ACUTE EFFECTS OF RESISTANCE TRAINING ON SERUM LIPIDS

by

Mike Conley

HONOR'S THESIS
BALL STATE UNIVERSITY
12/10/90
exercise bout (mean ± SE-- pretest= 174± 34 mg/dL; 30
min. post= 145± 25 mg/dL; 24 hr. post= 124± 14 mg/dL;
48 hr. post= 113± 12 mg/dL). A subset of subjects with
TG>150 mg/dl (n=4) exhibited a 44% decrease (mean ± SE-
pretest= 249± 39 mg/dL to 48hr. post= 140± 8 mg/dL) in
TG (p=.06). While no significant changes were seen in
TC or HDL, these data indicate that resistance training
tends to acutely lower elevated TG. Further study of
acute lipid changes after resistance training is
warranted to evaluate modification of CHD risk.
INTRODUCTION

Coronary heart disease (CHD) is the leading cause of death in the United States (2). Research has shown that abnormal lipid levels in the blood, particularly cholesterol transporting lipoproteins (high-density lipoproteins, or HDL's and low-density lipoproteins, or LDL's) are risk factors for CHD (17). The positive effect of endurance-type exercise (aerobic exercise) on blood lipoprotein levels and profiles has been well established (1). However, the research that has been conducted to determine the relationship between strength-type exercise (anaerobic or resistance exercise) on blood lipoprotein levels and profiles is inconclusive. Several studies have shown no benefit as a result of a strength training program (14, 7, 8, 4). While other studies have shown significant benefit (12, 10, 13, 22). These contradictory results may be due to the acute effect of strength training on blood lipoproteins. However, little research has been done to show what this effect may be. Therefore, the purpose of this study was to determine the acute effects of resistance training on serum lipids. Once this is established it will be possible to better determine the validity of long-term studies and their true effects on
blood lipids. Because abnormal blood lipid levels are risk factors for CHD, the information gained from this study will make it possible to better evaluate the effectiveness of exercise programs for those individuals who are exercising with the intent of lowering their risk of developing CHD. This knowledge will also be useful to those in the scientific community who may wish to incorporate these findings into other studies and to those people who are responsible for fitness programming at such places as hospitals and YMCAs. Depending on the results, it may allow for more variety of exercise to be performed without sacrificing the beneficial effects on blood lipids already seen with endurance exercise. This may help promote long-term compliance with exercise programs while still effectively controlling some of the risk factors associated with the development of CHD.

Even though little research has been done to show the acute effects of strength training on blood lipids, several studies have been conducted to demonstrate the acute effect of endurance exercise on blood lipid levels and profiles. Studies conducted by Lithell et al. (16), Swank et al. (20), Berger et al. (3), and
Skinner et al. (18) have shown beneficial (e.g., increases in HDL’s and decreases in total cholesterol and triglycerides) acute effects of endurance training on blood lipids. It was hypothesized that similar results will be seen following a bout of resistance training.
REVIEW OF LITERATURE

Much research has been conducted to demonstrate the beneficial effects of regular aerobic exercise on blood lipid levels and high-density lipoprotein (HDL) to low-density lipoprotein (LDL) ratios. However, in comparison, little has been done to show the relationship between resistance training and lipid levels and profiles. The research that has been done in this area is not conclusive. This research tends to fall into two distinct categories: those that find no change in blood lipid profiles and those show limited improvements in blood lipid profiles. None of the studies looked at found adverse effects on blood lipid levels as the result of resistance training except for those studies that involved the use of anabolic steroids (8, 12, 15).

Many of the studies examined found no significant change in blood lipid levels and profiles. One such study was conducted by Kokkinos et al. (14). In this project, 37 healthy untrained males (average age 21) were studied. All of the subjects were non-smokers and none used any medication known to alter lipid metabolism. None had engaged in a regular exercise
program for at least 3 months prior to the study. After preliminary testing, the subjects were divided into three groups: the low-repetitions, heavy resistance (LR) group (4-5 repetition maximum (RM)); the high-repetitions, low resistance (HR) group (14-16 RM) and the non-exercising control group. The subjects in both exercise groups trained 3 times/wk on non-consecutive days for 10 wks. The rest interval between sets was 60-80 sec. for the LR group and 30-40 sec. for the HR group. Subjects were provided with instructions and forms upon which to record their daily diets for a period of 7 days prior to pre-training blood sampling. All subjects were asked to abstain from alcohol consumption for at least 3 days prior to blood drawing. This diet was replicated prior to post-training blood sampling. Only those subjects (n=37) whose food records indicated that they did not deviate from their initial 7-day dietary record were used in the study. After a 12-14 hr. fast, blood was drawn both before and after exercise. After training, blood samples were taken approximately 24 and 72 hr. following the last training session. Neither training group showed any significant changes in blood lipid levels or profiles.
Another study that found no significant changes in blood lipid levels as a result of resistance training was conducted by Fang et al. (7). Fifty-seven men (age range from 21 to 44 yrs.) were studied. None were smokers, or taking drugs known to influence lipid metabolism; alcohol intake of all subjects was limited to not more than 2 oz./wk. No other dietary screening restrictions were placed on the subjects and nutritional analyses were not performed on individual diets. Subjects who had been running an average of 35 miles/wk., or who were engaged in intensive cycling or swimming, for at least 6 months prior to the study were considered to be endurance trained (ET); 19 subjects met this criteria. Nineteen men who were weight training intensely at least 3 days/wk. for 6 or more months prior to the study and who were not engaged in regular aerobic training comprised the strength trained (ST) group. Of the 19 men in this group, 16 followed a typical circuit training or body-building routine utilizing moderate workloads and high repetitions during training sessions; the remaining three subjects were powerlifters utilizing high workloads and few repetitions per exercise. The other 19 men in this study were age-matched sedentary (SED) controls who
were not engaged in any form of regular physical exercise. On two separate occasions following this initial data collection, subjects were asked to report for blood sampling in the morning following a 12 hr. fast and 48 hr. after their last bout of exercise. While total cholesterol varied little between the ET and ST groups, the ET group had a higher concentration of HDL's in the blood than the ST and SED groups.

A study conducted by Farrell et al. (8) also found no significant changes in blood lipid levels or profiles as a result of resistance training. In this study the subjects were divided into 3 groups. Group I consisted of 11 men (average age 22) who had not participated in any individual or group training program for at least six months prior to being studied. Group II consisted of 11 well-trained weightlifters (average age 28) who had trained continuously for several years. Their training consisted of heavy resistance, short-duration exercise using barbell and dumbell lifts. The training questionnaire revealed that none of the 11 lifters had trained aerobically during the six months prior to the study. Group III consisted of 11 candidates (average age 21) for the 1980 U.S. Olympic Speed Skating Team. The subjects in
Group III were in the final phases of preparation for the Olympics and were considered to be in a high state of training specific to speed skating. The endurance component of their training consisted of running, distance skating and cycling. The anaerobic component consisted of weight training, hill running and sprint intervals on the ice. Because of the two different types of training, the subjects in group III were considered to be highly conditioned both aerobically and anaerobically. Groups were similar with respect to diet, smoking and alcohol consumption. Blood was obtained after a 12-16 hr. fast. Mean HDL was similar in the non-athletes and weightlifters, but was significantly higher in the speed skaters. The total cholesterol/HDL ratio was significantly higher in the weightlifters. From this information, it appears that extensive weight-training, in contrast to endurance training, does not increase blood HDL.

Another study that found no significant change in blood lipids from resistance training was performed by Clarkson et al. (4). In this study, 51 males (average age 22) participated as subjects. They were classified into the following 3 categories: 6 trained distance runners who had been involved in competitive running
for several years and were averaging 70 miles per week; 28 weight trained athletes who had been lifting free weights on a regular basis (minimum of three times per week) for at least one year and 17 untrained subjects who were not participating in any regular endurance or strength exercise program. Dietary questionnaires completed by all subjects showed that dietary habits were similar. From the questionnaire, it was determined that alcohol use was moderate, no subject was taking medication or drugs and none were smokers. A blood sample was obtained from each subject following a 12 hr. fast. The results showed that the runners had considerably lower total cholesterol and higher HDL compared to weight lifters and controls. There was little difference between the weight-lifting group and control group.

The results of these studies indicate that there is no significant change in blood lipid levels or profiles as a result of resistance training. However, three of the studies examined were cross-sectional studies, not actual training studies. Cross-sectional are beneficial in showing general trends that exist in a population, but it is difficult to determine whether the results shown were from resistance training or from
other differences that may have existed between the groups. Several other studies have shown that there may indeed be some beneficial effects on blood lipids levels from resistance training.

In a study conducted by Hurley et al. (12) it was found that the training regimen of bodybuilders is associated with a more favorable lipid profile than the training used by powerlifters. In this study, 24 healthy men were studied (average age 30). There were 8 moderately to well-trained runners, eight competitive body-builders (BB), and eight competitive powerlifters (PL). Responses to questionnaire indicated that all BB and PL engaged in a regular exercise program (4-5 times per week) of high-intensity weight training for at least three years before the study; however, the training regimens of the BB and PL differed considerably. The exercise program of the BB consisted of weight training involving primarily moderate resistance and high repetitions (10-20), while the PL trained using exercises of the heavy-resistance and low-repetition type (1-5). The rest intervals between exercise bouts were much longer for PL than BB. The runners trained five days each week and averaged 8-11 km per 40-45 minute training session. None of the
runners strength trained. For all of the subjects, blood sampling, diet-histories and recalls, and other data were collected on the morning after a day of training. None of the subjects smoked cigarettes or consumed any alcohol in the three days before testing. No subject was on a special diet, or took medications. The data from the questionnaire and 24-hour dietary recalls indicated that both groups of weight-trained athletes tended to eat high-protein (approx. 20% of calories), high-fat (approx. 45-50% of calories), and low carbohydrate (approx. 30-35% of calories) diet. Runners and controls tended to eat diets that were higher in their carbohydrate content (approx. 45-50% of calories) and lower in their fat content (approx. 30-35% of calories). After a 12-14 hr fast, blood was drawn and analyzed. Results of this showed that there was no significant difference in total cholesterol levels among PL, BB, runners, and controls. However, HDL levels were considerably lower in the PL than in the BB, runners, and controls. Also, PL demonstrated a much lower HDL/LDL ratio. This difference may be partially the result of diet differences in comparison with the runners and controls. However, when comparing the PL to the BB there no significant difference in
diet. Because of this, the resulting difference in blood lipid profiles may be because of the different training programs; with the regimen associated with the BE producing the more favorable influence on blood lipid levels and profiles.

In another study, conducted by Goldberg et al. (10), it was also found that resistance training may produce favorable results on blood lipid levels. Eight women (average age 27) and 6 men (average age 33) participated. None took medications, smoked cigarettes, or had engaged in endurance or weight training in the preceding six months. A dietary questionnaire and exercise history were completed before participation and at the conclusion of the study. Morning blood samples after a 12 hr. fast were obtained at the beginning and end of the 16 weeks of training, at least 36 hours after an exercise period. Subjects participated in a 16-week exercise program of progressive resistance weight training and exercised 3 times each week, on non-consecutive days. The duration of each session was 45-60 minutes. Training consisted of 3 sets for each of the individual exercises. Each exercise set was continued until a subject could not complete an additional repetition. No less than 3 or
no more than 8 repetitions were allowed for each training set. If a subject could lift a training weight eight consecutive times the resistance was increased. A maximum rest period of two minutes was allowed between sets. The women demonstrated a 9.5% reduction in total cholesterol, 17.9% decrease in LDL cholesterol, and a 4.8% increase in HDL cholesterol. The men demonstrated a 6.8% reduction in total cholesterol, 16.2% decrease in LDL cholesterol and a 15.8% increase in HDL cholesterol.

Similar results were also demonstrated in a study by Hurley et al. (13). Eleven untrained males (average age 44) volunteered to be studied before and after training. A group that did not train, consisting of 10 untrained males (average age 52) underwent the same evaluations as the training group to serve as controls. None of the subjects included in this study had any signs of coronary heart disease (CHD). All of the subjects were non-smokers and none were using any medications known to alter carbohydrate or lipid metabolism. The subjects kept food records for 3 days preceding the drawing of their initial blood samples. They were also asked to keep food records for the 3 days preceding the drawing of blood samples at the end
of the study; they were given copies of their food records from the start of the study and were asked to duplicate their diet as closely as possible. The subjects trained 3-4 times/week for 16 weeks. During each workout, subjects performed one set of 14 different exercises, including 4 lower-body exercises and 10 upper-body exercises. 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. Subjects were also encouraged to move as quickly as possible to the next machine after completing an exercise; less than 15 seconds elapsed between exercises. This type of resistance training is somewhat aerobic in nature as it maintains an elevated heart rate throughout the duration of the exercise session. At the end of the training program the subjects showed a 5% drop in LDL levels and a 10% increase in HDL levels. Total cholesterol was not altered by training.

A further study that indicated that resistance training may improve blood lipid levels was conducted
by Ullrich et al. (22). Twenty-five subjects donated fasting blood samples before and after the 8 weeks training program. Subjects were randomly assigned to one of the following 4 groups: endurance group- 2 sets of 15 RM (repetition maximum), explosive group- 1 set of 15 RM, as quickly as possible, strength I - 3 sets of 6 RM, and strength II - 1 set of 10 RM two days per week and one set of 3 RM one day per week. Blood samples were drawn within 1 week before and after completion of weight training, and at least 48 hrs. after exercise. Considering all groups together, there was a significant increase in HDL-cholesterol, but total cholesterol remained unchanged. The most dramatic increases in HDL-cholesterol occurred in the endurance and strength I groups.

From these different studies it is obvious that there is inconclusive evidence of the effects of resistance training on blood lipid levels and profiles. There are many different parameters in each study that could directly effect the results. These need to be taken into consideration when evaluating the studies and may be partially responsible some of the discrepancies in their findings. These parameters include: normal variations of lipoproteins, changes in
plasma volume following exercise, when the blood samples were taken, postural control during blood sampling, type of chemical assay used, rest between sets, number of sets, number of repetitions, relative intensity of training, outside activity level of subjects during the experiment, use of medications that alter lipoprotein-lipid metabolism, age, sex prior level of conditioning, body composition, dietary changes, initial lipoprotein-lipid levels, and medical history of the subjects. Also, as in most research, the number of subjects was limited and it is difficult to determine if the subjects were truly representative of the population. However, even though some of these parameters were controlled for in the same manner in different studies, the results were still sometimes contradictory. Because of this, the effects of resistance training on blood lipid levels and profiles cannot be conclusively determined. This shows the need for further studies to accurately determine the effects of resistance training on blood lipids.

However, it is necessary to understand the acute effects of resistance training on serum lipids before it can be determined if the results seen in a long term study are accurate. Currently, the amount of
information available on the acute effects of
resistance training on blood lipids is severely
limited. However, several studies have been conducted
to show how endurance training acutely affects blood
lipids.

One such study was conducted by Lithell et
al. (16). This study looked at the changes in blood
lipids that resulted in 16 young men from prolonged
physical activity. It showed that immediately after
exercise HDL levels had increased from 40.5 mg/dL to
48.3 mg/dL. However this value returned to the
pre-trained level 24 hours following exercise. This
study also showed the serum triglyceride levels had
decreased 50% immediately after exercise and remained
at that level for at least 1 day following exercise.
Three to five days later this value was close to
pre-trained levels.

Another study that looked at the acute changes of
blood lipids as a result of endurance exercise was
performed by Swank et al. (20). In this study 9 females
were subjected to a 40 minute run on a treadmill at
approximately 70% of $V_{O_2} \text{ max}$. Blood samples were taken
before exercise and again at 5 minutes, 24 hours, 48
hours, and 96 hours following exercise. Results showed
an increase of 4.5 mg/dL of HDL's 5 minutes after exercise. This increase fell to 1.5 mg/dL 24 hours after exercise and to 0.1 mg/dL 48 hours after exercise. However, when measured 96 hours after exercise this HDL value was back to a 2 mg/dL increase. Triglyceride levels increased 18.1 mg/dL 5 minutes following exercise, but fell to 6.6 mg/dL below that of the pre-exercise value when measured 24 hours after exercise. These values remained below the pre-exercise level by 5.3 mg/dL when measured 48 hours after exercise and by 2.7 mg/dL when measured 96 hours after exercise.

Results similar to these studies were also seen in other studies (3, 17, 6, 21).

One study was found that examined the acute effects of resistance training on blood lipids (23). Ten male subjects (average age 25.4 years) were studied before and after 90 minutes of resistance exercise to determine the acute effects of both high volume (HV) and low volume (LV) regimens on lipid and lipoprotein levels. The HV exercise bout involved the use of 8-12 RM loads with 60 seconds of rest between sets. The LV regimen involved the same exercises at 1-5 RM with 3 minutes rest between each set. Blood samples were
taken immediately before and after exercise as well as 24, 48, and 72 hours post-exercise. When compared to the pre-exercise values, HV resistance exercise produced a 14% increase in triglycerides and 5% increase in HDLs immediately post-exercise. The HV exercise also showed a delayed increase in HDLs of 9% and a 12% decrease in triglycerides. The LV group showed no significant changes in any of the blood lipid or lipoprotein values analyzed.

The results from this study indicate that volume of exercise performed may be critical in determining the potential of resistance training to acutely change blood lipids. However, much more research is necessary before any conclusions can be made concerning resistance trainings acute effects on blood lipids.
METHODOLOGY

Subjects. Eight volunteers were recruited from the Ball State University community to participate in this research project. Individuals had the following characteristics to qualify for the study: in good health (as determined by Health History Questionnaire and following the guidelines established by the American College of Sports Medicine for contraindication to exercise); non-smokers; taking no medications that influenced blood lipid metabolism; and were accustomed to resistance exercise training. All subjects were males (mean age = 25.5 yrs., height = 5'11", weight = 192 lbs.). The subjects read and signed and institutionally approved informed consent form prior to beginning the study. An initial blood cholesterol screening was performed to ensure that a range of cholesterol values existed in the subject group. It was desired that subjects had TC>200 mg/dL and none were used that were <160 mg/dL.

Experimental Procedures. The study took place over a three day period. Prior to the first day of the study, subjects refrained from any vigorous physical activity for a minimum of 48 hours. On the morning of the first day subjects reported to the testing area (University Gym Weight Room) following and overnight fast of 10 hours. To prevent postural distribution effects from influencing the blood sample, the subjects sat quietly for 5 minutes before each
blood draw. Immediately after lying down a trained phlebotomist obtained a 7ml blood sample from a superficial arm vein. Subjects then "warmed-up" for the physical activity and then completed a circuit of 10 exercises on Nautilus resistance exercise equipment. Each subject completed two sets of exercise on each exercise machine that consisted of 6-10 repetitions to fatigue. The resistance setting for each machine was determined at a prior meeting between the investigator and the subject (note: all subjects already had experience with these exercises). Following the resistance training, all subjects participated in a "cool-down" activity and then had another blood sample taken 30 minutes after the completion of the last resistance exercise. Subjects then reported to the Human Performance Laboratory on the following two mornings (after an overnight fast for 10 hours) and have one blood sample taken each morning (24 and 48 hours post-training). All blood sampling and handling were done in accordance with the Universal Precautions guidelines established by the State of Indiana using appropriate aseptic and sterile techniques.

**Blood Analysis.** Blood samples were allowed to clot for 40 minutes and then centrifuged for 20 minutes. The resultant serum was stored at -80 °C. After thawing the serum, all analyses were performed on the same day in duplicate. The serum samples were analyzed for total cholesterol and triglyceride concentrations using the Reflotron analyzer (Boehringer-Mannheim Diagnostics,
Indianapolis, IN) and for high-density lipoprotein-cholesterol (HDL-C) using a Sigma Chemical Company (St. Louis, MO) diagnostic kit (an enzymatic method). After thawing the serum, all analyses were performed on the same day in duplicate. Appropriate standards and controls were used with each lipid analysis. If duplicate values differed by more than 5%, a third sample was to be analyzed. However, a third sample was not necessary for any measure in this study.

Statistical Analysis. Differences in lipid concentrations between the four samples (pre-exercise, 30-minute, 24-hour and 48-hour post-exercise) were analyzed using analysis of variance procedure with repeated measures. The significance level was set at P<0.05.
RESULTS

The variation in total cholesterol (TC) from pre-exercise values showed no significant change (Table 1). Similarly, there was no significant change in the high-density lipoprotein (HDL) subfraction (Table 1). However, the triglyceride (TG) values steadily declined following the exercise bout (Table 1). There was a 35% drop in triglycerides 48 hrs. post compared to pre-exercise values. This was not statistically significant, though, because of the large standard deviation for the pre-(96) and 30 min. post-(72) measurement.

Table 1. Changes in TC, HDL, and TG following a training bout (mean ± SD).

<table>
<thead>
<tr>
<th>Lipid</th>
<th>Pre</th>
<th>30 min.</th>
<th>24hr.</th>
<th>48hr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>TC mg/dL</td>
<td>191(23)</td>
<td>188(25)</td>
<td>193(26)</td>
<td>192(21)</td>
</tr>
<tr>
<td>HDL mg/dL</td>
<td>42.8(8.3)</td>
<td>43.4(6.5)</td>
<td>42.6(5.1)</td>
<td>42.0(4.4)</td>
</tr>
<tr>
<td>TG mg/dL</td>
<td>174(96)</td>
<td>145(72)</td>
<td>124(41)</td>
<td>113(34)</td>
</tr>
</tbody>
</table>

These changes are also depicted in Figure 1a-c.

Further analysis of the data showed that a subset of subjects with pretest TG>150 mg/dL (n=4) exhibited a 44% decrease (pre-exercise= 249(77) mg/dL to 48 hour post= 140(15) mg/dL) in TG (p=.06). The results are shown below and in Figure 2.
Figures 1a-c. Change in total cholesterol (a), high-density lipoproteins (b), and triglycerides (c) following a resistance training bout. Values are mean ± standard error.
Table 2. Change in TG following a resistance training bout of subjects (n=4) with initial TG 150 mg/dL (mean ± SD).

<table>
<thead>
<tr>
<th>Lipid</th>
<th>Pre</th>
<th>30min</th>
<th>24hr.</th>
<th>48hr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>TG mg/dL</td>
<td>249(77)</td>
<td>197(68)</td>
<td>156(27)</td>
<td>140(15)</td>
</tr>
</tbody>
</table>

Although not directly analyzed, the low-density lipoprotein (LDL) concentrations were estimated using the equation developed by Friedewald et al.:

\[ \text{LDL = TC - HDL - TG/5} \]

From this equation, the LDL levels showed a steady increase (although not statistically significant) from pre-exercise--113 mg/dL to 48 hours post--128 mg/dL. The results are shown in the table below and in Figure 3.

Table 3. Change in LDL following a resistance training bout as determined by the Friedewald formula--LDL=TC-HDL-TG/5 (mean ± SD).

<table>
<thead>
<tr>
<th>Lipid</th>
<th>Pre</th>
<th>30min</th>
<th>24hr.</th>
<th>48hr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDL mg/dL</td>
<td>113(25)</td>
<td>116(27)</td>
<td>126(23)</td>
<td>128(19)</td>
</tr>
</tbody>
</table>

All measurements were made in duplicate with no statistical difference between the 2 measures (p>.05). There was also a very low absolute difference (1diff.i= 0.3 mg/dL for TC, 0.9 mg/dL for HDL, 1.3 mg/dL for TG) and less than a 5% deviation for each duplicate measure.
Figure 2. Change in triglycerides following a resistance training bout of subjects whose initial level of TG was greater than 150 mg/dL (n=4). Values are mean ± standard error.

Figure 3. Change in low-density lipoproteins following a resistance training bout as determined by the Friedewald formula (LDL=TC-HDL-TG/5). Values are mean ± standard error.
DISCUSSION

The most noticeable acute effect of resistance training was a decrease in triglyceride levels. There was a 35% drop in triglycerides from pre-exercise to 48 hr. post. Since high triglycerides are thought to contribute to CHD development, this effect may be important in reducing the risk of CHD (11). The effect was even more dramatic in subjects with elevated levels of triglycerides. In a subgroup (n=4) of people with elevated initial triglycerides (>150 mg/dL), a decrease of 44% was observed. This approached statistical significance (p=.06). This indicates that resistance training may provide its greatest beneficial effects to people that need it the most: those with elevated initial triglycerides. These results are approximately the same as those observed in a study conducted by Wallace et al. (23). Even though their study showed an increase in triglycerides immediately following resistance training of 14%, this level dropped to 12% below that of the initial value 24 hrs. post-exercise. In this study, a drop of 31% 24 hrs. post-exercise was observed. Further comparison to Wallace's study of the acute effect of resistance training on triglycerides is not possible as only an abstract was available for review. In the present study, at 48 hr. post-exercise triglycerides were 35% lower than the pre-exercise
level and frequently these values were still decreasing. Thus, triglycerides may not have reached their minimum value. Taking blood samples until the triglycerides were at their lowest level would have been beneficial in determining the true extent to which resistance training can lower triglycerides.

Endurance exercise has also been shown to acutely lower triglycerides. A study conducted by Lithell et al. (16) showed a 50% decrease in TG immediately after exercise and remained at that level for at least 1 day following the exercise bout. Three to five days later this value was close to the pre-exercise level. Similarly, a study by Defaux et al. (6) reported a drop of 21.5 mg/dL 24 hr. post-exercise, and 13.1 mg/dL 48 hr. post-exercise.

The results from this study indicate that resistance training did not acutely alter HDL or TC levels significantly. Other types of exercise, specifically endurance training, have been shown to acutely raise HDL levels and lower TC levels. Defaux et al. (6) reported an increase in HDLs of 7% 24 hr. post-exercise and a decrease in TC of 4% 48 hr. post-exercise. Presently, the hypothesis that resistance training would produce similar beneficial changes in HDL and TC levels is unsupported.

Upon further analysis of the data, it became apparent that LDL levels steadily increased throughout
the post-exercise period (however, the change was not statistically significant). Although not measured directly, their value was estimated by using the Friedewald formula: LDL = TC - HDL - TG/5. The LDL values increased from 113 mg/dL pre-exercise to 128 mg/dL 48 hrs. post-exercise. This may be of concern to those individuals who are exercising with the intent of lowering their risk of CHD, since high LDL levels are thought to be contributing factors in CHD development (11). However, because of the mathematical formula employed, LDL values must increase whenever there is a decrease in TG levels, and HDL and TC levels are held constant (as seen in this study).

Physiologically, though, this effect is expected. When triglycerides are hydrolyzed, their remnants are high in cholesterol esters, which is the main component of LDLs (19). Because of the increased demand for energy during resistance training, triglyceride hydrolysis is increased, and thus there is a corresponding increase in the level of LDLs. Direct chemical analysis is warranted to more accurately determine the changes that occur in LDL levels following resistance training.

When interpreting the data from long-term studies on the effects of resistance training on lipoprotein-lipid profiles, it appears that the alteration in TC and HDL from the last bout of exercise training is minimal. Therefore, the contradictory results of such
studies on TC and HDL levels cannot be readily
explained by the acute effects of resistance training. 
However, these data suggest that the acute effects of 
resistance training may influence the results in such 
studies that examined TG and LDL levels. Though much 
more research is needed to verify this and before the 
extent and time considerations of the effects can be 
quantified.

Little is actually known of how resistance 
training effects lipoprotein-lipid profiles. Therefore, 
more research is needed in this area before the 
effects and mechanisms can be established. However, 
for this research to be accurate, many influences must 
be taken into consideration. One such influence is 
plasma volume.

It has been shown that exercise decreases plasma 
volume (5). Because of this, when observing a change 
in lipoprotein-lipid levels it is necessary to consider 
if the change is from an actual increase or decrease in 
the lipoprotein-lipid or the result of measurement in a 
reduced volume of plasma which would alter the 
concentration even if there was no actual change of 
lipoprotein-lipid quantity in the blood. A pilot study 
(n=2) was performed to suggest the changes in plasma 
volume that occur following a resistance training bout. 
It showed decreases in plasma volume of 7.7% 30 min. 
post-exercise, 4.5% 24 hr. post-exercise, and 5.6% 48
hr. post-exercise. If consistent, this change in plasma volume would cause the actual value for each measure to slightly increase.

Another factor that must be controlled for is relative training intensity. Different training intensities may influence the results by altering lipoprotein-lipid metabolism. In this study, the training load was set so that the subjects would not be able to complete another repetition (muscular failure) and the number of repetitions for each set were in the 6-10 RM range. Ratings of perceived exertion (RPE) were also taken immediately following each set (Borg). This method seemed to work well. However, in future studies it would be beneficial to determine each subject's 1 RM and set the load so that a certain percentage (e.g. 80%) of the 1 RM load was used until the subject reached failure and record an accompanying RPE. This technique may produce a more accurate measure of training intensity and allow for better comparison between different studies.

Many other factors also exist that may cause discrepancies in experimental results. These include: normal variations of lipoprotein-lipids, when the blood samples were taken, postural control during blood sampling, type of chemical assay used, rest between sets, number of sets, number of repetitions, outside activity level of subjects during the experiment, use
of medications that alter lipoprotein-lipid metabolism, age, sex, prior level of conditioning, initial lipoprotein-lipid levels, and medical history of the subjects. All of these factors except for normal variation of lipoproteins-lipids were controlled for in this study. In further research, it would be beneficial to control for normal variation of lipoproteins-lipids by taking more than one blood sample to determine the initial baseline values and to have a control group or control trial. Other factors such as changes in dietary habits and body composition must be controlled for in a long-term study, but would not significantly alter the results of an acute study. Also, as in most research, the number of subjects was limited and it is difficult to tell if the subjects were truly representative of the population. Despite these limitations, results from studies like this provide a good base of information for further research. Currently, because of the lack of information available, it is impossible to conclusively determine the effects of resistance training on lipoprotein-lipid profiles. However, evidence suggests that resistance training may acutely lower elevated TG. Further study of acute lipid changes after resistance training is warranted to evaluate modification of CHD risk.
REFERENCES


