Reducing-diet and exercise-training effects on serum lipids and lipoproteins in mildly obese women

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ABSTRACT
Twenty-one mildly obese women were fed a 1268-kcal lactovegetarian diet for 5 wk. Subjects were randomly divided into either an exercise (Ex) or a nonexercise (Nex) group. The Ex group walked at 60% heart-rate reserve (134 ± 2 bpm; x ± SEM) during 45-min sessions, five times per week. Although exercise improved estimated maximum oxygen consumption (VO₂,max; 20.9 ± 3.2% vs 21.7 ± 3.4% in Ex vs Nex, respectively), changes in total body, lean body, and fat weight did not differ significantly between groups. Total body weight decreased 5.5 ± 0.6 and 5.6 ± 0.2 kg in Ex and Nex, respectively. Statistical analysis revealed significant differences in the pattern of change between groups for serum high-density-lipoprotein cholesterol (HDL-C; F₁₀,₁₈ = 5.93, P = 0.006) but not for total cholesterol (TC), low-density-lipoprotein cholesterol, triglycerides, or glucose. Change in diet quality and body weight were found to account fully for the 12.7 ± 1.9% decrease in TC. When change in dietary quality and body weight are equated in a group of mildly obese women, the effect of moderate exercise training on indices of serum lipid and lipoprotein is limited to HDL-C. Am J Clin Nutr 1990;52:640-5.

KEY WORDS
Obesity, exercise, serum cholesterol, lipoproteins, reducing diet, high-density lipoprotein

Introduction
Weight loss has been associated with variable effects on the serum lipid profile. Most researchers have reported that with weight loss, total cholesterol, low-density-lipoprotein cholesterol (LDL-C), and triglycerides decrease (1–3). High-density-lipoprotein cholesterol (HDL-C) usually increases if sufficient weight is lost and maintained for several months in obese subjects (1, 4–7). When HDL-C is measured during active weight loss, however, females, in contrast to males, may experience no change or a decrease (8, 9).

Determining the independent effect of aerobic exercise training on serum lipids and lipoproteins from results from prospective studies has been difficult because of the confounding effect of concomitant changes in weight and diet (10–26). Data suggest that aerobic exercise training is independently related to increases in HDL-C, with variable effects on triglycerides and little or no effect on total cholesterol and LDL-C (3, 10, 12, 13, 18). Females, however, may experience a smaller degree of improvement in HDL-C than do males unless the females exercise a great deal (19–24).

Few researchers, however, have examined these relationships under strict dietary control (18, 24). Changes in diet have been associated with marked changes in all of the serum lipoprotein and lipid indices (25). Some of the reported changes in these indices that have been ascribed to weight loss and exercise may instead be more directly related to dietary changes (9, 18, 26). In addition, in many studies sedentary control groups have been absent or not randomly assigned (3, 11, 15, 19–22, 24).

The purpose of this study was to examine the independent effects of aerobic exercise training and weight loss on changes in the blood lipid profile in a group of mildly obese women who were randomly divided into exercise and nonexercise groups while under stringent dietary control.

Subjects and methods
Subjects
Approximately 100 women responded to advertisements for the study in local newspapers. Of these, 24 nonsmoking, premenopausal subjects were selected according to the following criteria: 1) mildly obese, defined as 20–40% overweight; 2) free of existing medical problems that might prevent them from exercising; and 3) not presently on a reducing diet or exercise program. All subjects voluntarily signed an informed consent statement approved by the Loma Linda University Institutional Review Board for Human Studies, which also approved the study’s procedures.

Experimental design
Complete 7-d diet records were kept by all subjects before the 5-wk diet-and-exercise treatment phase began. Baseline and posttreatment tests included measurement of body composition, maximal treadmill performance, and serum total cholesterol, triglycerides, LDL-C, and HDL-C. The serum val-

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ues were also measured after 2 wks of treatment for both groups. Two-week and 5-wk measurements were obtained 48 h after the Friday-morning exercise session in subjects who had fasted for 12 h.

After baseline testing, subjects were randomly divided into either an exercise (Ex) or a nonexercise (Nex) group. For 5 wk all subjects were fed a 1268 kcal diet, and the Ex group also followed a structured exercise program. The Nex group was instructed not to participate in any exercise besides normal daily activity.

Diet and exercise program

For 5 wk all subjects were fed a 1268-kcal lactovegetarian diet with meals rotated on a 3-d cycle. The food was prepared, weighed, and served in the Loma Linda University Nutrition Research Kitchen. This diet had 51% of total calories as carbohydrate, 30% as fat, 19% as protein, and did not contain alcohol or caffeine. It provided >67% of the US recommended dietary allowances (RDAs) for all nutrients; the calorie level was chosen in accordance with dietary recommendations that have been published for mildly obese subjects (27). All subjects were instructed that no other food was to be eaten during the 5-wk study. Subjects kept personal diaries wherein they were instructed to report any additional food consumed. Five evening group sessions were held each week during the study to encourage compliance and to educate the subjects in nutrition and exercise principles.

During the 5-wk treatment phase, the Ex group followed a closely supervised walk-jog program. This entailed five 45-min early-morning sessions each week at an intensity of 60% heart rate reserve (heart rate 134 ± 2 bpm). To ensure that the subjects exercised at a proper intensity, heart rates were monitored by checking pulse rates every 0.8 km. After 45 min, the supervisor recorded the subjects’ walking distance to the nearest 0.16 km. Gross energy expenditure was 320 kcal/session, as determined by the American College of Sports Medicine formula for walking (28).

Body composition and treadmill testing

Body density was determined by hydrostatic weighing, as outlined by Pollock et al (29), by use of Siri’s formula (30) for determining percentage of body fat. For the four subjects who experienced difficulty with the hydrostatic-weighing procedure, body composition was estimated by a three-site skinfold-thickness test according to the procedure of Pollock et al (29). Residual volume was measured by the closed-circuit helium-dilution method (31) with a 13.5-L respirometer (Warren E Collins, Inc, Braintree, MA).

Twelve-lead electrocardiograms (EKGs) were obtained during rest and during the maximal treadmill test. The Bruce treadmill protocol was used, with maximum oxygen consumption (VO2max) estimated from the equation of Foster et al (32).

Diet records

All subjects kept 7-d food records starting 2 wk before treatment began. Written and verbal instructions for keeping these records were given by a nutritionist. Baseline and treatment diets were analyzed by use of Nutritionist III (N-Squared Computing, Silverton, OR), a computerized diet-analysis program with a database of > 1800 foods, primarily based on the revised Agriculture Handbook No. 8 (33). Food records were coded and data were entered into the computer by one nutrition graduate student. Food items not included in the database were substituted with a similar food item of comparable nutrient content or broken down by ingredients. Recipes supplied by the subjects were also analyzed by ingredient, or a composite food item was substituted when appropriate.

Blood analysis

Serum glucose, total cholesterol, and triglycerides were measured by use of the Technicon SMAC II System (Technicon Instruments Corp, Tarrytown, NY). Quality-control tests were conducted every 10 serum samples. LDL-C was calculated with the following equation:

\[
LDL-C = \text{total cholesterol} - [\text{HDL-C} + (\text{total triglycerides}/5)]
\]

according to the method of Friedewald et al (34). HDL-C was measured by the electrophoresis method with the Corning Densitometer-720 (Ciba-Corning Diagnostics Corp, Palo Alto, CA) in accordance with the procedures of Hulley et al (35). Control samples were tested each time a gel was run.

Statistics

Results are expressed as \( \bar{x} \pm \text{SEM} \). A 2 × 2 or 2 × 3 repeated-measures analysis of variance (ANOVA) with one between-subjects factor (Ex vs Nex) and one within-subject factor (time of testing) was used to analyze the data. When Box’s M suggested that the assumptions necessary for the univariate approach were not tenable, the multivariate approach to repeated-measures ANOVA was used (36). In the latter case, Pillai’s trace statistic was used as the test statistic. The Dunn-Sidák procedure (37) was used to test between- and within-subject multiple comparisons. Pearson correlations were used to determine the association between certain variables, as noted in the Results section. Comparison between groups for age, weight, height, body mass index (BMI) (kg/m²), and percent body fat were evaluated by simple univariate t tests.

Results

Subjects

Characteristics of the subjects are given in Table 1. Age, weight, height, and percent body fat did not differ significantly between groups. BMI averaged 29.7 ± 1.0 and 30.1 ± 1.4 in the Ex and Nex groups, respectively, indicating mild obesity (27).

Of the initial 24 subjects selected, three dropped out for personal reasons within the first week of the treatment period, which resulted in 21 subjects (88%) completing the study. All 21 subjects adhered strictly to the treatment-diet program and each of the 11 subjects in the Ex group completed the 5-wk exercise program.

Body composition and treadmill data

The body composition and treadmill data were considered in more detail elsewhere (38). Briefly, the pattern of change in total body, lean body, and fat weight was not significantly different between groups. Weight loss averaged 5.5 ± 0.6 kg for the Ex group and 5.6 ± 0.2 kg for the Nex group, which accounted for 7.1% and 6.5% loss of original weight, respectively. Of this weight loss, 90% was due to loss of fat weight and only
10% to the loss of lean body weight in both groups. Mean residual volume was determined to be 1.40 ± 0.06 L in the Ex group and 1.57 ± 0.10 L in the Nex group. After 5 wk of training, the Ex group showed a strong improvement in treadmill performance, with an increase in estimated VO\textsubscript{2max} of 20.9 ± 3.2% (from 24.7 ± 0.8 to 29.7 ± 0.8 mL·kg\textsuperscript{-1}·min\textsuperscript{-1}), in contrast to a slight decrease (2.1 ± 3.4%) in the Nex group (from 25.6 ± 1.0 to 25.0 ± 1.1 mL·kg\textsuperscript{-1}·min\textsuperscript{-1}) (F\textsubscript{11,181} = 26.17, P < 0.001). These data are supported by the significant decrease in heart rate during the second stage of the treadmill test in the Ex group (from 160 ± 4 to 151 ± 4 bpm) as compared with the Nex group (162 ± 3 to 166 ± 3 bpm) (F\textsubscript{11,181} = 17.08, P = 0.001).

**Diet**

Details of the 7-d diet records taken at baseline and actual treatment diet consumed are shown in Table 2. The two groups did not differ significantly in any of the major nutrients at baseline. The treatment diet represented a 32.6 ± 4.8% and 40.4 ± 3.3% decrease in total kilocalories (based on 7-d food records) for the Ex and Nex groups, respectively. The protein content of the treatment diet remained at the pretreatment level. The treatment diet contained half the grams of saturated fatty acids and ~70% less dietary cholesterol than did the pretreatment diet.

**Blood analyses**

Table 3 shows that the pattern of change between groups during the 5-wk study did not differ significantly for serum glucose, triglycerides, total cholesterol, or LDL-C. For HDL-C, both groups experienced a significant decrease from baseline to 2 wk, but the decrease was less in the Ex than in the Nex group (−13.9 ± 2.3% vs −26.0 ± 1.4%, respectively). By 5 wk, the Ex group returned to pretreatment concentrations whereas the Nex group was 9.3 ± 2.2% below initial values. Figure 1 shows that the higher HDL-C concentrations in the Ex group resulted in a significantly lower ratio of total cholesterol to HDL-C (TC/HDL-C) at 5 wk for the Ex group, with a significantly different pattern of change overall compared with the Nex group (F\textsubscript{2,8} = 4.93, P = 0.012).

The patterns of change over time for glucose, total cholesterol, and LDL-C were very similar for both groups, with significant decreases compared with baseline values seen at both 2 and 5 wk for each variable in each group. For all subjects combined, glucose decreased an average of 10.3 ± 1.7% by 2 wk and 4.5 ± 1.1% by 5 wk; for total cholesterol, decreases were 16.5 ± 1.7% by 2 wk and 12.7 ± 1.9% by 5 wk; for LDL-C, decreases were 12.6 ± 2.7% by 2 wk and 13.5 ± 3.2% by 5 wk compared with baseline values. Although the decrease in triglycerides was greater in the Ex than the Nex group at both 2 wk (−34.3 ± 5.7% vs −11.2 ± 9.5%) and 5 wk (−31.9 ± 7.9% vs −14.4 ± 8.2%), subject response varied widely in both groups (from −46% to 66% at 2 wk and from −26 to 65% at 5 wk).

Figure 2 summarizes the predicted effects of change in diet quality and body weight on serum total cholesterol. The revised

### Table 1

**Characteristics of subjects, by group**

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Exercise (n = 11)</th>
<th>Nonexercise (n = 10)</th>
<th>Effect (group × time)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>37.1 ± 1.2</td>
<td>38.0 ± 2.0</td>
<td></td>
</tr>
<tr>
<td>Height (cm)</td>
<td>167 ± 1</td>
<td>168 ± 3</td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>80.1 ± 2.8</td>
<td>82.3 ± 4.1</td>
<td>0.07</td>
</tr>
<tr>
<td>Percent body fat (%)</td>
<td>38.2 ± 1.2</td>
<td>38.9 ± 1.2</td>
<td>0.32</td>
</tr>
<tr>
<td>Lean body weight (kg)</td>
<td>49.2 ± 1.1</td>
<td>50.1 ± 2.2</td>
<td>0.02</td>
</tr>
<tr>
<td>Fat weight (kg)</td>
<td>30.8 ± 1.9</td>
<td>32.2 ± 2.3</td>
<td>0.04</td>
</tr>
</tbody>
</table>

*SEM, derived from 7-d food records.

†Significantly different from baseline values, P < 0.05.

### Table 2

**Comparison of baseline and treatment diets for the exercise and nonexercise study groups**

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Baseline diet*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy (kcal)</td>
<td>1978 ± 153</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>256 ± 21</td>
</tr>
<tr>
<td>Weight (g)</td>
<td>50.8 ± 2.1</td>
</tr>
<tr>
<td>Percent of total kcal (%)</td>
<td>13.0 ± 0.5</td>
</tr>
<tr>
<td>Protein</td>
<td>65 ± 6</td>
</tr>
<tr>
<td>Weight (g)</td>
<td>81 ± 8</td>
</tr>
<tr>
<td>Percent of total kcal (%)</td>
<td>35.9 ± 2.0</td>
</tr>
<tr>
<td>Polysaturated fatty acids (g)</td>
<td>10.3 ± 1.6</td>
</tr>
<tr>
<td>Saturated fat (g)</td>
<td>23.4 ± 3.5</td>
</tr>
<tr>
<td>Cholesterol (mg)</td>
<td>218 ± 45</td>
</tr>
<tr>
<td>Crude fiber (g)</td>
<td>4.5 ± 0.9</td>
</tr>
<tr>
<td>Vitamin C (mg)</td>
<td>93 ± 17</td>
</tr>
<tr>
<td>Vitamin A (µg RE)</td>
<td>3319 ± 745</td>
</tr>
<tr>
<td>Calcium (mg)</td>
<td>922 ± 104</td>
</tr>
<tr>
<td>Iron (mg)</td>
<td>12.2 ± 1.6</td>
</tr>
<tr>
<td>Zinc (mg)</td>
<td>7.2 ± 1.0</td>
</tr>
<tr>
<td>Sodium (mg)</td>
<td>3059 ± 354</td>
</tr>
</tbody>
</table>

*SEM, derived from 7-d food records.
Discussion

In this 5-wk randomized, controlled study of mildly obese women, the patterns of change in serum HDL-C and TC/HDL-C, but not total cholesterol, triglycerides, LDL-C, or glucose, were significantly different between Ex and Nex groups. Because dietary intake was strictly controlled and weight loss was equal in both Ex and Nex groups, these results are directly related to the effects of the moderate exercise-training program.

Hegsted equation (39) was used to estimate the effect of change in diet quality, and the formula of Kromhout (2) was used to estimate the effect of change in body weight (1 kg of body weight change is related to a change of 0.05 mmol/L in serum cholesterol). The change in quality of diet was estimated to account for ~60% of the actual change in serum total cholesterol and change in body weight, ~40%. Although Kromhout's formula was derived from a study carried out in men, we found it to be a useful predictor in women as well.

TABLE 3
Plasma glucose, lipoprotein, and lipid comparisons between exercise and nonexercise groups*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Exercise</th>
<th>Nonexercise</th>
<th>Effect (group × time)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>2 wk</td>
<td>5 wk</td>
</tr>
<tr>
<td>Glucose</td>
<td>5.2 ± 0.1</td>
<td>4.7 ± 0.1†</td>
<td>5.0 ± 0.1†</td>
</tr>
<tr>
<td>Triglycerides</td>
<td>1.29 ± 0.15</td>
<td>0.80 ± 0.09†</td>
<td>0.82 ± 0.10†</td>
</tr>
<tr>
<td>Cholesterol</td>
<td>5.28 ± 0.22</td>
<td>4.39 ± 0.23†</td>
<td>4.61 ± 0.12†</td>
</tr>
<tr>
<td>LDL-C</td>
<td>3.14 ± 0.17</td>
<td>2.70 ± 0.20†</td>
<td>2.70 ± 0.16†</td>
</tr>
<tr>
<td>HDL-C</td>
<td>1.54 ± 0.10</td>
<td>1.33 ± 0.09†</td>
<td>1.54 ± 0.08</td>
</tr>
</tbody>
</table>

* x ± SEM.
† Significantly different from baseline, P < 0.05.

FIG 1. Exercise-training effects on the ratio of total cholesterol to HDL-C in mildly obese women while on a reducing diet. The pattern of change between the exercise and nonexercise groups was significantly different during the 5-wk study (F_{12,38} = 4.93, P = 0.012). †Significantly different from baseline values, P < 0.05.
HDL-C in females has been reported to decrease or remain unchanged during active stages of weight loss (4, 8, 9) and to decrease when a “prudent diet” is adopted (25). By 2 wk, these factors played a role in decreasing HDL-C in both Ex and Nex groups. Moderate exercise training, however, attenuated the decrease, and by 5 wk, HDL-C values in the Ex group were back to baseline concentrations compared with a 9.3% decrease in the Nex group. Thus, the results of the present study support those of others that reported that the predominant effect of exercise training on blood lipids and lipoproteins when diet quality and weight loss are controlled is on HDL-C (3, 12, 18). Sopko et al (18) reported that heavy amounts of exercise (3500 kcal expenditure/wk) and weight loss separately and independently increase HDL-C in males. Although diet composition was fixed for all subgroups, the calorie intake varied widely between groups. Differences in study design (ie, amount of exercise, sex of subjects, and varied caloric intake) make it difficult to compare their results with ours. Whether males and females react differently to the combination of dietary change, weight loss, and exercise training is not possible to ascertain at this time.

Whether HDL-C concentrations would have kept climbing in both groups had the study continued is difficult to surmise. HDL-C has been reported to rise above baseline concentrations if sufficient weight is lost and the weight loss is maintained in obese subjects (1, 4, 5). Although some researchers have stated that females respond to exercise training with the same HDL-C increase as males (40), most have concluded that women may experience little or no change unless the women are exercising heavily (19-24). It is questionable whether the moderate exercise training program our subjects were following would have been sufficient stimulus for a continued rise in HDL-C.

Tran and Weltman (10) in a meta-analysis of 95 studies concluded that reductions in serum total cholesterol and LDL-C with exercise training are minimal unless combined with body weight losses. Our results suggest that moderate exercise training by mildly obese women has no effect at all on these variables. As shown in Figure 2, change in dietary quality and body weight fully explain the 12.7% change in serum total cholesterol that our subjects experienced. We recommend that stricter dietary control and measurement of body weight changes be included with each exercise-training study that evaluates serum lipid and lipoprotein changes. Among the other major problems in interpreting the results from the literature is the lack of the practice of assigning subjects randomly to exercise and control groups.

Change in quality of diet has not been found to consistently affect serum triglycerides (25). Weight loss, however, usually leads to strong decreases (1, 8, 9, 16). Stevenson et al (1), for example, reported a 23.6% decrease in serum triglycerides in response to a 26% decrease in body weight in a group of 46 moderately obese males and females. In our subjects, triglycerides had fallen significantly in both of our groups in response to weight loss by 2 wk. The effect of exercise training was not consistent enough for a significant group X time interaction to be measured. Although some researchers have reported significant exercise-training effects on serum triglycerides (12, 40), others have not (3, 11, 17, 19, 20, 24).

Moderate exercise was not associated with an accelerated decrease in body weight in this study. In other tightly controlled studies, light to moderate amounts of exercise training have also been found to have little effect on change in body weight (12, 17, 24, 40, 41). We reviewed this information in more detail elsewhere (38).

Obesity is a common affliction in our society and is associated with significant perturbations in serum concentrations of lipids and lipoproteins (1). In this study, weight loss and change in quality of diet best predicted changes in serum total cholesterol and LDL-C. Moderate exercise training had its major effect on HDL-C, attenuating the decrease caused by both weight loss and change in diet. The most important lifestyle factors reported to affect HDL-C are alcohol, smoking, diet composition, body weight, and physical activity (18). In this study, each of these factors was controlled for, lending strength to our findings.

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References