CHOL), and triglycerides in the serum.

3. **Premenopausal** (eumennorrheic): Women who have their menstrual cycles regularly (10-12 cycles per year).

4. **Body Fat Percentage**: Percentage of body composed of essential and storage fat as estimated by skinfolds.

5. **Repetition Maximum** (RM): A term used to describe the interrelationship between repetitions and intensity in weight training.

6. **1-RM**: Maximal weight a person can lift only one time.

CHAPTER 2

Literature Review

This chapter will present a review of the literature regarding the effects of resistive training as well as aerobic exercise (both acute and chronic) on lipid profile in both men and women.

Acute Exercise-Resistive

Wallace and associates (1991) studied 10 healthy, trained males before and after 90 minutes of resistance exercise to determine the acute effects of high volume (HV) and low volume (LV) exercise sessions on alterations in lipid and lipoprotein concentrations as well as the activity of lecithin: cholesterol acyltransferase (LCAT). The high volume session involved the use of 8-12 repetition maximum (RM) loads performed to exhaustion with 60 second rest intervals between sets, while the low volume session involved the use of 1-5 RM loads with 3 minute rest intervals between sets. There was a control session where no exercise was performed. Fasting blood samples were obtained immediately before and after exercise as well as 24, 48, and 72 hours post-exercise. Significant increases in the concentrations of HDL-C (11%) and HDL_3-C (12%) ($P<0.01$) compared to baseline values were only found following the HV after adjusting for changes in plasma volume. Modifications in HDL-C were significantly different from both LV and control sessions. Triglycerides and lecithin:cholesterol acyltransferase (LCAT) were significantly decreased 24 hour post-exercise following the HV session when compared with immediate post exercise values. No significant changes were noted in either T-CHOL or HDL_2-C concentrations at any time. All lipoprotein values returned to baseline by 48 hours. The results of this study demonstrated that a single episode of high volume resistance exercise is capable of modifying plasma lipid-lipoprotein levels. However, results obtained from a single bout of exercise does not provide any conclusions to establish a chronic relationship between resistance training and lipoprotein-lipid profiles. Moreover, the subjects involved in this study were all males.

Chronic Exercise-Resistive

Boyden et al. (1993) studied 88 healthy, white, eumenorrheic women ranging in age from 28 to 39 years to determine the effects of resistance exercise training on serum lipid levels. Forty six subjects were in the experimental group and 42 in the control group. Supervised training sessions consisted of 12 exercises to load the major muscle groups in the arms, legs, trunk, and lower back, performed at 70% of a maximal single repetition using three sets of eight repetitions, three days per week, one (1) hour per day for five (5) months. Workload was increased at two months and at four months to maintain 70% of one repetition maximum. The control group was instructed to maintain their usual activity. The subjects were asked not to alter their diet. Fasting blood samples were drawn 36 to 48 hours after an exercise bout at baseline and after five months. The exercise group showed a 12.7 $mg \cdot dl^{-1}$ (0.33 mmol/L) decrease in the concentration of total cholesterol level and a 13.9 $mg \cdot dl^{-1}$ (0.36 mmol/L) decrease in the concentration of LDL-C ($p < 0.01$) compared to the control group. Body weight did not change significantly in either group. Although a small decrease in percentage of body fat occurred in the exercise group, the change was not correlated with the decreases in T-CHOL or LDL-C levels in the exercise group (T-CHOL, $r = 0.23$, LDL-C, $r = 0.12$). There were no significant changes in the concentration of serum HDL-C or triglycerides in either group. The authors concluded that in healthy, premenopausal women, with normal baseline lipid profiles, 5 months of resistance exercise training was associated with significant decreases in serum T-CHOL and LDL-C levels.

Goldberg and associates (1984) studied sedentary, healthy women ($n = 8$) and men ($n = 6$) to observe changes in lipid and lipoprotein levels after weight training. The subjects completed a 16-week exercise program of progressive resistive weight training using a Universal machine. Training consisted of three sets of 8 repetitions for each individual exercise. Each set was continued until a subject could not complete an additional repetition. If a subject could lift a training weight eight consecutive times, the resistance was increased by one level (4.5 to 6.8 kg). A maximum of 2 minutes was allowed between sets. They exercised 3 times a week on non-consecutive days. Each session was

45-60 minutes long. Triceps skinfold thickness, circumferential arm measurements and fasting lipids were obtained before and after the 16-week program. Reduction in the concentrations of T-CHOL, LDL-C, TG, and ratio of T-CHOL/HDL-C and arm circumference and skinfolds occurred following training. The women demonstrated a 9.5% reduction in the concentrations of T-CHOL ($p<0.05$), 17.9% decrease in LDL-C ($p<0.01$), 28.3% decrease in TG ($p<0.05$), and an insignificant 4.8% increase in HDL-C. The ratios of T-CHOL/HDL-C and LDL-C/HDL-C were reduced by 14.3% ($p<0.05$) and 20.3% ($p<0.05$), respectively. The men demonstrated a 6.2% decrease in the concentration of LDL-C ($p<0.05$), 21.6% decrease in T-CHOL/HDL-C ratio ($p<0.05$), 28.9% decrease LDL-C/HDL-C ratio ($p<0.05$) and an insignificant 15.8% increase ($p>0.052$) in the concentration of HDL-C. The body weight was not significantly altered in either men or women. All the subjects improved their performance for each exercise. This study suggests that weight training appears to result in favorable changes in lipid and lipoprotein levels in previously sedentary men and women. However, there was no control group in the study and the authors did not mention whether the exercise sessions were supervised or not.

Hurley et al. (1988) found that high intensity resistive training improves plasma lipoprotein profiles, reduces glucose-stimulated plasma insulin concentration, and reduces diastolic blood pressure in middle-aged men, despite the absence of an effect on maximal oxygen consumption (VO_{2max}), body weight or body composition. Eleven healthy, untrained males (mean ± SD; age = 44 ± 3 years) were studied to determine the effects of 16 weeks of high-intensity resistive training on risk factors for coronary artery disease. The training program was classified as high intensity due to the short rest intervals (less than 15 seconds) between each exercise. Ten healthy, untrained males (mean ± SD; age = 52 ± 2 years) served as controls in the study. Lipoprotein profiles, plasma glucose and insulin responses during an oral glucose tolerance test, and blood pressure at rest were determined before and after training for all the subjects. Subjects were asked not to alter their diets during the study period. The subjects trained on Nautilus machines 3 to 4 times a week for 16 weeks. All subjects were shown the proper exercise technique by a qualified instructor. During each workout, subjects performed one set of each of the 14 exercises in the following order: hip and back; leg extension; leg press; leg curl; arm cross; decline press; pullover; torso-arm pullover; lateral raise; overhead press; behind neck press; behind neck pulldown; omni triceps; and omni biceps. The subjects performed between 8 and 12 repetitions maximum for all upper body exercises, and between 15 and 20 repetitions maximum for all lower body exercises during each training session. Weight was adjusted throughout the training program as strength levels increased. The training program resulted in 50% increase in upper body strength and 33% increase in lower body strength. The results also showed that there was a 13% increase in the concentration of HDL-C ($p < 0.05$), 43%

increase in HDL_2-C ($p<0.05$), 5% reduction in LDL-C ($p<0.05$), an 8% decrease in the T-CHOL/HDL-C ratio and 14% decrease in LDL-C/HDL-C ratio ($p<0.01$). There were no changes in VO_{2max}, body weight, or percent body fat. Glucose stimulated plasma insulin concentrations during oral glucose tolerance testing were significantly lower, and supine diastolic blood pressure was reduced ($p<0.05$). No changes in any of these variables occurred in the sedentary control group. The results of this study indicate that resistive training can lower risk factors for coronary artery disease by improving lipid profile and reducing diastolic blood pressure in untrained middle-aged men.

The findings of the above research studies demonstrated that chronic resistive exercise resulted in significant decreases in the concentrations of T-CHOL and LDL-C in healthy premenopausal women (Boyden et al. 1993). Goldberg et al. (1984) showed that chronic resistive exercise resulted in reduction of LDL-C, T-CHOL/HDL-C and LDL-C/HDL-C ratios in both men and women. The female subjects in their study also showed reduction in the concentrations of T-CHOL and TG. Hurley et al. (1988) showed that in male subjects chronic resistive exercise resulted in an increase in HDL-C and HDL_2-C and decrease in LDL-C, LDL-C/HDL-C and T-CHOL/HDL-C ratios.

Exercise-Aerobic vs Strength Training

Smutok and associates (1993) designed a study to compare the effectiveness of strength training (ST) with that of aerobic training (AT) for risk factor intervention in subjects at risk for CHD. Thirty seven untrained male subjects who had abnormal lipid profiles participated in the study. Among them, 14 volunteered for ST and 13 for AT. The ST group trained 3 times/week on non-consecutive days for 20 weeks using Nautilus equipment. The ST program consisted of 2 sets using maximum amount of weight that could be lifted 12 to 15 times per set, with 11 different exercises and modified sit-ups. All subjects did a brief warm-up consisting of static stretching and calisthenics before each training session. Following flexibility and warm-up exercises, the AT group walked and/or jogged on a treadmill for 30 minutes a day, 3 days/week for 20 weeks. Lipoprotein and lipid profiles, blood pressure, and glucose and insulin responses to an oral glucose tolerance test (OGTT) were assessed before and after the training period. Both the AT and ST group showed improvement in glucose tolerance and reduced insulin responses to oral glucose following training, but neither training regimen had any effect on lipid profiles or blood pressure. Therefore, the findings of this study suggest that 20 weeks of ST had the same effects as 20 weeks of AT (walking/jogging) on risk factors for coronary heart disease. Although both training modalities reduced glucose and insulin responses to an OGTT, neither program altered lipid profiles or resting blood pressure.

Blumenthal and associates (1991) examined the effects of exercise on lipid levels in 46 healthy, sedentary premenopausal and postmenopausal women (mean age, 50 years). Among 46 subjects, 23 were premenopausal and 23 were postmenopausal. The subjects were not on any hormone replacement therapy. Subjects were randomly assigned to one of the two exercise programs. One group of 24 women (12 pre and 12 postmenopausal) participated in aerobic endurance exercise 3/week for 12 consecutive weeks. These sessions consisted of 15 minutes of warm-up and 35 minutes of continuous brisk walking and jogging on a 400-m outdoor track at an intensity of at least 70% of subjects' heart rate reserve. The other group of 22 women (11 pre and 11 postmenopausal) participated in strength and flexibility training exercises. These sessions consisted of 20 minutes stretching and 35 minutes of circuit Nautilus training. The Nautilus training used seven exercise stations and nine exercises, including leg extension, leg curl, overhead pulldown, pullover, two chest press exercises, overhead press, side lateral raise, and arm curl. Subjects performed 12-15 repetitions at a given work load. Resistance was increased when the subject was able to complete 15 repetitions. All the subjects were asked to maintain their usual diet throughout the study. The subjects had lipid and lipoprotein analysis and treadmill test of VO_{2max} before and after the exercise program. Following the training, the aerobic group had significantly lower heart rates at rest and higher peak VO_2 compared to the strength training group. Pre and postmenopausal women of comparable ages showed similar improvements in aerobic power, indicating that female hormones did not affect the training response. Significant decreases in the concentration of HDL-C and T-CHOL and increased apolipoprotein A-1 and the apo A-1 to apo B ratio were observed in both exercise groups. The authors concluded that premenopausal and postmenopausal women had similar changes in aerobic capacity and lipid levels with exercise and that the short-term effects of aerobic and non-aerobic exercise on lipid profiles are generally comparable.

The above research studies examined the effects of aerobic exercise versus strength training on lipids and lipoproteins in men and women and reported conflicting findings. Smutok et al. (1993) showed that neither strength training nor aerobic training altered lipoprotein and lipid levels in untrained male subjects. In contrast, Blumenthal et al. (1991) showed that both aerobic and non-aerobic exercises resulted in reduction in the concentration of T-CHOL and HDL-C and an increase in apolipoprotein A-1 and apo A-1 to apo B ratio in premenopausal and postmenopausal women.

<u>Acute Exercise-Aerobic</u>

Pronk and associates (1995) conducted a study involving 11 premenopausal and 10 postmenopausal women, who were non-users of estrogen, to evaluate the effects of walking performed at light (50% VO_{2max}) and moderate (70% VO_{2max}) intensities on serum lipids and lipoproteins. The subjects participated in two isocaloric (350 Kcal) walking sessions at the light and moderate intensities. The two sessions were one month apart. All subjects walked on a motor-driven treadmill at each exercise intensity for a total duration sufficient to expend 350 Kcal of energy. Venous blood samples were obtained immediately following exercise, and 24 and 48 hours after each exercise bout. The baseline samples were obtained following at least 48 hours abstinence from exercise. All subjects were tested for VO_{2max} one week prior to each respective bout. All subjects were on a defined diet. The blood samples were analyzed for lipids and lipoproteins. Immediately following the 70% VO_{2max} walk, reduction in the concentration of LDL-C was observed for both groups of women while the 50% VO_{2max} condition increased HDL_2 -C concentration (19.8%, $p<0.05$) only in postmenopausal women. Authors concluded that a single bout of walking has the potential to acutely affect the blood lipid profile of pre and postmenopausal women. However, there was no control group in the study and the authors did not mention whether the subjects were physically active or sedentary.

Berger and Griffiths (1987) studied 12 normolipidemic, healthy, moderately fit males to observe the effects of moderate exercise on plasma lipoprotein parameters. Eight subjects participated in systematic physical training (exercising group) , where as the other 4 exercised sporadically (sedentary, control group). Subjects in the exercise group ran 5.5 km at a comfortable pace completing the course in an average of 31.5 minutes. Exercise was disallowed 48 hours prior to the run and only fluids were permitted in the 12 hours preceding the run. Blood was taken immediately before and within 1 or 2 minutes of completing the course. Another sample was taken 2 hours later. The same procedure was followed on a separate occasion, but without the exercise. Results showed that apo B lipoprotein, total phospholipid, TG, and free fatty acid levels increased substantially immediately after the run and, except for TG, were still elevated 2 hours later. Significant increases in HDL-C, HDL_3-C, and HDL-phospholipid concentrations were observed after the run. The authors concluded it is possible that, because of the cholesterol-mobilizing properties of phospholipid and HDL_3-C, these changes may exert a cumulative anti-atherogenic action in addition to and independent of the long-term effects of exercise on the plasma lipoprotein profile. No changes in apolipoprotein A, LDL-C and T-CHOL were observed. The findings of this study show that a 30-minute episode of moderately intense physical activity elicited changes in lipoprotein parameters. However, results obtained from a single bout of exercise do not provide any conclusions to establish a chronic relationship between moderately intense physical activity and plasma lipoprotein parameters. Moreover, subjects were all male and were moderately fit and the four control subjects exercised sporadically.

Gordon et al. (1994) studied the acute effects of exercise intensity on HDL-C metabolism in 12 healthy male recreational runners who ran 15-30 miles per week (mean$\pm$SD:age$=$24.8$\pm$4 years). Subjects exercised on a motor driven treadmill at 60% and 75% VO_{2max} under an isocaloric expenditure of 800 kcal per experimental trial. Exercise trials were separated by 1-2 weeks. Subjects were asked to refrain from exercise for 72 hours prior to each experimental trial. Venous blood samples were obtained at 5 points during each trial: 24-hour before exercise, immediately post-exercise, 1-hour post-, 6-hour post- and 24-hour post-exercise. All blood samples were taken following 12 hour fast except the 6-hour post exercise sample, which was conducted after 4-hour fast. The blood samples were analyzed for the concentrations of HDL-C, HDL_2-C and HDL_3-C. In addition, post-heparin plasma samples, obtained 24-hour before exercise, 6-hour post exercise and 24-hour post exercise were analyzed for lipolytic activity-lipoprotein lipase (LPLA) and hepatic triglyceride lipase (HTGLA). An exercise trial by time interaction was observed for the concentration of HDL-C ($p<0.01$). Post-hoc analysis revealed a significant increase in the concentration of HDL-C 24-hour post exercise following the 75% VO_{2max} ($p<0.01$). This increase in HDL-C was attributed to an elevated HDL_3-C ($p<0.01$), with no change in HDL_2 -C. There was no change in the concentration of HDL-C following 60% VO_{2max}. Analysis of plasma lipolytic activity revealed an increase in LPLA 24-hour post- exercise ($p<0.05$) which may be responsible for the post-exercise alterations in HDL-C concentration. However, HTGLA decreased 6-hour post- ($p<0.01$) and 24-hour post exercise ($p<0.05$). Authors concluded that increases in the concentration of HDL-C levels following endurance activity in moderately trained individuals are influenced, in part, by the intensity of the exercise.

Angelopoulos et al. (1993) studied nine sedentary men to determine the effect of repeated bouts of exercise on the concentrations of HDL-C, HDL_2-C and HDL_3-C. Thirty minute exercise sessions were performed in the following patterns: (1) single bout, (2) two bouts, each administered 48 hours apart, (3) three bouts, each administered 48 hours apart. The exercise bouts in patterns 2 and 3 were separated by 48 hours. Patterns 1, 2, and 3 were conducted 7 days apart. All subjects completed each pattern. The treadmill speed and grade was adjusted to elicit 65% of each subject's previously determined VO_{2max}. Blood samples were obtained prior to each pattern and at 5 minutes, 24 and 48 hour after the last session within each pattern. Significant main effects were found for HDL-C, HDL_2-C, and HDL_3-C concentrations. Total concentration of HDL-C remained higher ($p<0.05$) than the pre-exercise level 5 min and 24 hours post exercise for all exercise patterns. HDL_3-C levels were higher ($p<0.05$) at 5 minutes and 48 hours post-exercise than at pre-exercise for all patterns. HDL_2-C was lower ($p<0.05$) at 48 hours post-exercise than pre-exercise for all patterns. Total HDL-C declined to pre-exercise values 48 hours post-exercise in all patterns. There were no significant differences in triglycerides and total cholesterol between any of the time points for all exercise patterns. The authors concluded that the effect of repeated exercise bouts resulted in a prolonged elevation in the concentration of HDL-C (i.e 24 hours). This increase in HDL-C was primarily due to an increase in HDL_3-C. However, the change in HDL-C concentration was transient since no change in HDL-C was observed 48 hours post-exercise.

Research has shown that a single bout of aerobic exercise has beneficial effects on lipid metabolism in men and women. Some studies (Angelopoulos et al. 1993; Gordon et al., 1994; Berger et al., 1987) have shown that acute aerobic exercise has resulted in significant increases in the concentration of HDL-C and its subfractions in male subjects. However, these increases were transient since the post-exercise HDL-C values returned to pre-exercise values after 48 hours.

Chronic Exercise-Aerobic

Despres et al. (1989) studied the effects of long-term exercise training with constant energy intake on plasma lipoprotein levels. Five young, healthy, slightly obese men (mean±SD: body mass index (BMI):27.5± 2.9;age: 25±3) participated in the study. Fourteen days before the beginning of the exercise training protocol, the subjects were admitted to the metabolic ward to determine their mean energy intake, which was then strictly controlled during the exercise protocol to ensure that the daily 4.2 MJ (equivalent of 1,000 kilo calories) deficit was solely induced by the exercise sessions. Subjects performed their exercise sessions (two 55 minute sessions per day) on bicycle ergometers for a period of 100 days, 6 days/week followed by one day rest. Maximal oxygen uptake, weight and lipids were measured at the beginning, during (25 and 50 days) and at the end of the program. The results showed that the daily 4.2 MJ caloric deficit produced by the exercise training program induced significant reductions in body weight and in fat mass with a preservation of fat-free mass. There was a significant reduction in plasma T-CHOL ($p<0.05$) after 25 days of exercise which remained significantly lower at the end of the program. A significant reduction in plasma LDL-C concentration was observed after 50 and 100 days of training. The Concentration of HDL-C did not change until the end of the training program, where a significant increase was noted ($p<0.01$). There was no increase in plasma apo A-1 levels. Reductions were observed in plasma apoprotein-B, and LDL-apo B levels ($p<0.05$). Ratios of HDL-C/T-CHOL ($p<0.01$) and apo A-1/apo B ($p<0.05$) were significantly increased. The authors concluded that prolonged aerobic exercise training induces a substantial weight loss and reduction in fat mass and has beneficial effects on plasma lipoprotein levels. The exercise training not only increases the HDL-C levels, but also the ratio of HDL to LDL particles which is especially helpful in reducing the risk of cardiovascular disease in moderately obese men. However, there was no control group in the study, the subjects were all males, and the training sessions were too long (two 55 minute sessions per day) and the mean energy intake was strictly controlled during the exercise protocol.

Marti et al. (1991) studied two groups of former elite athletes (27 runners and 9 bobsledders) and a control group of 23 healthy untrained men to evaluate the effects of past as well as current exercise, aerobic power, and subcutaneous fat on the serum lipid profile. In 1973 and 1988, exercise testing and physical examination included a maximal treadmill test (for all runners) and a maximal bicycle ergometer test (for all non-runners), with measurement of VO_{2max}, and an estimation of subcutaneous fat based on measurement of skinfold thickness at ten sites. In addition, subjects completed a detailed questionnaire on exercise habits. In 1988, waist to hip ratio was measured to determine fat distribution. Fasting venous blood samples were obtained for lipid analysis. Results showed a significant effect of the type of sports activity on HDL-C, apolipoprotein A-1, and triglyceride levels and on the LDL-C/HDL-C and apolipoprotein B/A-1 ratios, with the most favorable values seen in runners and the least favorable values seen in controls. Of the 27 former elite runners, one third had ceased or strongly reduced training. This subgroup showed the steepest 15-year decrease (from 1973 to 1988) in maximum aerobic power and largest increase in subcutaneous fat, and the lipid profile (measured in 1988). The 15-year change in abdominal skinfolds was related ($p<0.01$; $r=0.45$) to the LDL-C/HDL-C ratio in both runners and non-runners. The 15-year change in exercise and subcutaneous fat themselves were negatively related in runners ($p<0.01$; $r=-0.53$) but unrelated in non-runners. These results suggest that, in both the presence and absence of an athletic predisposition, behavioral factors tend to influence the atherogenic risk of the serum lipid profile, predominantly via alterations in body composition.

Lamarche and associates (1992) report that aerobic exercise training have beneficial effects on lipid and carbohydrate metabolism in obese, premenopausal women. Thirty-one obese, premenopausal women (mean ± SD; age 35.4 ± aeries) participated in the study. The subjects exercised for 90 minutes a day at 55% VO_{2max} for 4 to 5 times per week for 6 months. VO_{2max} measurement, fasting lipid analysis, body composition, and oral glucose tolerance test were performed for all the subjects before and after the exercise program. Subjects were asked not to alter their diet. Results showed that there was a significant improvement in VO_{2max} and significant improvement in carbohydrate and lipid metabolism, as reflected by decreased plasma insulin concentrations, T-CHOL, TG and LDL-C, and by increased ratios of T-CHOL/HDL. There was no significant change in the mean body fat mass with exercise. No significant increase in fat-free mass was observed in either group. Authors concluded that aerobic exercise training have beneficial effects on both carbohydrate and lipid metabolism irrespective of changes in body composition. However, there was no control group in the study and the authors have not mentioned about the activity level of the subjects prior to the study.

Santiago et al. (1995) studied the effects of a 40-week program of brisk treadmill walking on blood lipid and lipoprotein levels, aerobic power, and body composition of sedentary, normolipemic, eumenorrheic, premenopausal women. Twenty seven women (age$\pm$SD:30.8$\pm$5.7 years) with high baseline levels of plasma HDL-C (63.3$\pm$15.1 $mg \cdot dl^{-1}$) were randomly assigned to a walking (n=16) or a control group (n=11). The 40-week treadmill walking program consisted of a 2 week pre-conditioning period (walking at 3 mph, 4 times/week) followed by three training phases in which exercise intensity was progressively increased. The three training phases consisted of walking at 3.2 mph at 5% grade in the first phase (weeks 3-10), 3.4 mph at 6%, in the second phase (weeks 11-25), and 3.6 mph at 7% grade in the third phase (weeks 26-40). The mean exercise intensities, expressed as a percent of age-predicted maximal heart rate (HR max), for training phases 1, 2, and 3 were 68, 71, and 76%, respectively (mean = 72%). The training program improved aerobic power by 22% ($p < 0.05$), but no training effect was observed in blood lipid levels or body composition. Plasma HDL-C changes observed were found to be inversely related to the baseline levels of the lipoprotein with a correlation coefficient of -0.51 ($p < 0.05$). The authors concluded that a long-term program of 40-weeks of moderate-intensity walking improved aerobic power, but had no effect on body composition or lipid levels in previously sedentary, normolipemic, eumenorrheic women.

These studies show that chronic aerobic exercise has favorable effects on lipid profile by increasing HDL-C and by decreasing LDL-C in both obese men and elite athletes. However, the results of Santiago et al. (1995) revealed that chronic aerobic exercise did not alter blood lipid levels in women who have favorable baseline lipid levels.

Comparison of Exercises: Anaerobic, Aerobic and Mixed

Giada et al. (1991) examined the effects of different types of physical training on serum lipoprotein cholesterol, apoproteins A-1 and B and lipolytic activities in 39 white male top level athletes and 15 healthy controls in an age range of 20 to 30 years. The athletes were divided into 3 groups based on the energy sources used in the various stages of training. The first group, practicing aerobic activities, included 13 athletes (2 marathon runners, 3 middle distance runners, and 8 road cyclists). The second group, practicing anaerobic activities, included 17 athletes (8-100 meter and 9-400 meter runners) training with high intensity, short burst activities. The last group of athletes, practicing mixed activities, included 9 basketball players, whose training consisted of alternate aerobic and anaerobic activities. Fasting venous blood samples were obtained at least 36 hours after the last training session. The results showed that in the aerobic and mixed groups serum TG were significantly lower compared to sedentary controls while T-CHOL and LDL-C, and apoprotein B levels were only slightly lower. HDL-C and HDL_2-C were slightly higher while T-CHOL/HDL-C ($p<0.01$) and LDL/HDL-C ($p<0.05$) ratios were significantly lower only in aerobic athletes compared to the control group. The authors concluded that specialized training programs have a different effect on lipoprotein pattern and only aerobic exercise has a potentially anti-atherogeneic effect. Body composition was significantly different among the athletes at the onset of the study.

Literature Summary

The reports from several studies have shown that both acute and chronic aerobic exercise resulted in favorable changes in lipid and lipoprotein levels in men and women. The investigators from most training studies have reported favorable changes in blood lipid and lipoprotein levels following resistance training exercises (Boyden et al. 1993; Hurley et al. 1988; Goldberg et al. 1984). Wallace et al. (1993) reported that a single bout of high volume (85% of 1-RM) resistance exercise is capable of modifying plasma lipid concentrations in healthy, trained male subjects. However, inadequate control for factors that influence lipoprotein profiles, the small number of subjects used in some studies, and the inherent weaknesses in the design of some studies make the results difficult to interpret. Many studies involved only male subjects.

Boyden et al. (1993) found that resistance exercise results in reduction of the concentration of T-CHOL and LDL-C in premenopausal women. But they did not find significant changes in the concentrations of HDL-C levels, triglyceride levels, and body composition. The subjects performed eight repetitions at 70% of one repetition maximum (1-RM), which is a low intensity compared to the 80-84% 1-RM in the other studies (Hurley et al. 1988; and Goldberg et al. 1984). Furthermore, the resistance was increased at only 2 months intervals. It should be possible to increase the resistance much more frequently (Goldberg et al. 1984; Hurley et al.1988). Hurley et al (1988) found that high intensity (80-84% of 1-RM) resistance exercise (8-10 rep maximum with only 15 sec rest between exercises) results in an increase in the concentration of HDL-C and HDL_2-C, and reduction in the concentration of LDL-C and T-CHOL/HDL-C ratio despite no changes in body weight and body composition. But the subjects involved were all males. In the study performed by Goldberg et al (1984), subjects performed weight training at high intensity (85% of 1-RM). Male subjects demonstrated decrease in the concentration of LDL-C and in the ratios of T-CHOL/HDL-C and LDL-C/HDL-C following weight training exercise where as female subjects showed reduction in the concentration of LDL-C, T-CHOL, TG, and T-CHOL/HDL-C and LDL-C/HDL-C ratios and an insignificant increase in the concentration of HDL-C. There was no control group in this study. Wallace et al (1991) also found significant increase in the concentrations of HDL-C and HDL_3-C following a single bout high volume resistance (8-10 repetition maximum) exercises compared to low volume (1-5 repetition maximum) resistance exercise. In this study also, the subjects were all males. It seems possible that the low intensity (70% of 1-RM) in the Boyden et al. (1991) study was responsible for the lack of change in HDL levels and body composition. Therefore, the purpose of this study is to determine the effects of a 14 week supervised, high-intensity (85% of 1-RM) resistance training exercise program on lipid profile and body composition in healthy, sedentary premenopausal women.

CHAPTER 3

Methodology

Introduction

This chapter describes the methodology used to investigate the effects of resistive training on lipid profile and body composition in healthy, sedentary premenopausal women. The subjects, experimental design, and instrumentation and procedures will be presented in this section.

Subjects

Thirty healthy, sedentary and nonsmoking premenopausal women (mean $\pm$ SD:age $= 27 \pm 6.5$ years) from the Tidewater area participated in the study. The baseline physical characteristics of the subjects are detailed in Table1(Appendix A). All subjects completed a health history survey and an exercise history questionnaire (Appendix C). Subjects were chosen based on their health (apparently healthy according to American College of Sports Medicine guidelines (1991)), activity level (sedentary) and smoking status (nonsmokers). Each subject was informed of the procedures of the study and signed an informed consent approved by the Institutional Review Board of Old Dominion University. Subjects were informed of the random design of the research project prior to participation in this study.

Sampling:

Type of sampling was Convenience sampling. Subjects were recruited by advertising in the campus newspaper, by posting fliers in various places on the campus and by word of mouth. Subjects were selected based on the fulfillment of the criteria such as healthy, sedentary, eumennorrheic and nonsmoking. Once the subjects were selected, they were randomly assigned to one of the two groups; exercise and sedentary control.

Instrumentation

Body Mass and Height:

Body mass was measured to the nearest 0.1 kg using a Continental 159.0 kg capacity scale. The subjects were weighed in their exercise clothes, without shoes. The scale was set to zero and calibrated with a 4.0 kg known weight before each use. Height was measured without shoes to the nearest 0.5 cm using a 198.0 cm stadiometer.

Skinfolds

Skinfolds were measured using a Lange Caliper (10g. mm^{-2} constant pressure). All sites were measured to the nearest 0.5 mm.

Circuit Training Machine (DVF Inc. Newport News, VA)-- was used for subjects to perform strength training exercises such as leg press, leg curl, leg extension, latissimus pull, and bench press.

Free Weights-- were used for biceps curls, triceps extension and military press.

Experimental Design

Approximately one week prior to the onset of the 14-week exercise program and the week following the completion of the program, the subjects underwent: 1) skinfolds, 2) lipid profile, and 3) 1-RM measurement. Nutritional analysis was done during the first week of the program, and again during the last week of the program.

Body Composition:

Body composition was assessed by skinfold measurements. Body density was estimated using Jackson and Pollock and Ward (1980) equation with subsequent estimation of body fat percentage using the Siri equation (1961). Skinfold measurements were done by the same investigator both before and after on all the subjects. The investigator was blinded to the readings of the pre-training measurements when the post-training measurements were done to reduce investigator bias.

Skinfold Measurements:

Three site skinfolds were taken using Lange caliper. All sites were measured on the right side of the body to the nearest 0.5 mm. 1. **triceps**-- a vertical fold on the posterior midline of the upper right arm half way between acromion and olecranon process, 2. **suprailiac**-- an oblique fold taken in line with the natural angle of the iliac crest taken in the anterior axillary line immediately superior to the iliac crest, 3. **thigh**--a vertical fold on the anterior midline of the thigh, midway between the proximal border of patella and the inguinal crease (hip).

The circuit of skinfold measurements was recorded three times for each site during circuit (skinfold sites were measured in succession and then the cycle was repeated three times). The average of the 3 measurements were used for each site for analytical purposes. The sum of skinfolds was inserted into appropriate equations to derive the percent body fat (Jackson et al., 1980). Body density (Db) was determined by the following formula:

$$Db = 1.099421 - 0.0009929\ (X_1) + 0.0000023\ (X_1)^2 - 0.0001392\ (X_2)$$

Where: X_1 = sum of triceps, suprailiam, and thigh (mm)

X_2 = age (years)

Percent body fat (BF%) was calculated using the Siri (1961) formula.

$$\%BF = (495 / Db) - 450$$

Lipid Profile: Subjects were asked to report to the Human Performance Laboratory 12-hours post-prandial. Ten milliliter (ml) blood samples were obtained from the antecubital forearm vein into serum separator tubes. Blood samples were immediately centrifuged at 1,500 RPM for 10 minutes. Extracted serum was immediately frozen until analysis. The same procedure was repeated at the end of the study and all the blood samples were analyzed by Lab Corp (Norfolk, VA) for total cholesterol (T-CHOL), high density lipoprotein cholesterol (HDL-C), low density lipoprotein cholesterol (LDL-C), and triglycerides (TG).

Nutritional Analysis:

Each subject was instructed on the procedure of maintaining a 3-day dietary record. Data from the diet records were entered into the Food Processor software program (Salem, OR). Dietary records were analyzed for total calories and fat calories. Subjects were asked not to alter their diet throughout the study.

1-RM Measurement:

Estimated one-repetition maximum test was performed prior to and upon completion of the study to measure strength. The subjects were asked to perform as many repetitions as possible in each exercise for each muscle group. If the subjects performed more than 15 repetitions on any exercise the weight was adjusted so that they performed 8-15 repetitions for each exercise. The resistance selected was based on the capability of the subject. The subjects were given several familiarization sessions before assessing their 1-RM. The software Power 5.1 (L J C, Inc. Carone Corporation, Hudson, FL) was used to obtain 1-RM for each muscle group. A validity coefficient of 0.99 was reported for this software by the manufacturer (personal communication). Based on the number of repetitions performed for the specified resistance, the software generated the 1-RM. The formula used by the software to generate 1-RM is:

$$\text{1-RM} = \text{weight} + (\text{weight}*0.035) + [\text{weight}*(\text{repetition}-1)(0.03)].$$

Exercise Protocol

Thirty subjects were randomly divided into two groups: exercise and sedentary control. The exercise group participated in supervised 40-50 minute strength training sessions. The supervised sessions were offered three times per week for 14 weeks. The subjects were informed that they must attend at least 80% of the sessions to remain in the study. The subjects were asked not to participate in any other physical activity throughout the study. The sedentary group was asked not to participate in any exercise during the 14 weeks.

Exercise Training

Training consisted of exercises to load the major muscle groups (legs, arms, trunk and lower back) performed at 85% of 1-RM; three sets of 8 repetitions, three days per week, 45-50 minutes per session. Before training, all subjects were shown the proper exercise technique. The subjects performed the following exercises: bench press, leg press, leg extension, leg curl, and lattisimus pull using a circuit training machine; biceps curl, military press, and triceps extensions were performed using free weight. Abdominal crunches (as many crunches as possible) were performed on an exercise mat. Subjects performed one (1) warmup set of eight (8) repetitions at 60% of their 1-RM and three (3) sets of eight (8) repetitions per set at 85% of their 1-RM. Subjects were asked to perform as many repetitions as possible on their third set. The subjects were given an exercise log sheet every week so that they could record how many repetitions they completed on the third set for each muscle group. At the end of each week the data of the log sheets were assessed by software. Based on the number of repetitions they performed in the third set the software generated 1-RM for each muscle group. Resistance was then increased as needed to maintain at 85% of 1-RM for each muscle group throughout the study. The subjects were asked to increase the number of abdominal crunches in each session and to enter that number in their exercise log sheet.

Statistical Analysis

The effects of resistive training on blood lipids, body composition, and 1-RM for various muscle groups were analyzed by 2 group by 2 trial ANOVA, with repeated measures on trial using SAS 6.08 (Cary, NC). The alpha-level for significant main effect and interaction was at 0.05, with a Bonferroni adjustment for appropriate post-hoc comparisons.

CHAPTER 4

Results

The purpose of this study was to investigate the effects of fourteen weeks of resistance training on lipid profile and body fat percentage in healthy, sedentary, premenopausal women. This chapter will provide results for each dependent variable.

More than 50 women expressed an interest to participate in the study, with 40 meeting the criteria for participation. Of these, ten subjects were excluded due to unwillingness to abide by randomized group assignment. Therefore, a total of 30 subjects participated in the study. Fifteen were placed in the control group and 15 in the exercising group. Only 24 subjects completed the study, 12 in the control group and 12 in the exercising group. One subject in the control group changed her diet drastically (she was on a low calorie diet consuming approximately 850 calories/day). Therefore her data were not included in the final analysis of the results. Two more control subjects did not show up for the post study blood analysis. Three subjects in the exercising group did not attend at least 80% of sessions. Due to their sporadic attendance, they were dropped from the study. The twelve subjects in the exercise group who completed the study attended 92% of the sessions.

Baseline Measurements of Physical Characteristics, Lipid Profile and Strength

An independent t-test showed that there were no baseline differences between the control and the exercising group in age, weight, height, body fat percentage, lipid profile and strength measurements with the exception of abdominal crunches . The exercising group had significantly higher abdominal endurance compared to the control group at the baseline ($p<0.05$). There were no differences in the consumption of total calories and fat calories between the control and the exercising group. The mean and standard deviation for physical characteristics, lipid profile and strength measurements are given in Table 1 (Appendix A).

Effect of Resistance Training on Total Cholesterol (T-CHOL)

The mean and standard error of T-CHOL for the control group at baseline and after 14-weeks (post-study) were 171.9 $\pm$10.9 and 177.3 $\pm$ 10.9 $mg \cdot dl^{-1}$, respectively. The mean and standard error of total cholesterol for the exercise group at baseline and after 14-weeks of exercise training were 179.8$\pm$11.8 and 163.7$\pm$8.7 $mg \cdot dl^{-1}$, respectively.

There was a group by trial interaction in T-CHOL ($p<0.05$), explained by a significant decrease in the exercise group following 14-weeks of strength training. There was no significant difference in the post study total cholesterol value compared to baseline value in the control group (Figure 1; Appendix B).

Effect of Resistance Training on Low Density Lipoprotein Cholesterol (LDL-C)

The mean and standard error of LDL-C for the control group at baseline and 14-weeks post-study were 105.3 ± 9.1 and 107.8 ± 10.1 mg·dl^{-1}, respectively. The mean and standard error of LDL-C for the exercise group at baseline and after 14-weeks of strength training were 114.9 ± 11.1 and 98.8 ± 7.7 mg·dl^{-1}, respectively.

As with T-CHOL, a significant group by trial interaction ($p < 0.05$) was due to a decrease in LDL-C in the exercise group following 14-weeks of strength training. There was no change in the control group post study values compared to their baseline values (Figure 2; Appendix B).

Effect of Resistance Training on T-CHOL/HDL-C Ratio

The mean and standard error of T-CHOL/HDL-C ratio for the control group at baseline and post-study were 3.6 ± 0.2 and 3.5 ± 0.2, respectively. The mean and standard error of T-CHOL/HDL-C ratio for the exercise group at baseline and after 14-weeks of exercise were 4.2 ± 0.4 and 3.6 ± 0.4 respectively.

The ratio of T-CHOL/HDL-C decreased for the exercise group ($p < 0.05$) following 14-weeks of strength training compared to their baseline values, but remained unchanged in the control group (Figure 3; appendix B).

Effect of Resistance Training on LDL-C/HDL-C Ratio

The mean and standard error of LDL-C/HDL-C ratio for the control group at baseline and post-study were 2.1 ± 0.2 and 2.1 ± 0.2, respectively. The mean and standard error of LDL-C/HDL-C ratio for the exercise group at baseline and after the 14-weeks of strength training were 2.7 ± 0.4 and 2.3 ± 0.4, respectively.

The exercise group showed a strong trend toward a significant decrease in the ratio of LDL-C/HDL-C following a 14 weeks of strength of training ($p = 0.057$). There was no change in the post-study values of LDL-C/HDL-C ratio in the control group compared to baseline values (Figure 4; Appendix B).

Effect of Resistance Training on Triglycerides (TG)

The mean and standard error of triglycerides for the control group at baseline and 14-weeks post-study were 86.7 ± 9.5 and 89.4 ± 9.4 $mg \cdot dl^{-1}$, respectively. The mean and standard error of triglycerides for the exercise group at baseline and after the 14-weeks of strength training were 92.8 ± 10.6 and 79.3 ± 8.6 $mg \cdot dl^{-1}$, respectively.

Although the exercise group showed a decrease in the post training study triglycerides values compared to baseline values, it was not statistically significant. The control group did not show any change in the triglycerides values between baseline and post-study (Figure 5; Appendix B).

Effect of Resistance Training on High Density Lipoprotein Cholesterol (HDL-C)

The mean and standard error of HDL-C for the control group at baseline and after 14-week study were 48.9 ± 2.3 and 51.3 ± 3.1 mg·dl^{-1}, respectively. The mean and standard error for HDL-C for the exercise group at baseline and after 14-weeks of exercise training were 46.0 ± 3.9 and 48.8 ± 4.3 mg·dl^{-1}, respectively.

There was no change in HDL-C between baseline and post-study values in either the control or exercise group (Figure 6; Appendix B).

Effect of Resistance Training on Body Fat Percent (BF%)

The mean and standard error for body fat percentage for the control group at baseline and 14 weeks post-study were 25.6 ± 1.9 and 25.7 ± 2.0%, respectively. The mean and standard error for body fat percentage for the exercise group at baseline and after 14-weeks of exercise were 27.9 ± 2.1 and 26.5 ± 2.2%, respectively.

Fourteen weeks of resistance training resulted in a significant decrease in estimated percent body fat ($p < 0.05$) with no change in the control group (Figure 7; Appendix B).

Effect of Resistance Training on Strength (1-RM)

The baseline and post-study means with standard error of estimated 1-RM for all the muscle groups tested for both control and exercise groups are presented in Table 2 (Appendix A). Following the 14-weeks of strength training, there was a significant increase in estimated 1-RM ($p < 0.05$) in all the muscle groups for the exercise group. The control group revealed no change in the estimated 1-RM for leg press, leg extension, lat pull, bench press, military press and biceps curl and showed a significant reduction in 1-RM for leg curl and triceps extension ($p < 0.05$) after 14-weeks compared to baseline values. During the course of the study the resistance was increased on the average two to three times for triceps extension and leg curl and five to six times for leg press, leg extension, bench press, lat pull, military press and biceps curls. The exercise group showed an increase in estimated 1-RM for each of the following: 33% leg press, 28.3% leg extension, 11.9% leg curl, 10.1% lat pull, 35.6% bench press, 19.7% military press, 21.1% biceps curl, and 18.6% triceps extension. In addition, the exercise group showed a 101.7% increase in the number of abdominal crunches.

Nutritional Analysis

Only 11 subjects in the control group completed 3-day dietary record at the beginning of the study, whereas all of the 12 subjects in the exercise group completed the baseline 3-day dietary record. No one in the control group completed the 3-day dietary record at the end of the study. Only 8 out of 12 subjects in the exercise group completed the 3-day dietary record at the end of the study. An independent t-test revealed that there was no baseline difference between groups in the consumption of total calories or fat calories. A dependent t-test showed that there was no difference in the consumption of total calories and fat calories between baseline and at the end of the study in the exercise group.

Results Summary

Fourteen weeks of resistance training exercise resulted in a 9% decrease in T-CHOL, 14% decrease in LDL-C, 14.3% decrease in T-CHOL/HDL-C ratio and 5% decrease in body fat percent ($p<0.05$) in the exercise group compared to their baseline values. There was a strong trend towards a significant decrease in LDL-C/HDL-C ratio ($p=0.057$). LDL-C/HDL-C showed a reduction of 14.8%. There was no significant change in triglycerides and HDL-C levels. No significant changes were observed in any of the measured variables in the control group. Body weight did not change significantly in either group. Nutritional analysis showed that there was no difference in total calories and fat calories between exercise and control group at baseline, and also no change in the diet was observed following the 14-weeks in the exercise group. There was a significant increase in strength in the exercise group as measured by estimated 1-RM. The strength of the control group however remained the same or decreased in all of the measured muscle groups. These results indicate that fourteen weeks of resistance training exercise at 85% of 1-RM had a positive effect on T-CHOL, LDL-C, T-CHOL/HDL-C ratio and body fat percentage in healthy, sedentary premenopausal women. There was also a strong trend towards a significant decrease in LDL-C/HDL-C ratio. There was a significant increase in strength as evidenced by the 1-RM post-test. However, the concentration of total plasma TG and HDL-C were not altered by training.

CHAPTER 5

Discussion

Introduction

The purpose of this study was to investigate the effects of resistance training on lipid profile and body composition in healthy, sedentary, nonsmoking premenopausal women. Subjects were matched according to estimated body fat and body mass and randomly assigned to either a sedentary control or 14-weeks strength training group. Dependent variables were analyzed with a two group (control vs exercise) by two trial (baseline vs post-training) ANOVA with repeated measures on trial, with a Bonferroni adjustment for appropriate post-hoc comparisons. Results indicate that 14-weeks of resistance training does have favorable effect on lipids and BF% in healthy premenopausal women. The following discussion presents a comparison of this research with other studies as to the effects of resistance training on lipid profile and body composition.

T-CHOL, LDL-C, HDL-C, T-CHOL/HDL-C, LDL-C/HDL-C, and TG Responses

The results of this study indicate that resistance training program resulted in significant decreases in T-CHOL, LDL cholesterol, T-CHOL/HDL-C ratio, and body fat percentage ($p<0.05$). There was a strong trend towards a significant decrease in LDL-C/HDL-C ratio ($p=0.057$). The training program also resulted in significant increases in strength ($p < 0.05$). The concentrations of total plasma triglycerides and HDL cholesterol were not altered by training.

Results from previous resistance training studies (Boyden et al. 1993, Goldberg et al. 1984), suggest that resistance training is associated with lower levels of total cholesterol, LDL-C, and TG; and in one study (Hurley et al. 1988) an increase in HDL-C levels. The changes in T-CHOL and LDL-C of the present study is consistent with the findings of the Boyden et al. (1993). In the study by Boyden et al., the subjects trained at 70% of 1-RM and the resistance was increased only twice during the study (once every 2 months, the duration of the study was 5 months). The subjects in the current study trained at 85% of 1-RM which resulted in significant decreases in T-CHOL, LDL-C, BF% and T-CHOL/HDL-C ratio ($p < 0.05$) and strong trend towards a significant decrease in LDL-C/HDL-C ratio ($p = 0.057$). These findings are also in agreement with Goldberg et al (1984), in which male and female subjects performed weight-training at 84% of 1-RM. Female subjects demonstrated reductions in T-CHOL ($p < 0.05$), LDL-C ($p < 0.01$), TG, T-CHOL/HDL-C ratio and LDL-C/HDL-C ratio ($p < 0.05$). Reductions in T-CHOL, LDL-C and LDL-C/HDL-C are in agreement with the present study. The male subjects in Goldberg et al. (1984) research demonstrated reductions in LDL-C, T-CHOL/HDL-C ratio, LDL-C/HDL-C ratio ($p < 0.05$), and an insignificant increase in HDL-C. Hurley et al. (1988) reported a significant increase in HDL-C ($p < 0.05$) and significant decrease in LDL-C ($p < 0.05$) and in the ratios of LDL-C/HDL-C and T-CHOL/HDL-C

($p < 0.01$) following a 16 week resistance training program in male subjects. Wallace et al. (1991) showed that acute resistance exercise performed at 85% of 1-RM resulted in an increased level of HDL-C and HDL_3-C in male subjects. However, results obtained from a single bout of exercise do not provide any conclusions to establish a relationship between resistance training and lipid profiles.

The concentration of TG and HDL-C were not altered by training in the current study. However, the subjects' mean baseline value of HDL-C in Hurley et al. (1988) research was 39 ± 6 $mg \cdot dl^{-1}$ which is much less than the baseline values of HDL-C of 46.0 ± 13.6 $mg \cdot dl^{-1}$ in the present study. The baseline HDL-C value (46.0 $mg \cdot dl^{-1}$) of the current study is higher than the post training values (44 $mg \cdot dl^{-1}$) of subjects in the Hurley study. The HDL-C values of female subjects in Boyden et al. (1993) study (53.4 $mg \cdot dl^{-1}$) and Goldberg et al. (1984) study (77.4 $mg \cdot dl^{-1}$) were unchanged following 5 months of resistive training performed at 70% of 1-RM and 16 weeks of resistive training performed at 84% of 1-RM, respectively. The male subjects in Goldberg et al. study had HDL-C values of 50.6 $mg \cdot dl^{-1}$ that was also not changed following 16 weeks of resistive training performed at 84% of 1-RM.

In chronic aerobic training study done by Despres et al. (1989) the male subjects showed an increase in HDL-C (40 $mg \cdot dl^{-1}$ vs 48 $mg \cdot dl^{-1}$). In contrast the female subjects in the study by Santiago et al. (1995) had high baseline HDL-C values ($63.3 \pm 15.1 mg \cdot dl^{-1}$) that were unchanged following a 40-week aerobic training program.

Several studies have demonstrated that young to middle aged women have higher concentration of HDL-C and lower concentration of LDL-C than do their male counterparts (Fulwood et al. 1986 and Wenger, 1995). It has been suggested that endogenous or exogenous hormones may be responsible for gender differences in lipid patterns (Wahl et al.; 1983, Krauss et al. 1979; Srinivasan et al. 1985).

The most likely explanation for the lack of change in the concentration of HDL-C in the current study is that the subjects had a normal baseline values (46.0 ± 13.5 $mg \cdot dl^{-1}$) of HDL cholesterol and women in general have higher levels of HDL-C as indicated by other studies (Fulwood et al., 1986; Wenger, 1995). HDL cholesterol may be very resistant to the intervention of resistance training. It is possible that resistance exercise training is more effective in increasing HDL-C in male subjects who have lower baseline values (Hurley et al, 1988).

Body Fat Percentage Response

There was a significant decrease ($p<0.05$) in body fat percentage in the exercise group compared to their baseline values following a 14 weeks of resistance training program whereas the values of control group did not show any change from their initial values. In the Goldberg study (1984) both male and female subjects showed significant decrease in triceps skinfold thickness. However, the subjects did not show any change in their body fat percentage following a 16-week resistive training study by Hurley et al. (1988) and 5-month resistive training by Boyden et al. (1993).

Strength (1-RM) Responses

The training program resulted in significant increases in strength as evidenced by the estimated 1-RM test. The subjects increased their strength in all the muscle groups tested. These findings are consistent with the findings of the Hurley et al. (1988); and Goldberg et al. (1984).

Conclusions

The following conclusions may be drawn from the results of this investigation.

1. Resistance training did significantly lower T-CHOL, LDL-C, and T-CHOL/HDL-C ratio ($p<0.05$) in healthy, sedentary premenopausal women. There was a strong trend towards significant decrease in LDL-C/HDL-C ratio ($p=0.0568$).
2. Resistance training did significantly lower body fat percentage in healthy, sedentary premenopausal women.
3. Resistance training did significantly increase strength in healthy sedentary premenopausal women as evidenced by the 1-RM strength tests.
4. Resistance training did not have any effect on triglycerides or HDL-C.

Recommendations

The design of this study focused upon a representative segment of the premenopausal female population. The number of subjects ($n=24$) is small in this study. Due to monetary conditions, more subjects could not be recruited. Based on the findings of this study the following recommendations are proposed:

1. Increase the number of subjects in the study.
2. Increase the duration of the study (more than 14 weeks)
3. Analyze the blood samples for HDL subfractions and apo lipoproteins.

TABLE 1.
BASELINE MEASUREMENTS OF PHYSICAL CHARACTERISTICS, LIPID PROFILE AND STRENGTH ($\bar{x} \pm SD$)

Variable	Control (n=12)	Exercise (n=12)
Age (years)	26.0 ± 6.0	28.0 ± 6.0
Height (cm)	165.0 ± 7.0	162.5 ± 7.0
Weight (kg)	65.5 ± 17.3	66.8 ± 7.3
Estimated body fat %	25.6 ± 6.8	27.9 ± 7.3
Total Cholesterol ($mg{\cdot}dl^{-1}$)	171.9 ± 37.7	179.8 ± 40.9
HDL-C ($mg{\cdot}dl^{-1}$)	48.9 ± 8.1	46.0 ± 13.6
LDL-C ($mg{\cdot}dl^{-1}$)	105.3 ± 31.6	114.9 ± 38.4
Triglycerides ($mg{\cdot}dl^{-1}$)	86.7 ± 32.7	92.8 ± 36.8
LDL-C\HDL-C Ratio	2.1 ± 0.7	2.6 ± 1.0
T-CHOL\HDL-C Ratio	3.6 ± 0.8	4.2 ± 1.5
Total Calories (Kcal)	1601.0 ± 361.2 (n=11)	1744.0 ± 424.3
Fat Calories (Kcal)	494.0 ± 153.9 (n=11)	580.0 ± 172.6
Leg press 1-RM (kg)	123.8 ± 32.3	115.8 ± 31.5
Leg extension 1-RM (kg)	28.3 ± 8.7	24.4 ± 9.0
Leg curl 1-RM (kg)	19.8 ± 5.4	17.6 ± 4.8
Latpull 1-RM (kg)	35.7 ± 7.5	34.9 ± 5.2
Bench press 1-RM (kg)	25.6 ± 5.1	26.4 ± 7.9
Military press 1-RM (kg)	6.9 ± 1.7	6.6 ± 1.1
Biceps curl 1-RM (kg)	7.3 ± 1.5	7.1 ± 1.3
Triceps extension 1-RM (kg)	6.1 ± 1.4	6.0 ± 1.2
Abdominal crunches (number)	25.8 ± 8.9	45.6 ± 13.8*

*Exercise greater than control, $p<0.05$.

TABLE 2
EFFECT OF RESISTANCE TRAINING ON STRENGTH ($\bar{x} \pm SE$)

Variable	Pre-Training	Post-Training	Percent change
Leg press 1-RM (kg)			
Control	123.8 ± 9.3	127.2 ± 9.1	2.7%
Exercise	115.8 ± 9.1	154.4 ± 9.7	33.0%*
Leg extension 1-RM (kg)			
Control	28.3 ± 2.6	25.3 ± 1.1	-10.0%
Exercise	24.4 ± 1.7	31.3 ± 3.7	28.3%*
Leg Curl 1-RM (kg)			
Control	19.8 ± 1.6	16.7 ± 1.4	-15.7%†
Exercise	17.6 ± 1.4	19.7 ± 1.4	11.9%*
Lat pull 1-RM (kg)			
Control	35.7 ± 2.2	29.6 ± 1.9	-17.0%
Exercise	34.8 ± 1.5	38.3 ± 2.2	10.1%*
Bench press 1-RM (kg)			
Control	25.6 ± 1.5	24.5 ± 1.5	-3.9%
Exercise	26.4 ± 2.3	35.8 ± 3.6	35.6%*
Military press 1-RM (kg)			
Control	6.9 ± 1.1	6.3 ± 1.0	-8.7%
Exercise	6.6 ± 0.7	7.9 ± 1.4	19.7%*
Biceps curl 1-RM (kg)			
Control	7.3 ± 0.9	6.4 ± 0.8	-12.3%
Exercise	7.1 ± 0.8	8.6 ± 1.3	21.1%*
Triceps extension 1-RM (kg)			
Control	6.1 ± 0.9	4.9 ± 0.6	-19.7%†
Exercise	5.9 ± 0.7	7.0 ± 1.0	18.6%*
Abdominal crunches (Num)			
Control	25.8 ± 2.5	23.9 ± 3.0	-7.4%
Exercise	45.6 ± 3.9	92.0 ± 7.7	101.7%*

*Exercise post-training is greater than exercise pre-training, $p<0.05$

†Control post-training is less than control pre-training, $p<0.05$

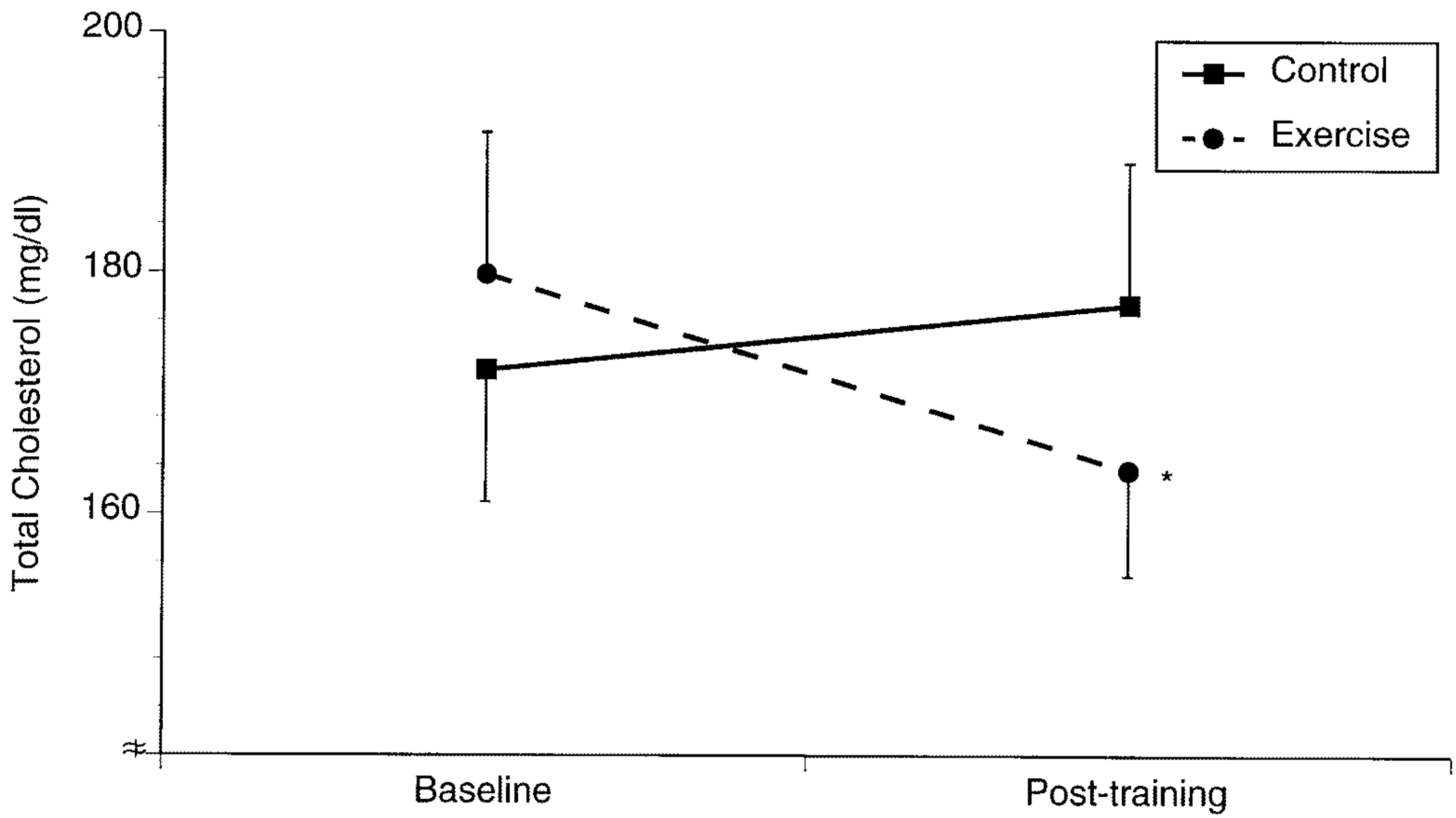

Figure 1. Effect of Resistance Training on Total Cholesterol

* Exercise Post < Exercise Baseline; $p < 0.05$

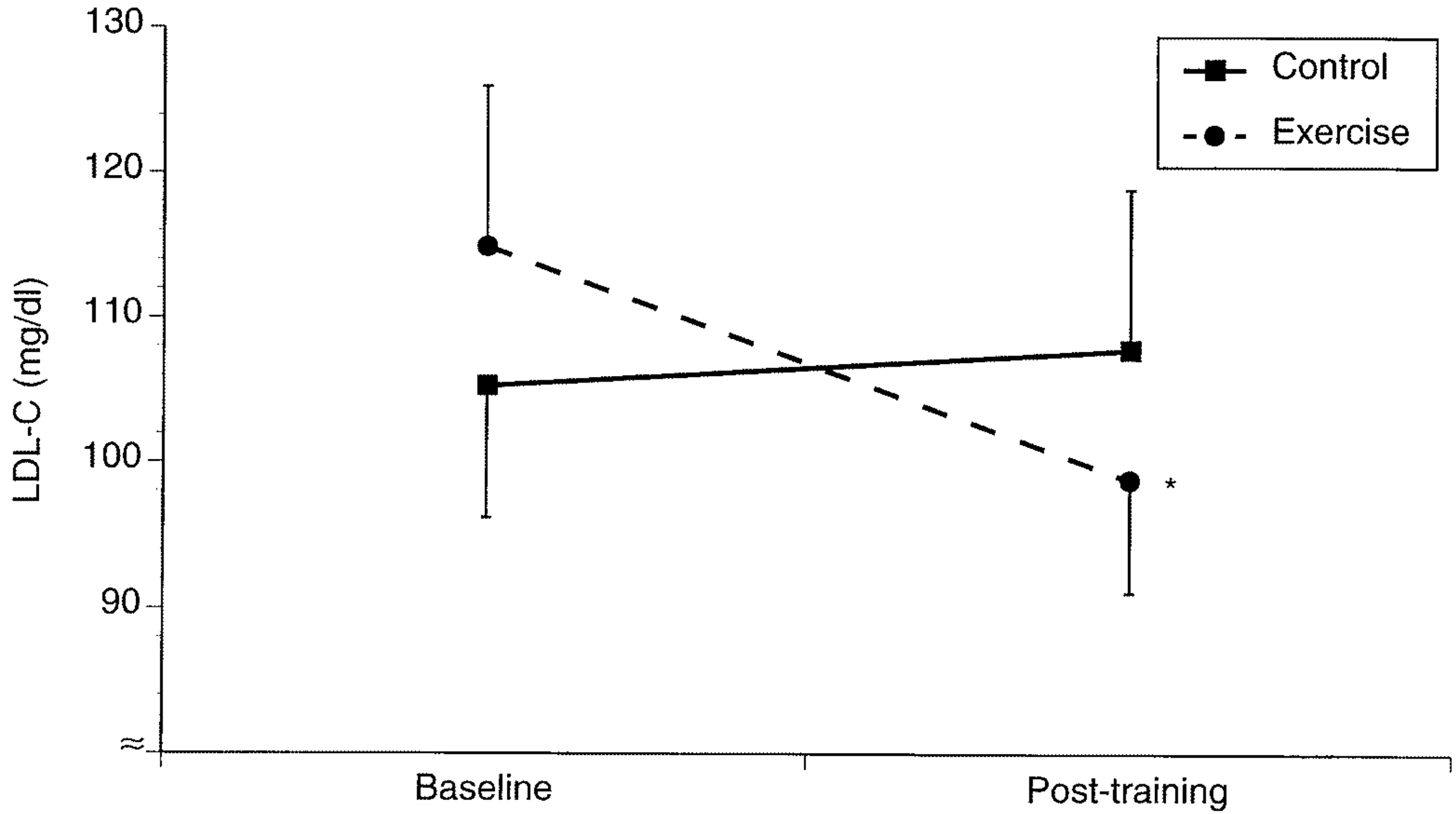

Figure 2. Effect of Resistance Training on LDL-C

* Exercise Post < Exercise Baseline; $p < 0.05$

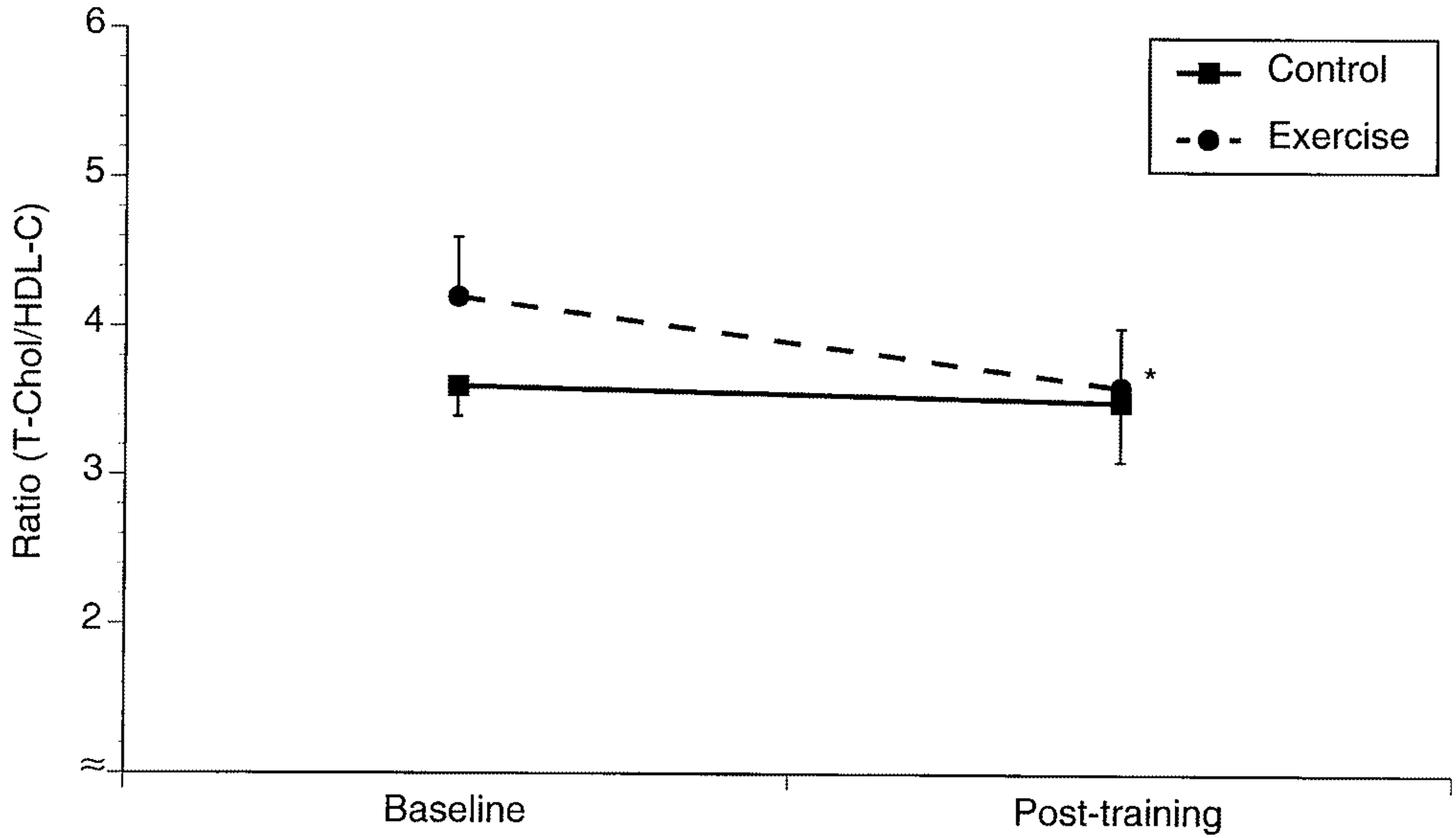

Figure 3. Effect of Resistance Training on T-CHOL/HDL-C Ratio

* Exercise Post < Exercise Baseline; $p < 0.05$

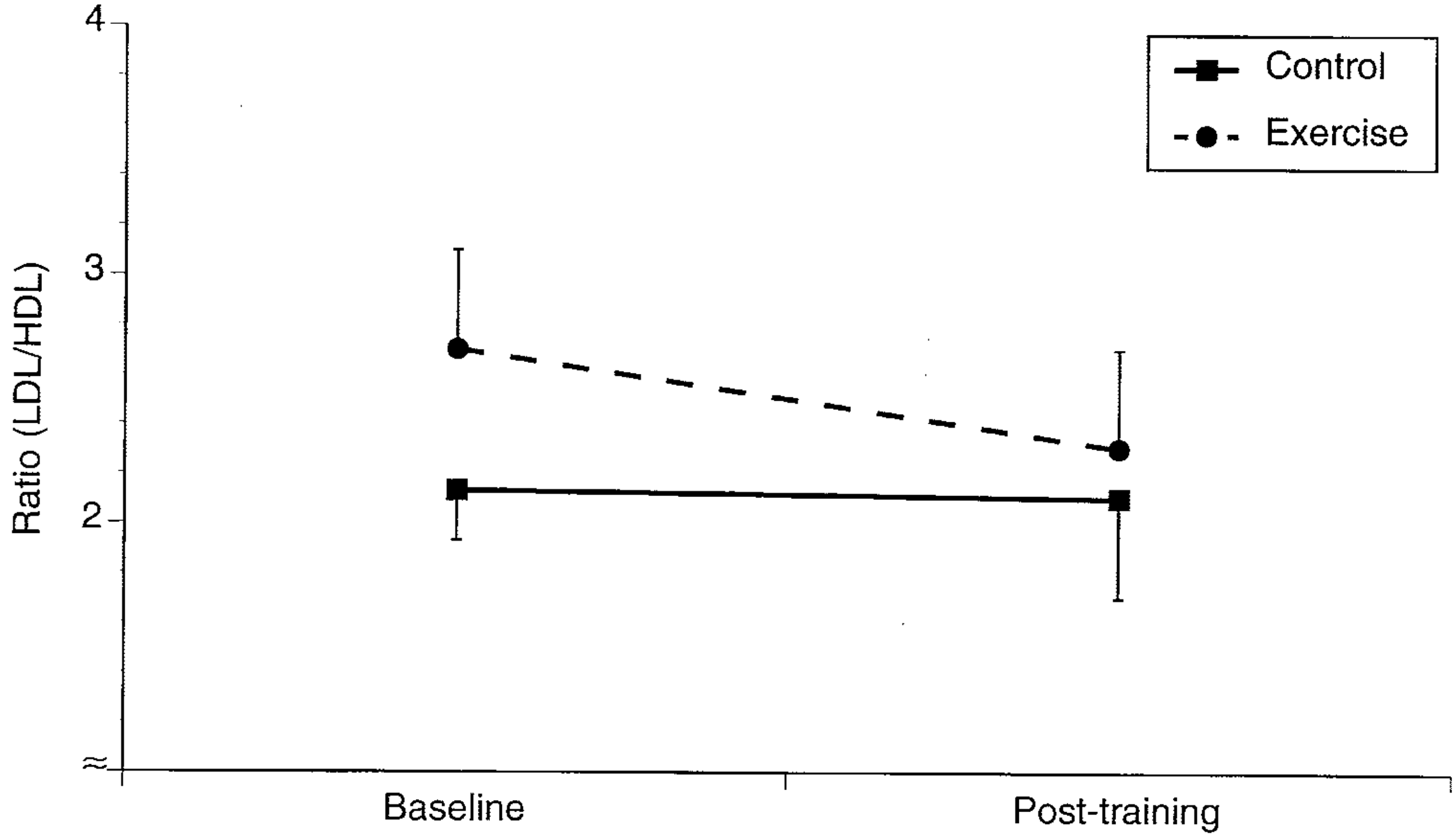

Figure 4. Effect of Resistance Training on LDL-C/HDL-C Ratio

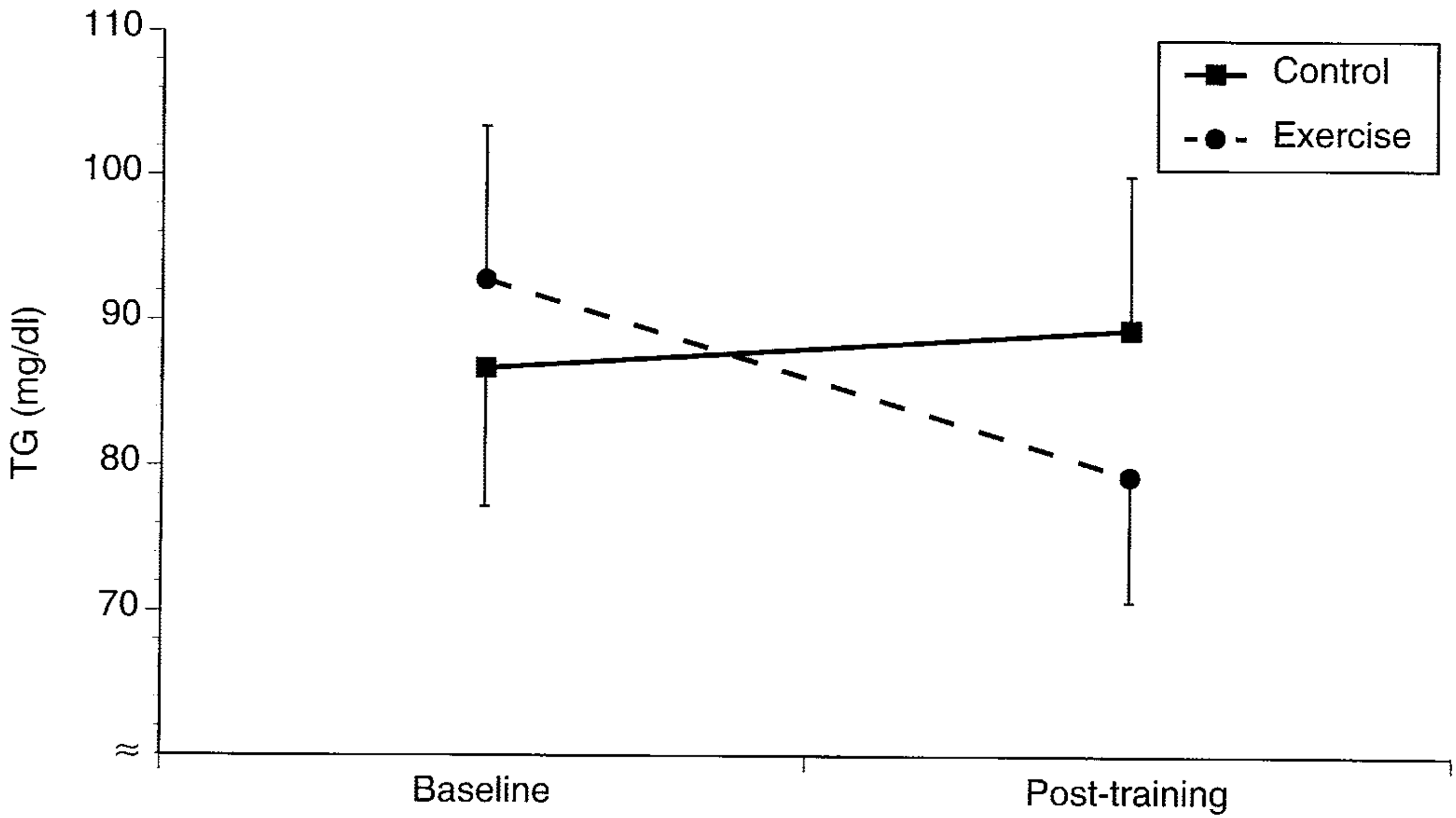

Figure 5. Effect of Resistance Training on Triglycerides

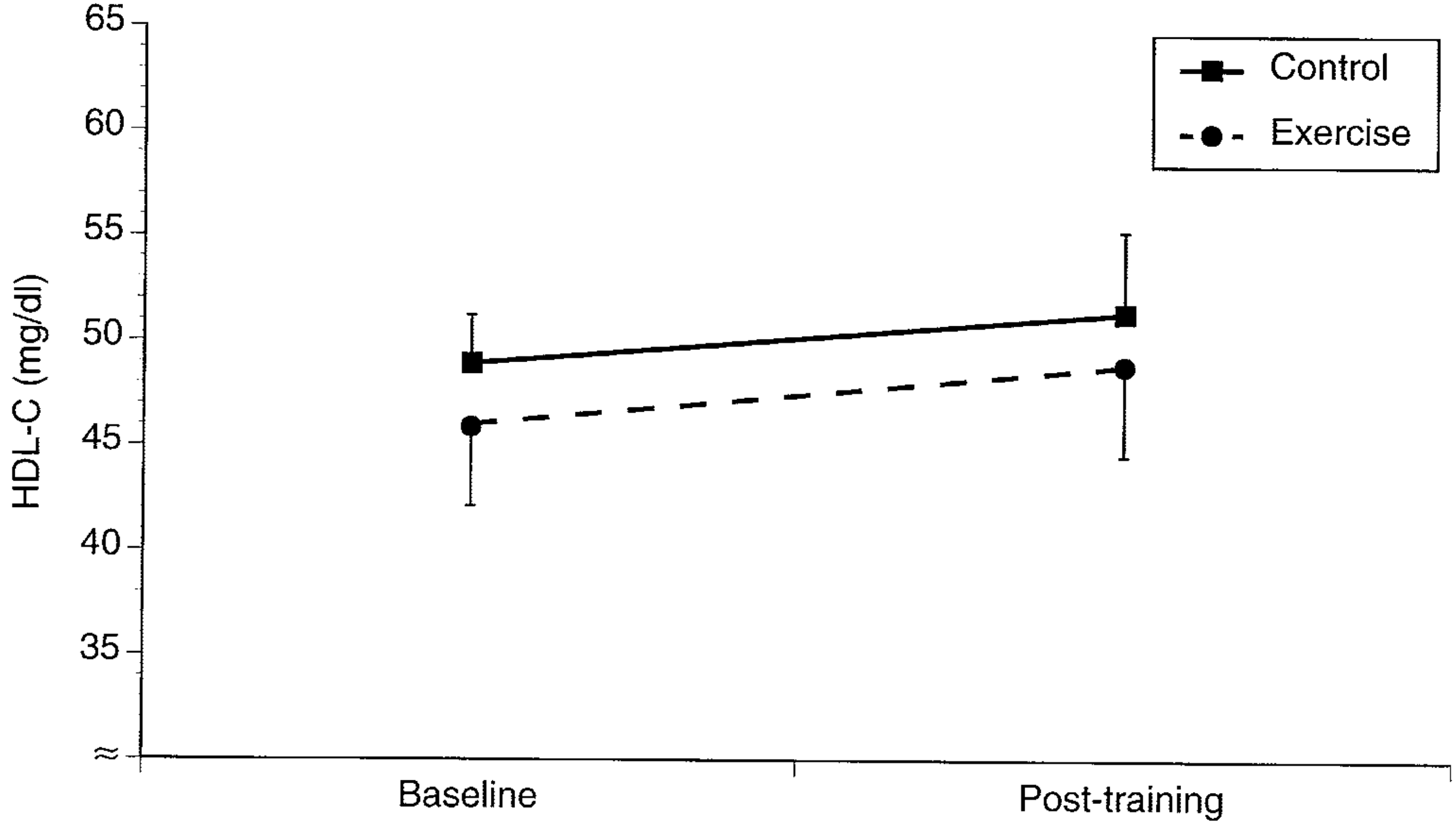

Figure 6. Effect of Resistance Training on HDL-C

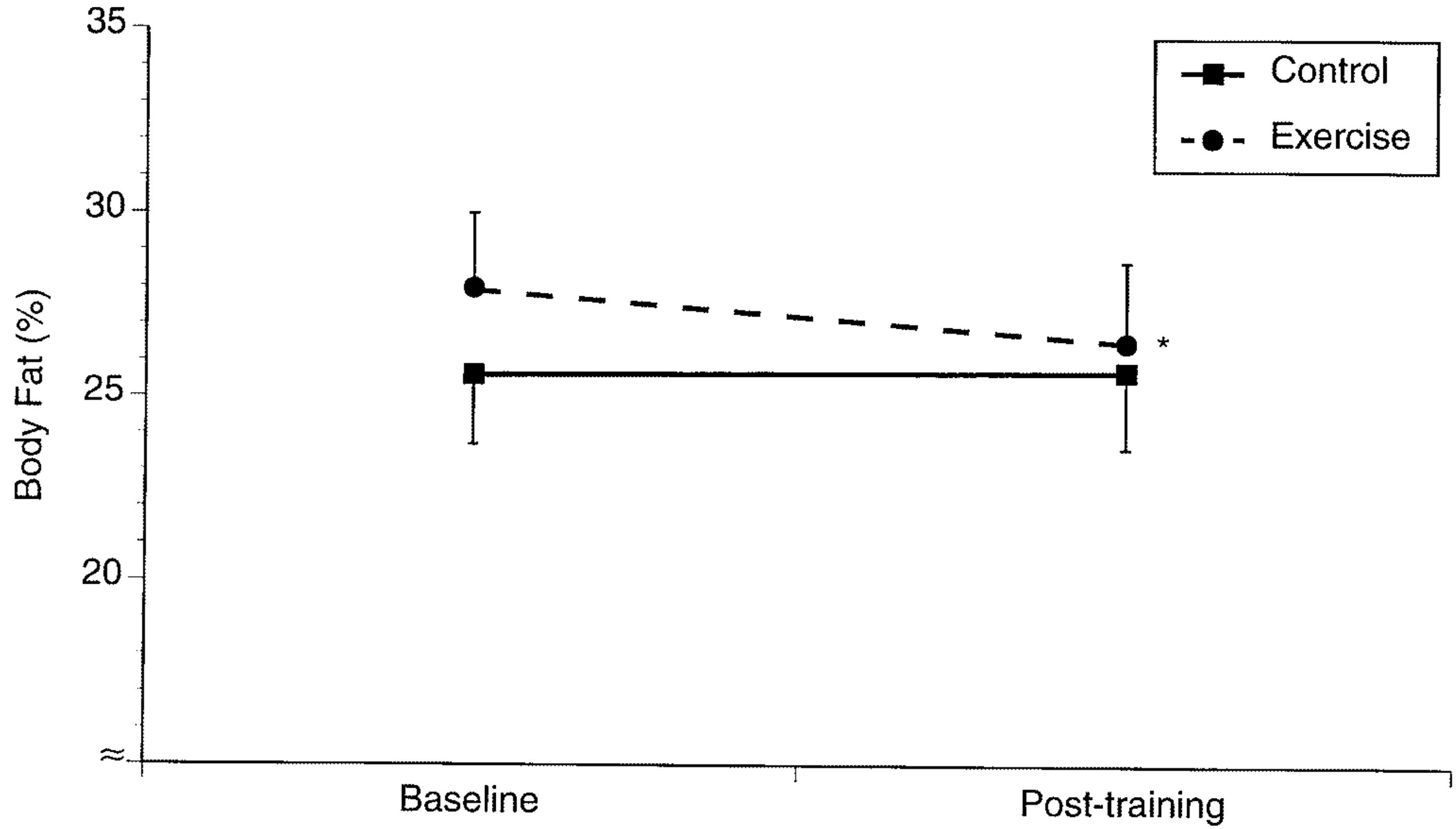

Figure 7. Effect of Resistance Training on Body Fat %
* Exercise Post < Exercise Baseline; $p < 0.05$

OLD DOMINION UNIVERSITY

HUMAN PERFORMANCE LABORATORY

Medical History Inventory

Directions. The purpose of this questionnaire is to enable the staff of the Wellness Institute and Research Center to evaluate your health and fitness status. Please answer the following questions to the best of your knowledge. All information given is **CONFIDENTIAL.**

Name:______________________________Age_____Date of Birth_________

Work Address:____

Home Address:____

Work Phone Number:______________ Home Phone Number________________

SS#_______________________

Name and Address of your Physician:_______________________________

____

MEDICAL HISTORY

Do you have or have you ever had any of the following conditions? (Please write the date when you had the condition in blank).

____ Heart murmur, clicks, or other cardiac findings?
____ Frequent extra, skipped, or rapid heartbeats?
____ Chest pain of Angina (with or without exertion)?
____ Pregnancy (at present)?
____ Diagnosed high blood pressure?
____ Heart attack or any cardiac surgery?
____ Leg cramps (during exercise)?
____ Chronic swollen ankles?
____ Varicose veins?
____ Frequent dizziness/fainting?
____ Musculoskeletal/Orthopedic problems?
____ Asthma?

____ Bronchitis?
____ Cancer?
____ Stroke?
____ Emphysema?
____ Epilepsy
____ Rheumatic Fever?
____ Scarlet Fever?
____ Chronic back pain?
____ Pneumonia?
____ Blood Clots?

Do you have or have you been diagnosed with any other medical condition not listed?____

____

Please provide any additional comments/explanations of your current or past medical history.____

Please list any recent surgery (i.e.,type, dates etc).____________

____

List all prescribed or non-prescription medications that you currently take.____

____

What was the date of your last complete medical exam?_____________

____

Do you know of any medical problem that might make it dangerous or unwise for you to participate in vigorous exercise _____ if yes, please explain:____

FAMILY HISTORY

Indicate the age of diagnosis and relationship (i.e., sister, father, mother, grandfather, grandmother, children) of your immediate family members who have had any of the following conditions:

Condition	Relation(s)	Age(s)
Cardiovascular Disease	______	______
Heart Attack	______	______
Stroke	______	______
High Blood Pressure	______	______
Diabetes	______	______
High Cholesterol	______	______
Overweight/Obesity	______	______

Health Inventory

Height (in)_____ Weight (lbs)_____ Weight at age 21(Lbs)_____

What is the most that you ever weighed(lbs)___ What was your age___

Do you currently follow a special diet or weight reduction program? if so explain:________________________________

What was your most recent resting blood pressure?________________

Please indicate your normal daily intake of the following:

Coffee (cups)_____ Tea (cups)_____ Colas (12 oz serving)______

Please indicate your normal weekly intake of the following:

Alcohol (number of beers and/or 1 oz drinks)____________________

Cigarettes (packs/day and packs/week)__________________________

If you smoke, how long have you smoked?________________________

EXERCISE HISTORY

Do you currently exercise on a regular basis? Yes___ No___
If yes, respond to the following:

Number of exercise sessions per week? ________________
Duration of each exercise session? ________________
What is your approximate heart rate maintained? ________________
What type of exercise do you do? ________________
What type of exercise do you enjoy? ________________

If you do not exercise on a regular basis, when was the last time you exercised and what was the type of exercise you performed.

____

MENSTRUAL HISTORY

What age were you when you had your first menses?________________

How would you classify your menstrual cycles:

______ 10 or more cycles per year

______ 3 to 9 cycles per year

______ 0 to 2 cycles per year

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