The Influence of Exercise and Estrogen Replacement on Primary Lipid Coronary Risk Markers in Postmenopausal Women

John S. Green, Peter W. Grandjean, Shelly Weise, Stephen F. Crouse, and J. James Rohack

Although endurance exercise and supplemental estrogen have both been shown to improve serum lipid cardiac risk profiles in postmenopausal women, data regarding a possible synergistic influence are scarce and inconsistent. The purpose of this study was to determine whether such a synergistic influence could be demonstrated. Serum concentrations of total cholesterol (TC), HDL-cholesterol (HDL-C), HDL₂-C, HDL₃-C, LDL-C, and triglycerides (TG) were obtained from postmenopausal women (N = 45) in each of 4 groups: currently exercising and taking estrogen replacement, exercising and not taking estrogen, sedentary and taking estrogen, and sedentary and not taking estrogen. HDL-C was on average 21% higher (p < .05) and the HDL-C:LDL-C ratio on average 45% higher (p < .05) in the exercise-plus-estrogen group than in any of the other 3 groups. It was concluded that the combination of endurance exercise and estrogen replacement might be associated with better lipid coronary risk profiles in postmenopausal women than either intervention alone.

Key Words: coronary artery disease, hormone supplementation

Risk of coronary artery disease (CAD) has been shown to significantly increase in women after the onset of menopause, which might be partially explained by changes in lipid metabolism (Castelli et al., 1986; Matthews et al., 1989). As an example, postmenopausal women have been found to have greater serum concentrations of total cholesterol (TC) and low-density lipoprotein cholesterol (LDL-C) and lower high-density lipoprotein cholesterol (HDL-C) than their premenopausal counterparts do (Matthews et al.). In addition, the incidence of CAD has generally been found to be lower in postmenopausal women who are taking estrogen supplements than in women who are not (Manolio et al., 1993; Stampfer & Colditz, 1991; Walsh et al., 1991). This reduction in disease incidence might be attributable, at least in part, to favorable alterations in serum lipid concentrations mitigated by the supplemental estrogen (Cauley, LaPorte, Kuller, Bates, & Sandler, 1983; Greendale, 

Green, Weise, and Crouse are with the Netum Steed Physiology Lab, Department of Health and Kinesiology, at Texas A&M University, College Station, TX 77843-4243. Grandjean is with the Department of Health and Human Performance at Auburn University, Auburn, AL 36849-5323. Rohack is with the Scott & White Medical Group, College Station, TX 77840.
Bodin-Dunn, Ingles, Haile, & Barrett-Connor, 1996; Nabelsi et al., 1993; Walsh et al., 1991).

Endurance exercise training in women is also associated with a reduced risk for CAD that might be partially attributed to its favorable effect on serum levels of HDL-C, LDL-C, and triglycerides (TG; Gibbons, Blair, Cooper, & Smith, 1983; Haddock, Hopp, Mason, Blix, & Blair, 1998; Harting, Moore, Mitchell, & Kappus, 1984; Rainville & Vaccaro, 1984). For example, higher HDL-C and lower TC and LDL-C have been reported in women who regularly exercise than in inactive women, regardless of menopausal status (Harting et al.; Rainville & Vaccaro). Results from experimental studies are less definitive; however, higher HDL-C and lower TC, LDL-C, and triglycerides (TG) have been observed in both pre- and postmenopausal women after exercise training (Krummel, Etherton, Peterson, & Kris-Etherton, 1993). Thus, it is reasonable to conclude that estrogen-replacement therapy (ERT) and exercise training, acting as separate entities, might reduce CAD risk in postmenopausal women by favorably changing serum lipid concentrations. At present, little is known about whether ERT and exercise training might act synergistically on lipid concentrations in these women. The purpose of this investigation, therefore, was to determine whether serum lipid concentrations would be more favorable in postmenopausal women who engage in both regular endurance exercise and a regimen of ERT than in those who only participate in one or the other. We were especially interested in the HDL-C, LDL-C, and the HDL-C:LDL-C ratio because these are the parameters most often used by clinicians to evaluate cardiac risk status and to explain that risk status to their patients.

Methods

PARTICIPANTS

Women were recruited from the surrounding community and the central and southeast Texas regions to participate. They were recruited through notices posted throughout the university community; mass mailings to physicians, local businesses, and university offices; inserts in local road-race packets; and follow-up telephone calls to potential participants who were referred by those already recruited. Although every effort was made to recruit women of minority status, none volunteered to serve as participants.

All participants were required to be nonsmokers, drink less than 2 oz of alcohol per week, and have experienced complete cessation of menses for at least 3 but not more than 10 years. Those classified as regular exercisers were required to have engaged in endurance exercise in the form of walking, running, cycling, or exercising on a mechanical ergometer for at least 1 year. Throughout their exercise history, these participants had to have averaged three or more exercise bouts per week for 30 or more min/bout at an intensity level of at least 11 on the Borg rating of perceived exertion scale. The scale rating of 11 corresponds to a moderate level of exercise (Hage, 1981) and represented the minimum exercise-intensity criterion for inclusion in the study. Participants recruited into the sedentary category were required to not have engaged in any form of regular exercise for at least 1 year. Participants classified as estrogen users were required to have undergone a regimental ingestion of estrogen or estrogen with low-dose progesterone for 1 or more years,
whereas nonusers had to demonstrate a plasma estradiol concentration of less than 20 pg/ml. In accordance with these criteria, postmenopausal women participants were recruited into one of four groups: exercising and taking estrogen replacement (XE), exercising and not taking estrogen replacement (XNE), sedentary and taking estrogen replacement (SE), and sedentary and not taking estrogen replacement (SNE).

MEDICAL HISTORY, EXERCISE DATA, AND PHYSICAL EXAM

Before the collection of physiological data, all participants completed an orientation visit to the laboratory. At this time, they were given written and oral explanations of all the tests to be performed and were acquainted with the testing equipment and experimental protocols. After being fully informed regarding the nature of the study and the risks involved, all participants signed an informed consent. Next, they completed a comprehensive health history and physical activity questionnaire designed to ascertain, in detail, their pertinent medical and exercise histories. Those recruited as exercisers were instructed to carefully record the modality, frequency, intensity, and duration of their exercise regimen. The principle investigator of the study was present during the completion of this questionnaire to ensure that all information concerning medical and physical activity history was recorded accurately. During this visit, participants also underwent a physical examination by a cardiologist. Those who showed evidence of medical contraindications to exercise or were taking medication known to affect lipid metabolism or alter cardiovascular function were excluded from the study. Also excluded were those with any type of chronic disease or ailment that might influence physiological responses to either estrogen or exercise and those who currently smoked. From a total of 49 volunteers screened, 45 met the inclusion criteria and served as participants for the study: 12 in the XE group, 10 in the XNE group, 14 in the SE group, and 9 in the SNE group.

ASSESSMENT OF BODY COMPOSITION

Percent body fat and lean body mass were calculated from body density estimated from the sum of seven skinfold measurements (Jackson, Pollock, & Ward, 1980). All assessments were performed by the same experienced investigator.

ASSESSMENT OF PEAK OXYGEN CONSUMPTION

A symptom-limited graded exercise test using a protocol of progressively increasing workloads on a motor-driven treadmill (Quinton model Q65) was conducted under the direct supervision of a cardiologist, who evaluated all test results. Any participant who demonstrated hemodynamic or ECG criteria for heart disease during the test would have been excluded from the study, but none did. Blood pressure was monitored and a 12-lead electrocardiogram was run (Quinton model Q-3040) while each participant was at rest, throughout the test at each stage of the protocol, and for at least 4 min after volitional test termination. Oxygen consumption and carbon-dioxide production (VO₂ and VCO₂) were measured continuously and averaged over 15-s intervals via open-circuit spirometry, using an automated metabolic cart calibrated with gas mixtures of known composition (Medical
Graphics CPX/D). A treadmill protocol that had been previously validated in our laboratory was used to assess peak oxygen consumption. The protocol began at a workload of 3 metabolic equivalents (METs) and continued until volitional termination. The first six stages were 4 min in length each, with the workload increasing by 1 MET per stage. After a participant completed the fourth stage, the workload for subsequent stages was determined by her heart rate. If it was ≥85% of the age-predicted maximum heart rate, the work rate for subsequent stages was increased by 1 MET per stage. If, after Stage 4, the heart rate was less than 85% of the age-predicted maximum, the work rate for subsequent stages was increased by 2 METs per stage. The protocol was continued until the participants indicated they could no longer proceed. The test for VO$_2$peak was judged to be valid if at least two of the following criteria were met (Issekutz, Birkhead, & Rodahl, 1962): (a) The participant attained a maximum heart rate that was within 10 beats/min of the age-predicted value (220 – age); (b) the respiratory exchange ratio was greater than 1.1 at peak exercise; (c) the rating of perceived exertion on the Borg scale was ≥18; or (d) VO$_2$ values reached a plateau despite further increases in workload.

**DIETARY ANALYSIS**

All participants completed a 7-day diet record in order to assess the influences of caloric intake and diet composition on serum lipid concentrations. They were encouraged to maintain their normal diet and were asked to record all nutrient intake for the 7 days prior to blood sampling. Daily total caloric intake and dietary composition were averaged over the 7-day period using Nutricalc™ software. Diets were not otherwise controlled.

**BIOCHEMICAL ANALYSIS**

After a 48-hr period with no exercise and a 12-hr period during which all nutrition except water was withheld, each participant reported to the laboratory before 10:00 a.m. for a blood draw. After the participant rested for 10 min in a reclining phlebotomy chair, a 20-gauge Teflon™ catheter was introduced into an antecubital vein and 20 ml of blood were withdrawn and then refrigerated for lipid and estradiol analysis. Serum was isolated within 3 hr of collection at 4°C by centrifugation.

Plasma estradiol was measured by radioimmunoassay (Double Antibody Estradiol KE2D, Diagnostics Products Corporation, Los Angeles, CA). HDL-C and HDL$_2$-C were separated from aliquots of serum by contemporary precipitation methods (Gidez, Miller, Burststein, Slagle, & Eder, 1982; Warnick & Albers, 1978). Serum and the HDL-C and HDL$_2$-C fractions were frozen at −70°C until further analysis could be performed. The collected frozen samples were thawed and then analyzed in duplicate for concentrations of TC, HDL-C, HDL$_2$-C (Allain, Poon, Chan, Richmond, & Fu, 1974), and TG (Bucolo & David, 1973; Total Cholesterol #352 and Triglyceride #339, Sigma Chemical Co., St. Louis, MO). The concentration of HDL$_2$-C was calculated as the difference between HDL-C and HDL$_1$-C. LDL-C was calculated according to the procedure of Friedewald, Levy, and Fredrickson (1972). Assays were performed in duplicate and then averaged for statistical analysis. The intra-assay coefficients of variation for the measured lipid variables were (a) TC, 0.15%; (b) TG, 0.24%; (c) HDL-C, 0.58%; and (d) HDL$_1$-C, 0.95%.
STATISTICAL ANALYSIS

Given the retrospective nature of the study, multifactorial statistical procedures and experimental interaction analysis were deemed inappropriate; therefore, a one-way analysis of variance was employed to test for significant differences in the dependent measures among the four participant categories. The data distributions for TG, HDL-C, HDL₂, and HDL₄ were not normally distributed. Consequently, log transformations were performed on each of these variables, and the data were reanalyzed. Results from the transformed and untransformed variables were not different; therefore, results from the untransformed data are reported. The General Linear Models procedure (SAS, Version 6.11, Cary, NC) was used to analyze the data because of its robustness with regard to nonnormal data distributions. To examine possible relationships between body-composition variables and the measured lipid values, Pearson product-moment correlations were calculated for the data within each participant grouping. Significance for all statistical tests was accepted at the $p < .05$ level. After initial analyses were completed, follow-up analyses on specific participant stratifications were performed to facilitate additional comparisons. Although these additional analyses are necessary to the understanding of the data and subsequent discussion, it should be noted that they do inflate the "experimentwise" error rate associated with the study.

Given the relatively small number of participants in each of the four groups, an analysis of statistical power was warranted. Portney and Watkins (1993) provide a detailed power computation for analysis-of-variance models based on the effect size of the sample. Our data for HDL-C, the primary variable of interest, demonstrated an effect size of $\frac{.53}{SD}$. For an $\alpha$ level ($p$) of .05 and our average of 11 participants per cell, statistical power would fall between .76 and .91 (Portney & Watkins). Power analyses for other dependent measures yielded similar results.

Results

PARTICIPANT CHARACTERISTICS

There were no significant differences in the height, weight, and number of years past menopause among the participant groupings ($p > .05$). A relatively small but statistically significant difference in participant age was detected, along with a substantial difference in percent body fat between the exercising and sedentary participants.

No significant differences in any of the estrogen-prescription parameters were noted between the two groups taking estrogen with respect to dosage or length of time of administration ($p > .05$). It should be noted that within the XE and SE groups, there were no significant differences in any of the dependent measures with regard to whether or not the participants were taking a progestin along with their estrogen. As expected, the estradiol levels in the two groups taking supplements were substantially higher than in those not taking supplements. Participant demographics and estrogen-status parameters are displayed in Table 1.

No significant differences were observed between the two exercise groups with respect to the frequency, intensity, or bout duration of their exercise regimens. The results of the exercise test showed the two exercise groups to have a significantly greater postmenopausal women VO₂peak than their sedentary counterparts.
Table 1. Subject Demographics and Estrogen Status (M ± SD)

<table>
<thead>
<tr>
<th></th>
<th>XE (n = 12)</th>
<th>XNE (n = 10)</th>
<th>SE (n = 14)</th>
<th>SNE (n = 9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>53.2 ± 4.8†</td>
<td>55.5 ± 5.1†</td>
<td>51.9 ± 4.3†</td>
<td>56.9 ± 2.7†</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>164 ± 6'</td>
<td>162 ± 6'</td>
<td>163 ± 4'</td>
<td>161 ± 5'</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>59.5 ± 7.6†</td>
<td>66.2 ± 10.1†</td>
<td>69.0 ± 15.6†</td>
<td>71.7 ± 16.0†</td>
</tr>
<tr>
<td>% Body fat</td>
<td>28.4 ± 4.6†</td>
<td>29.0 ± 6.8†</td>
<td>35.3 ± 6.4†</td>
<td>36.3 ± 6.4†</td>
</tr>
<tr>
<td>Time past menopause</td>
<td>5.3 ± 2.3†</td>
<td>5.3 ± 3.9†</td>
<td>5.2 ± 2.2†</td>
<td>6.9 ± 2.2†</td>
</tr>
<tr>
<td>Plasma E₂ (pg/ml)</td>
<td>43.3 ± 17.8*</td>
<td>5.5 ± 2.9*</td>
<td>46.5 ± 26.0*</td>
<td>12.8 ± 15.0†</td>
</tr>
<tr>
<td>Dose (mg/day)</td>
<td>0.91 ± 0.2*</td>
<td>—</td>
<td>0.65 ± 0.3*</td>
<td>—</td>
</tr>
<tr>
<td>Duration (years)</td>
<td>5.8 ± 2.5*</td>
<td>—</td>
<td>6.5 ± 4.0*</td>
<td>—</td>
</tr>
</tbody>
</table>

Note. Means with the same symbol are not significantly different among subject groups (p > 0.05). XE = exercise group taking estrogen supplements; XNE = exercise group not taking estrogen; SE = sedentary group taking estrogen; SNE = sedentary group not taking estrogen; % body fat = body composition assessed by the sum of 7 skinfold measurements; plasma E₂ = plasma concentration of estradiol; dose = prescription dosage of estrogen replacement; duration = how long the participants had taken estrogen replacement.

did, reflecting the expected adaptation to exercise. All four groups were similar with respect to average daily total caloric intake and dietary composition, with the exception that participants in the two exercise groups consumed a smaller percentage of their calories from fat than did participants in the two sedentary groups. Exercise-parameter means, along with the results of the nutritional analysis, are listed in Table 2.

LIPID VALUES

Serum HDL-C concentrations and the HDL:LDL-C ratio were significantly greater in the XE group than in all other groups (p < .05). Serum concentrations of HDL₄-C and HDL₅-C tended to be greater, and TC, LDL-C, and TG concentrations, lower, in the XE group; however, the differences did not reach statistical significance. Serum lipid measurements are depicted in Figure 1. When lipid values and body-composition data within each group were analyzed, significant correlations appeared between body-composition variables and LDL-C in the two exercising groups only. These correlations are listed in Table 3.

Discussion

The primary objective of this study was to determine whether ERT and exercise training act synergistically to favorably influence primary serum lipid coronary risk markers in postmenopausal women. The results suggest that postmenopausal women who participate in regular aerobic exercise and are on ERT exhibit a more
Table 2. Exercise Training Parameters and Dietary Information (M ± SD)

<table>
<thead>
<tr>
<th></th>
<th>XE</th>
<th>XNE</th>
<th>SE</th>
<th>SNE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise frequency</td>
<td>4.2 ± 1.5*</td>
<td>4.9 ± 1.3*</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>(days/week)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exercise intensity</td>
<td>13.7 ± 1.4*</td>
<td>13.9 ± 1.5*</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>(Borg scale)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exercise duration</td>
<td>40.4 ± 10.6*</td>
<td>55.3 ± 24.4*</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>(min/bout)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Years exercising</td>
<td>8.0 ± 5.8*</td>
<td>13.0 ± 9.2*</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>VO_{peak} (ml · kg⁻¹ · min⁻¹)</td>
<td>28.6 ± 5.0*</td>
<td>28.0 ± 5.6*</td>
<td>20.7 ± 3.6*</td>
<td>21.1 ± 3.9*</td>
</tr>
<tr>
<td>Energy intake (kcal/day)</td>
<td>1832 ± 396</td>
<td>2155 ± 1106</td>
<td>1917 ± 650</td>
<td>2095 ± 856</td>
</tr>
<tr>
<td>Carbohydrate (g/day)</td>
<td>294 ± 94</td>
<td>304 ± 123</td>
<td>236 ± 86</td>
<td>264 ± 120</td>
</tr>
<tr>
<td>Fat (g/day)</td>
<td>45 ± 22</td>
<td>72 ± 66</td>
<td>78 ± 30</td>
<td>89 ± 47</td>
</tr>
<tr>
<td>% Calories from fat</td>
<td>22.3 ± 10.0*</td>
<td>27.2 ± 1.0*</td>
<td>36.2 ± 6.4*</td>
<td>36.7 ± 1.0*</td>
</tr>
<tr>
<td>Protein (g/day)</td>
<td>72 ± 18</td>
<td>78 ± 27</td>
<td>75 ± 29</td>
<td>72 ± 23</td>
</tr>
</tbody>
</table>

Note. Means with the same symbol are not significantly different among subject groups (p > 0.05). XE = exercise group taking estrogen supplements. XNE = exercise group not taking estrogen; SE = sedentary group taking estrogen; SNE = sedentary group not taking estrogen; VO_{peak} = oxygen consumption measured at peak exercise.

favorable lipid profile than do those who (a) exercise and are not on ERT, (b) are sedentary and on ERT, or (c) are sedentary and not on ERT. Specifically, higher HDL-C concentrations and greater HDL:LDL-C ratios were found in the XE group than in any of the other three groups. In light of these findings, it would seem prudent to compare our results with those of other related studies dealing with both the separate and combined influences of estrogen and exercise on lipid profiles, especially as they pertain to HDL-C and LDL-C, our primary variables of interest.

ESTROGEN EFFECTS

Recent cross-sectional studies have concluded that 0.625 mg/day of oral estrogen, with or without progestin supplementation, can significantly alter lipid profiles in postmenopausal women. Specifically, HDL-C concentrations are increased while LDL-C concentrations are reduced (Derby, Hume, McPhillips, Barbour, & Carleton, 1995; Walsh et al., 1991). Others have reported that ERT prevents a postmenopausal decline in HDL-C and rise in LDL-C, rather than significantly changing serum lipid profiles (Matthews et al., 1989). Regardless, it would seem that the
Figure 1. Serum lipids. All measurements are given in mg/dL. XE = exercise group taking estrogen supplements; XNE = exercise group not taking estrogen supplements; SE = sedentary group taking estrogen supplements; SNE = sedentary group not taking estrogen supplements.

therapeutic or “protective” effect of ERT regarding serum lipid coronary risk markers is well established. In contrast, results from the present investigation demonstrated no differences in HDL-C or LDL-C between the sedentary groups taking and not taking ERT (SE versus SNE, p > .05). The discrepancies between our findings and those of the large cohort studies mentioned were unexpected and cannot be accounted for by any of the supplemental data gathered. As shown in Tables 1 and 2, body weight, body composition, and nutrient-intake variables were not significantly different between the two sedentary groups. It should be noted, however, that not all studies purport favorable changes in lipids with estrogen supplementation (Derby et al.; Lobo, 1991). Nevertheless, it is likely that extraneous factors coupled with the small number of participants in the two groups precipitated this finding. One possible source of such error is that a significant
Table 3. Pearson Product–Moment Correlations for Weight (kg) and Percent Body Fat Versus Lipid Variables for Each Group

<table>
<thead>
<tr>
<th></th>
<th>TC</th>
<th>HDL-C</th>
<th>HDL₂-C</th>
<th>LDL-C</th>
<th>TC/HDL</th>
<th>TRIG</th>
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<tr>
<td>XE (n = 12)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>.57</td>
<td>-.30</td>
<td>.24</td>
<td>.60</td>
<td>.50</td>
<td>.24</td>
</tr>
<tr>
<td>% Body fat</td>
<td>.56</td>
<td>-.39</td>
<td>.08</td>
<td>.58</td>
<td>.56</td>
<td>.43</td>
</tr>
<tr>
<td>XNE (n = 10)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>.53</td>
<td>-.02</td>
<td>-.48</td>
<td>.77</td>
<td>.59</td>
<td>.37</td>
</tr>
<tr>
<td>% Body fat</td>
<td>.39</td>
<td>.07</td>
<td>.24</td>
<td>.50</td>
<td>.32</td>
<td>.12</td>
</tr>
<tr>
<td>SE (n = 14)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>-.26</td>
<td>-.57</td>
<td>.06</td>
<td>-.20</td>
<td>.20</td>
<td>.20</td>
</tr>
<tr>
<td>% Body fat</td>
<td>-.12</td>
<td>-.40</td>
<td>.36</td>
<td>-.08</td>
<td>.21</td>
<td>.11</td>
</tr>
<tr>
<td>SNE (n = 9)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>.11</td>
<td>-.09</td>
<td>.04</td>
<td>.07</td>
<td>.16</td>
<td>.31</td>
</tr>
<tr>
<td>% Body fat</td>
<td>.16</td>
<td>.18</td>
<td>.25</td>
<td>.04</td>
<td>.07</td>
<td>.43</td>
</tr>
</tbody>
</table>

Note. XE = exercise group taking estrogen supplements. XNE = exercise group not taking estrogen; SE = sedentary group taking estrogen; SNE = sedentary group not taking estrogen. Bold numbers indicate significant correlations (p < .05).

Number of participants in the SNE group might have had preexisting lipid profiles that, as a result of some unknown variant, were already relatively high in HDL-C and low in LDL-C, thus contributing to the lack of differences between the two groups.

Triglyceride differences between the SE and SNE groups did not reach statistical significance, but the value for the SE group was 63 mg/dl higher than that for the SNE group. Similar elevations in TG with estrogen use have been described previously (Bush et al., 1987; Hong, Romm, Reagan, Green, & Rackley, 1992; Klebanoff, Miller, & Fernhall, 1998) but are not thought to be associated with an increased risk for atherosclerotic disease in this population (Hong et al.). Total cholesterol was also not different between the two sedentary groups. This finding is in agreement with the results of Klebanoff et al., who found that TC values in
women taking and not taking ERT did not change in response to a 12-week exercise-training regimen.

EXERCISE EFFECTS

As noted previously, exercise-trained women have been shown to exhibit more favorable lipid profiles than their sedentary counterparts. For example, Harting et al. (1984) compared serum lipid measurements of pre- and postmenopausal recreational joggers, long-distance runners, and inactive controls. The exercise-trained groups demonstrated higher HDL-C concentrations and greater HDL:LDL-C ratios than their sedentary cohorts did. Among the postmenopausal women, HDL-C concentrations were 16–22% higher, and the HDL:LDL-C ratios were 15–21% greater in the exercisers than in their inactive peers. In a similar study, Rainville and Vaccaro (1984) observed higher HDL-C concentrations, a greater HDL:LDL-C ratio, and lower LDL-C in exercise-trained postmenopausal women than in inactive controls. Collectively, the results of these two studies suggest that exercise exerts a significant influence on serum lipid cardiac risk markers in postmenopausal women. In our study, serum concentrations of HDL-C and the HDL-C:LDL-C ratio were significantly greater in the XE group than in any of the other groups. This finding, coupled with the lack of estrogen influence in the sedentary participants discussed previously, supports the notion that the combination of ERT and exercise might be a more potent influence on serum lipids in postmenopausal women than ERT alone. This might be especially true when the dose and duration of exercise training are as large as they were in our study.

In a related study, Binder, Birge, and Kohrt (1996) examined serum lipid changes over an 11-month exercise-intervention period. They reported a reduction in LDL-C and elevations in both HDL-C and TG concentrations with ERT alone. With exercise training alone, TC and LDL-C were reduced, but HDL-C remained unchanged. When exercise and ERT were combined, however, TC and LDL-C were both reduced, HDL-C was increased, and TG values were not elevated as they were with ERT alone. In their conclusions, the authors suggested that exercise and ERT provided independent and complementary effects on serum lipid measurements and optimized the serum lipid response in postmenopausal women. Although their analysis and corresponding results were not identical to ours, their conclusion that the combination of exercise and ERT might alter lipid risk markers to a more favorable extent than either one alone is supportive of our contentions.

Lindheim et al. (1994) examined serum lipid changes over a 6-month period in previously inactive postmenopausal women who were not taking any form of hormonal supplementation. The women were randomized into groups similar to ours in that some remained inactive while others underwent exercise training. These two groups were then further divided into those taking and not taking ERT. The authors found that TC and LDL-C concentrations were reduced with ERT and exercise training as separate interventions. The combination of ERT and exercise training reduced LDL-C, whereas serum HDL-C concentrations were elevated with ERT alone and in combination with exercise, but not with exercise alone. Similar to the findings in our study, HDL-C values were not altered by any treatment. In their conclusions, the authors purported that ERT had the greatest impact on serum lipid concentrations and the combined interventions of exercise and ERT offered no added improvement to the lipid measurements. The differences between the results
of our findings and those of Lindheim's group might be explained by the large discrepancies in the duration of the exercise bout and the length of time the participants had been exercising. The exercising women in our study exhibited a mean exercise-session duration time of almost 48 min, compared with 30 min in Lindheim's participants. Furthermore, Lindheim's training regimen was only 6 months long, whereas the average participants in our exercise categories had been exercising for over 10 years. Clearly, the exercising women in our study were provided with a larger training stimulus, which might have contributed to the more favorable lipid profile seen in the XE group.

POTENTIAL CONFOUNDING FACTORS

Differences in body weight and body fat between the exercise and sedentary groups in our study did not explain the larger HDL-C level and HDL:LDL-C ratio that were observed in the XE group. When all four groups were compared separately and body weight and percent fat were statistically accounted for using analysis of covariance, HDL-C and the HDL:LDL-C ratio still remained significantly greater in the XE group than in all other participant groupings (p < .05). These results are similar to those reported by Harting et al. (1984). It is interesting to note, however, that LDL-C was moderately correlated with body weight in both of the exercise groups and with percent fat in the XE group. It is possible that estrogen use contributed to the inconsistency of these correlations. This notion is in part supported by Klebanoff et al. (1998), who found supplemental estrogen to influence relationships between body weight and lipid variables. Specifically, they found an inverse correlation between body weight and training-induced beneficial changes in both LDL-C and TC in women not taking estrogen, but not in women taking estrogen. Given this confounding influence of estrogen and the fact that overall body weight was not significantly different among our participant groupings, we do not believe the aforementioned relationships to be influential or explanatory regarding the differences in lipid parameters seen in the XE group of our study.

Another interesting finding in our study is that the two exercise groups consumed a significantly smaller percentage of their calories from fat, yet their TC, LDL-C, and triglyceride values were not significantly different from those of their sedentary counterparts. Most likely, the lower fat intake reflects a conscious effort on the part of the two exercising groups to maintain a more optimal level of cardiovascular health. Although the larger intake percentage of the sedentary groups was not appreciably higher than recommended levels, it remains unclear to what extent this difference affected lipid values.

In summary, our data clearly demonstrate greater HDL-C concentrations and a more favorable HDL:LDL-C ratio in postmenopausal women who report regular aerobic exercise and oral estrogen supplementation, suggesting that together, exercise and estrogen supplementation yield a more favorable lipid risk profile for coronary disease in postmenopausal women than either does alone.

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References


