Influence of Resistance Training on Serum Lipid and Lipoprotein Concentrations in Young Men and Women

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ABSTRACT

Although endurance training has been repeatedly shown to favorably alter lipid and lipoprotein concentrations, data on the effects of resistance training are equivocal. The purpose of the present study was to assess the effects of short-term, high-intensity resistance training on the lipid profile of young men and women. The resistance training program was known to result in significant adaptations within the vastus lateralis muscle (39), which could contribute to alterations in lipid profile. Thirty-two college-aged individuals were divided into four groups: training men (n = 12), control men (n = 7), training women (n = 8), and control women (n = 5). The short-term (8-week) training period consisted of three exercises for the lower extremity (squats, leg press, and leg extension) performed two times a week for three sets to failure, performing 6–8 repetitions maximum (RM) on Mondays and 8–10 RM on Fridays. After fasting, blood was drawn at three time points (pre-, mid-, and posttraining) and analyzed for lipid and lipoprotein concentrations (total cholesterol, low- and high-density lipoprotein cholesterol, and triglycerides). Although the training program resulted in significant alterations in body composition (decrease in percent body fat) and fiber composition (hypertrophy and type IIB to IIA fiber conversions), no change was detected over time for any of the blood lipid parameters in either young men or young women. Thus, while any form of physical activity may prove beneficial for individuals at risk for coronary heart disease (CHD), short-term, high-intensity resistance training does not appear to influence serum lipid and lipoprotein concentrations in young individuals not at risk for CHD.

Key Words: cholesterol, lipid-lipoprotein profile, HDL-C, LDL-C, strength training


Introduction

Low plasma concentrations of high-density lipoprotein cholesterol (HDL-C) and high plasma concentrations of triglycerides (TG) appear to play an important role in the pathogenesis of coronary heart disease (CHD) (4). HDL-C is involved in preventing cholesterol from entering into the process of atherogenesis and may even help remove cholesterol from atherosclerotic lesions. In addition, it has been shown that high levels of HDL-C result in an enhanced ability to clear ingested fat from the circulation (35). Thus, elevated levels of HDL-C are favorable, whereas low levels (below 35 mg·dl⁻¹) place the individual at risk for CHD (28, 29, 53). For TG, elevated levels may place an individual at risk for CHD through alterations of the coagulation system (increases in several clotting factors and decreases in fibrinolytic activity). Life-style factors that negatively impact an individual's cholesterol profile (i.e., decreased HDL-C/increased TG) are obesity, smoking, and inactivity. As such, one of the primary treatments against these CHD risk factors is some form of regular physical exercise (11, 47).

Most CHD prevention programs have emphasized aerobic training. Numerous studies have demonstrated the beneficial effects of regular endurance training on serum lipid and lipoprotein concentrations in both men and women (24, 26, 47). Although the exact mechanisms involved in these exercise-induced alterations in cholesterol metabolism are not well understood, endurance training has been shown to increase skeletal muscle lipoprotein lipase activity, which results in a greater amount of TG hydrolysis and subsequent extraction (17). In addition, it is known that HDL2-C (a subfraction of HDL-C) is formed from degradation
products from the TG-rich lipoproteins (33). As such, vigorous aerobic training programs result in decreases in the concentrations of total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), and TG and an increase in HDL-C concentration (31, 43).

Less is known about the effects of resistance training on cholesterol profile, especially in women. Most studies investigating the effects of resistance training on plasma lipid and lipoprotein concentrations have used men, and the results are conflicting. Some resistance-training studies using men have suggested that resistance training can lower the risk for CHD (i.e., increase HDL-C and/or lower TC and LDL-C concentrations) (2, 10, 13, 42, 52), while others have reported either no change (6, 8, 19, 20, 37) or an increased risk (1, 22). Although fewer studies have been performed using weight-trained women, the results are just as equivocal, with some claiming favorable changes in lipid and lipoprotein levels (10, 30) and others reporting no difference between the resistance-trained women and sedentary controls (31). Reasons for these varied findings in both men and women may be because of differences in training regimen, duration, and/or intensity, as well as age, body composition, and diet of the subjects (12). As such, it is perhaps not surprising that resistance training studies using older populations at risk for CHD (higher initial levels of TC and LDL-C and lower initial levels of HDL-C) have demonstrated a beneficial effect on lipid profile (2, 13, 42).

Further confounding the results of studies investigating the effects of resistance training on serum lipid and lipoprotein concentrations is the use of anabolic-androgenic steroids. Anabolic steroids have been shown by a number of studies to cause extreme adverse alterations in lipid profile, including increases in the levels of TG and LDL-C and a dramatic decrease in HDL-C in both men (3, 8, 14, 18, 21, 23, 50, 54) and women (30). As such, these individuals have an increased risk for premature atherogenesis.

Finally, body composition and even muscle fiber composition may play a role in determining lipid profile. It has been demonstrated that a decrease in the percentage of body fat has a favorable influence on lipid profiles (38, 51). In addition, Tikkanen et al. (45, 46) have demonstrated an association between muscle fiber type distribution (percentage of slow fibers in the vastus lateralis muscle) and serum HDL-C levels. Those individuals with a higher percentage of slow fibers had a higher concentration of HDL-C (46). Because resistance training is known to have a greater hypertrophic effect on fast fibers (44), the resulting decrease in the percentage area occupied by the slow fibers may therefore unfavorably alter lipid profile.

The purpose of the present study was to investigate the effects of short-term, high-intensity resistance training on serum lipid and lipoprotein concentrations in both young men and young women. This was accomplished over three time points (pre-, mid-, and posttraining) and involved the use of serum collected from individuals during their participation in a resistance training study (39). To our knowledge, this is the first study to investigate the effects of short-term, high-intensity resistance training on lipid and lipoprotein concentrations in young men and women with known muscular adaptations. The resistance training program not only resulted in significant increases in maximal strength and decreases in body fat but caused adaptations within the quadriceps femoris muscle group, consisting of significant increases in the cross-sectional area of the muscle fibers and transformations within the fast fiber types (IIB to IIA), which could contribute to alterations in the lipid profile in this young population.

Methods

Subjects. Thirty-five healthy individuals (21 men and 14 women) volunteered to participate in the present investigation. All subjects signed informed consent documents, and approval was given by the Ohio University Institutional Review Board before the beginning of the study. Two subjects (one man and one woman) dropped out shortly after the study began, and no blood was drawn from one training man. Therefore, a total of 32 individuals completed the present investigation. The resistance training group consisted of 12 men (age 23.4 ± 3.4 years, height 1.78 ± 0.09 m) and 8 women (age 20.6 ± 1.5 years, height 1.66 ± 0.05 m). The training subjects had not previously been involved in any heavy-resistance training. The remaining 12 individuals served as controls, and included seven men (age 20.7 ± 1.4 years, height 1.80 ± 0.09 m) and five women (age 20.6 ± 1.6 years, height 1.61 ± 0.01 m). The controls were physically active but were not involved in any resistance training or regular exercise program. Body composition, determined at the beginning, middle, and end of the study, was estimated using skinfold measurements from three sites for the women (anterior thigh, posterior brachium, and supraillium) (16) and men (chest, umbilicus, and anterior thigh) (15). The subjects were asked not to alter their eating habits throughout the study.

Training Protocol. The specific training protocol used in the present study was similar to programs in our previous resistance training studies (40, 41) and has been published elsewhere (39). Briefly, the training period consisted of a 1-week preconditioning/orientation phase (week 1) followed by 8 weeks of high-intensity resistance training (weeks 2–9). Three lower limb exercises for the quadriceps femoris muscle group (squat, leg press, and leg extension) were performed twice a week (Monday and Friday) with every other Wednesday used for maximal dynamic strength (one
repetition maximum [1RM]) testing. Workouts consisted of two warm-up sets of 10 repetitions using approximately 40 and 60% of the 1RM value, followed by three sets to failure of either 6–8 repetitions (Mondays) or 10–12 repetitions (Fridays) for each of the three exercises with approximately 2 minutes of rest between sets. The weights were progressively increased to maintain this range of repetitions per set. Workouts began and ended with 10–15 minutes of flexibility exercises combined with calisthenics.

Maximal Dynamic Strength Testing. Maximal dynamic strength was measured at the beginning and end of the study and every other week during the study. For the 1RM measurements, the subjects performed warm-up sets (10 repetitions/set at 40 and 60% of 1RM), three repetitions at 75%, and one repetition at approximately 90% of the 1RM value, followed by an attempt at the target 1RM determined for each exercise (32). The weight was progressively increased for each subsequent attempt until failure.

Serum Collection. After the subjects had fasted for 12 hours, 10–15 ml of blood were drawn from the median cubital vein with the use of a needle, syringe, and vacuum assembly. Blood samples were taken 24 hours before each muscle biopsy at the beginning, middle, and end of the study. For most of the subjects (18 of 32), the midpoint was week 5. However, for 14 of the subjects, the midpoint blood sample was drawn during either week 3 or 7. The subjects abstained from ingesting any substances containing alcohol or caffeine during the fasting period and did not perform strenuous exercise for at least 36–48 hours before giving blood. Identical blood collection procedures were used throughout the study. Blood samples were taken at the same time of day to reduce the effects of diurnal variations. The subjects reported to the laboratory and sat quietly for 10–15 minutes before giving a blood sample while in a slightly reclined seated position. Whole blood was allowed to clot at room temperature and was centrifuged at 1,060 x g for 10 minutes. Subsequently, 4–5 ml of serum were removed and stored in 1-ml aliquots at −74 °C until analysis was performed.

Lipid and Lipoprotein Analyses. Consistent 10 μg analysis of TC, HDL-C, and TG was performed in duplicate utilizing the dry-chemistry technique on a Kodak Ektachem DT-60 analyzer. LDL-C calculation was performed using the equation of Friedewald et al. (7), i.e., LDL-C = TC − HDL-C − TG/5. All reactions for a single quantitative measurement took place within a multilayered analytical element of the self-contained slide. Colorimetric measurement by reflectance spectrophotometry provides the basis for determining the concentrations of TC, HDL-C, and TG. HDL-C specimens were initially treated with a reagent to remove the very low-density lipoprotein cholesterol (VLDL-C). Following completion of the study, aliquots of 1 ml of serum were removed from the ultralow freezer for each subject from each time point. Analysis of samples from all three time points was performed at the same time to minimize differential analysis effects. Serum was thawed to room temperature (approximately 23°C), vortexed for 1 minute, and analyzed for each respective agent. In no case were samples subjected to repeated freeze-thaw cycles. A 10 μl drop of specimen was deposited on the slide and evenly distributed. Duplicate samples were analyzed and averaged. If the samples varied by greater than 2–3%, a third sample was measured. Values are reported in mg·dl⁻¹ (mg %).

Statistical Analysis. Descriptive statistics were used to derive means ± SD for all variables. A repeated measures two-way analysis of variance (ANOVA) was used to detect possible changes occurring over time for the anthropometric data. For lipid and lipoprotein comparisons, the four groups (control women, control men, training women, training men) were compared using a one-way ANOVA to determine if any gender differences existed. If no gender differences were found between the men and women for a particular blood parameter, the data were collapsed into two groups (control and training) and the gender factor was ignored. Lipid profile data were analyzed using a two-way repeated measures ANOVA with treatment group (control and training) a between factor and time (pre, mid, and post) a within factor. Significant differences were evaluated using a Tukey’s HSD post hoc test. Statistical differences were considered significant when p ≤ 0.05.

Results

Anthropometric Measurements. When assessing total body weight and body fat percentage every 2 weeks during the study, no significant changes occurred over time for any of the groups (39). However, when these anthropometric measurements were assessed over the course of the three time points used in the present investigation (pre, mid, and post), a significant decrease occurred in body fat percentage. Percent body fat was significantly lower after training for both the training men and the training women compared to the pretraining value (Table 1). No significant change in body fat percentage occurred in the control group (Table 1). Percent body fat was significantly different between all groups at all three evaluation time points except between the control and training men at the end of the study. In addition, no significant change in total body mass took place over the course of the study for any of the groups (Table 1). However, at all three time points, the training men were significantly heavier than both the control and training women, whereas the control men were significantly heavier than training women (Table 1).
Table 1. Anthropometric measurements (mean ± SD).

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<tr>
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<th>Pre</th>
<th>Mid</th>
<th>Post</th>
<th>Pre</th>
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<tr>
<td><strong>Total body mass (kg)</strong></td>
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<tr>
<td>Control men</td>
<td>76.9 ± 13.8§</td>
<td>76.9 ± 13.3§</td>
<td>77.0 ± 13.8§</td>
<td>12.5 ± 4.4</td>
<td>13.1 ± 3.9</td>
<td>13.2 ± 4.0</td>
</tr>
<tr>
<td>Training men</td>
<td>83.3 ± 18.0</td>
<td>82.9 ± 17.5</td>
<td>83.6 ± 18.0</td>
<td>15.6 ± 4.6</td>
<td>15.2 ± 4.5</td>
<td>13.8 ± 4.5³</td>
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<tr>
<td>Control women</td>
<td>68.8 ± 12.8</td>
<td>68.1 ± 14.0</td>
<td>68.3 ± 14.3</td>
<td>28.3 ± 3.1</td>
<td>28.2 ± 4.5</td>
<td>29.5 ± 4.7</td>
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<tr>
<td>Training women</td>
<td>60.4 ± 5.8</td>
<td>61.1 ± 5.7</td>
<td>61.7 ± 5.3</td>
<td>23.8 ± 5.1</td>
<td>22.1 ± 4.5‖</td>
<td>20.9 ± 4.8 †</td>
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<tr>
<td><strong>% Body fat</strong></td>
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<tr>
<td>Control men</td>
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<td>Training men</td>
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<td>Control women</td>
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<td>Training women</td>
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* Percent body fat was significantly different between all groups at all time points (pre, mid, and post) except between the control and training men posttraining.
† Significantly less than the pre value.
‡ Significantly greater than respective value for training women.
§ Significantly greater than respective value for control and training women.
|| Significantly greater than respective value for control and training men.

Table 2. Serum lipid and lipoprotein concentrations (mg·dl⁻¹).

<table>
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<th>Pre*</th>
<th>Mid*</th>
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<tbody>
<tr>
<td><strong>Triglycerides</strong></td>
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<tr>
<td>Control men and women (n = 12)</td>
<td>128 ± 16†</td>
<td>111 ± 13†</td>
<td>122 ± 16†</td>
</tr>
<tr>
<td>Training men and women (n = 20)</td>
<td>103 ± 6</td>
<td>90 ± 6</td>
<td>101 ± 10</td>
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<tr>
<td><strong>Total Cholesterol</strong></td>
<td></td>
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<tr>
<td>Control men and women (n = 12)</td>
<td>175 ± 14</td>
<td>161 ± 8‡</td>
<td>169 ± 11</td>
</tr>
<tr>
<td>Training men and women (n = 20)</td>
<td>154 ± 4</td>
<td>148 ± 5‡</td>
<td>150 ± 4</td>
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<td><strong>LDL-C</strong></td>
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<tr>
<td>Control men and women (n = 12)</td>
<td>102 ± 13</td>
<td>89 ± 9</td>
<td>94 ± 10</td>
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<tr>
<td>Training men and women (n = 20)</td>
<td>84 ± 5</td>
<td>82 ± 6</td>
<td>79 ± 5</td>
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<td><strong>HDL-C</strong></td>
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<tr>
<td>Control men (n = 7)</td>
<td>47 ± 3</td>
<td>46 ± 3</td>
<td>50 ± 3</td>
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<tr>
<td>Training men (n = 12)</td>
<td>47 ± 3</td>
<td>45 ± 2</td>
<td>44 ± 3</td>
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<tr>
<td>Control women (n = 5)</td>
<td>50 ± 6</td>
<td>58 ± 7</td>
<td>53 ± 4</td>
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<tr>
<td>Training women (n = 8)</td>
<td>58 ± 6§</td>
<td>58 ± 5§</td>
<td>56 ± 5§</td>
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* Values are means ± SD.
† Significantly greater than respective value for training group.
‡ Significantly less than the pre value.
§ Significantly greater than respective value for control group.

Strength Measurements. Maximal dynamic strength was assessed at the beginning and end of the study and every 2 weeks during the training. As has been previously reported (39), maximal dynamic strength significantly increased for all three lower limb exercises after 4 weeks of training for the men. For the women, maximal dynamic strength significantly increased after 4 weeks of training for the squat and leg extension and significantly increased after just 2 weeks for the leg press. For both sexes, relative strength continued to increase throughout the study such that the maximal strength measured during the last week of training was significantly greater compared to all previous weeks (39).

Lipid and Lipoprotein Concentrations. Because there were no gender differences for the levels of TG, TC, and LDL-C, these data sets were analyzed in two groups (control and training) and gender was ignored. For TG, the control group (control men + control women) had significantly higher levels compared to the resistance training group (training men + training women) (Table 2). No differences were found either over time or between groups for LDL-C. TC was significantly lower for both the control and training groups at the midpoint compared with their respective pretreatment measurements (Table 2). However, the mean TC value obtained at the end of the study was found not to be different from the pretreatment value for either the training or control groups. There was a significant gender difference for HDL-C. Values obtained for the resistance training women were significantly higher at all three time points compared with
Resistance Training and Serum Lipid and Lipoprotein Concentrations

Discussion

One factor that appears to play an important role in exercise-induced alterations in lipid profile is the ability to affect changes in lipoprotein metabolism. Skeletal muscle lipoprotein lipase (LPL), which is located on the intraluminal surface of the capillaries within the muscle (36), is involved in the hydrolysis of triglyceride-rich lipoprotein particles in the plasma and the formation of HDL2-C (34). The primary HDL-C particle is produced in the liver and intestine. After entering into the circulation, HDL-C is immediately transformed into HDL3-C, which is subsequently transformed into HDL2-C following the hydrolysis of TG-rich particles in the plasma by LPL (33). As such, increases in lipoprotein lipase activity result in increased TG breakdown and extraction and HDL2-C production. It is therefore not surprising that endurance training, which causes skeletal muscle to increase its oxidative capacity (i.e., causes increases in capillarization and enzymes of aerobic-oxidative metabolism), results in higher LPL activity and has a favorable influence on lipid profile (17, 25).

Although some resistance-training studies have reported improvements in lipid profiles for both men and women (2, 10, 13, 30, 42, 52), it is not clear if this is the result of an acute effect, subject selection, or an adaptation from training. Indeed, Wallace et al. (48) demonstrated a favorable acute modification in lipoprotein profile (increased HDL-C and decreased TC levels) 24 hours after a 90-minute resistance exercise session, which returned to baseline by 48 hours. In the present study, care was taken to ensure that all blood samples were drawn at least 36–48 hours following the last training bout. Subject selection may also influence the effects of training on lipid profile. It is obvious that individuals at risk for CHD (i.e., with an unfavorable lipid profile) may show an improvement regardless of the type of training stimulus. In support of this, training studies using middle-aged men at risk for CHD have demonstrated a beneficial effect of resistance training on lipid profile (2, 13, 42). However, resistance training may result in specific adaptations that could potentially contribute to improvements in lipid and lipoprotein concentrations and lower the risk for CHD even in young individuals.

Although lifting weights expends far fewer calories compared with endurance training, a significant decrease in percent body fat has been demonstrated previously (41) and in the current investigation. A decrease in the percentage of body fat has been reported to favorably influence lipid profiles (38, 51). Likewise, resistance training can potentially improve the oxidative capacity of skeletal muscle via an increase in the activity levels of specific enzymes of aerobic-oxidative metabolism (49), fiber type conversions from the low-oxidative type IIB fibers to the moderate-to-high oxidative type IIA fibers (39–41), and an increase in capillaries per fiber (27). Such favorable muscular adaptations may offset unfavorable adaptations, e.g., decrease in the slow fiber type area. Tikkanen et al. (45, 46) have demonstrated an association between muscle fiber type distribution and serum HDL-C levels. Individuals with a higher percentage of slow, type I fibers have a higher concentration of HDL-C (46). This makes sense when considering that, in human skeletal muscle, slow fibers have the highest oxidative potential and greatest number of capillaries per fiber (49). Because resistance training is known to have a greater hypertrophic effect on fast fibers (44), the resulting decrease in the percentage area occupied by the slow fibers may therefore unfavorably alter the lipid profile. Indeed, analysis of the vastus lateralis muscle from individuals in the present study (9) revealed a tendency for the percentage of type I fiber area to decrease with training—the fast fibers hypertrophied twice as much as the slow fibers for the women (IIB 22.6%, IIA 11.3%), with a less dramatic difference for the men (IIB 19.6%, IIA 18.7%, I 16.7%). The potential deleterious effect of increasing the fast fiber type area may, however, be offset by an increase in local muscular endurance (increases in oxidative capacity of all fibers combined with a type IIB to IIA transformation) and decrease in percent body fat.

Relatively few studies have investigated the effects of resistance training on skeletal muscle in women. However, data from our laboratory suggest that women appear to tolerate and adapt to high-intensity resistance training in a manner similar to men (39–41). This appears to include the effects of resistance training on lipid and lipoprotein concentrations. Although in the present study the training women had significantly higher levels of HDL-C compared with the men (training and control) and the control women, no change was detected over time in lipid profile for either the men or women after 8 weeks of resistance training. Higher concentrations of HDL-C are commonly found in women compared with men and appear to relate to the protective effects of estrogen (5). Of the few published studies investigating the effects of resistance training on lipid profile in women, most have been cross-sectional in design. Elliot et al. (5) compared the blood lipid values between female bodybuilders and runners and found no differences. However, the bodybuilders in their study were also involved in aerobic training and no control group was used. Morgan et al. (31) compared the serum lipid profiles of women runners, weight lifters, and controls and found no difference between the lifters and controls, but the runners had higher HDL-C values com-
pared to the other two groups. Last, Moffat et al. (30) investigated the effects of anabolic steroids on lipoprotein profiles of female weight lifters and found significantly higher levels of HDL-C in nonusers compared to controls. In one of the few training studies using female subjects, Goldberg et al. (10) reported a significant decrease in TC, LDL-C, and TG in women after 16 weeks of resistance training. However, no control group was used.

One of the most consistent and dramatic findings published on anabolic-androgenic steroid use is its effect on lipid profile. Anabolic steroids have been shown by a number of studies to cause extreme adverse alterations in lipid profile, including increases in the levels of TG and LDL-C and a decrease in HDL-C in both men (3, 8, 14, 18, 21, 23, 50, 54) and women (30). HDL-C appears to be most affected, dropping from a normal level of approximately 45–60 mg·dl⁻¹ to almost undetectable levels of 2–11 mg·dl⁻¹ (8). Although these adverse effects are apparently reversible (8), as long as an individual remains with such low levels of HDL-C, they are at risk for premature atherogenesis. This is true even if the individual may have low TC levels. Although not measured in the present study, the normal ranges for lipid and lipoprotein concentrations for the men and women in the present study suggest that none of them was using anabolic-androgenic steroids.

In conclusion, short-term, high-intensity resistance training appears to have little or no effect on lipid and lipoprotein concentrations in both young men and young women. This is apparently true even though dramatic skeletal muscle adaptations (hypertrophy and type IIB to IIA fiber conversions) have taken place. Thus, although resistance training may increase local muscular endurance, lipid profile remains unchanged. Conversely, resistance training does not appear to adversely influence serum lipid and lipoprotein concentrations and thus should not increase the risk for CHD. It must be emphasized that the training program used in the present study was of short duration, low volume and frequency, and utilized moderate to heavy resistance. A training program of longer duration and increased frequency may have resulted in favorable changes in the lipid profile.

**Practical Applications**

Endurance exercise has been shown to effectively alter blood lipid profiles and is thought to lower the risk for CHD. However, data gathered from various resistance training studies, although equivocal, appears to indicate that strength training has little or no effect on blood lipid and lipoprotein concentrations in individuals not at risk for CHD. The present investigation supports these previous resistance training studies. No significant change in the various blood lipid parameters (HDL-C, TC, LDL-C, and TG) occurred after 8 weeks of high-intensity weight training in either young men or young women. Although it can be argued that the training program was of short duration, significant changes were elicited in body composition (decreased percent body fat) and within the thigh musculature (hypertrophy and type IIB to IIA fiber type transformations) that could have an impact on lipid profile. It is not known if a longer duration training period would have resulted in alterations in the lipid profile. More research utilizing young individuals is needed to answer this question.

**References**


**Acknowledgments**

We wish to thank Dr. Jeffrey Falkel for assisting with the blood collection. Also, a very special thanks goes to all the men and women who volunteered for this study. This study was supported, in part, by a grant from the National Strength and Conditioning Association.