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Effect of 14 Weeks of Resistance Training on Lipid Profile and Body Fat Percentage in Premenopausal Women

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Effect of 14 weeks of resistance training on lipid profile and body fat percentage in premenopausal women

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Abstract

Objectives—To study the effects of a supervised, intensive (85% of one repetition maximum (1-RM)) 14 week resistance training programme on lipid profile and body fat percentage in healthy, sedentary, premenopausal women.

Subjects—Twenty four women (mean (SD) age 27 (7) years) took part in the study. Subjects were randomly assigned to either a non-exercising control group or a resistance exercise training group. The resistance exercise training group took part in supervised 45–50 minute resistance training sessions (85% of 1-RM), three days a week on non-consecutive days for 14 weeks. The control group did not take part in any structured physical activity.

Results—Two way analysis of variance with repeated measures showed significant ($p < 0.05$) increases in strength (1-RM) in the exercising group. There were significant ($p < 0.05$) decreases in total cholesterol (mean (SE) 4.68 (0.31) *v* 4.26 (0.23) mmol/l (180 (12) *v* 164 (9) mg/dl)), low density lipoprotein (LDL) cholesterol (2.99 (0.29) *v* 2.57 (0.21) mmol/l (115 (11) *v* 99 (8) mg/dl)), the total to high density lipoprotein (HDL) cholesterol ratio (4.2 (0.42) *v* 3.6 (0.42)), and body fat percentage (27.9 (2.09) *v* 26.5 (2.15)), as well as a strong trend towards a significant decrease in the LDL to HDL cholesterol ratio ($p = 0.057$) in the resistance exercise training group compared with their baseline values. No differences were seen in triglycerides and HDL cholesterol. No changes were found in any of the measured variables in the control group.

Conclusions—These findings suggest that resistance training has a favourable effect on lipid profile and body fat percentage in healthy, sedentary, premenopausal women.

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Keywords: weight training; cholesterol; women; triglycerides; strength

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Hyperlipidaemia is a well documented risk factor for cardiovascular disease, and is the leading cause of death in men and women in the United States.[1 2] Several epidemiological studies have shown that low concentrations of total serum cholesterol and low density lipoprotein (LDL) cholesterol, as well as a normal body fat percentage, are associated with decreased cardiovascular disease morbidity and mortality.[3–6] Considerable research has also been devoted to the effect of exercise on lipid metabolism. Regular physical activity has been shown to improve lipid and glucose metabolism by increasing insulin sensitivity and serum high density lipoprotein (HDL) cholesterol, and decreasing serum LDL cholesterol and triglycerides.[6–8] Acute exercise has also been shown to improve lipid profiles.[9–13] Therefore, the therapeutic effect of exercise is a widely recognised strategy to reduce the risk of cardiovascular disease.

The effect of aerobic exercise on serum lipids has been the focus of most study. Favourable changes in triglycerides, LDL and HDL cholesterol have been reported in men after acute aerobic exercise[12–14] and chronic endurance training.[4] The effect of aerobic exercise on lipid metabolism in women, who have higher HDL cholesterol than men,[15 16] has been less studied. In one study of women no change was seen in HDL cholesterol after aerobic training.[17]

Many women take part in resistance training, either as a supplement or alternative to aerobic training. High intensity resistance training has been reported to improve body composition and strength,[18–20] with no significant change in aerobic capacity.[7 8 21 22] The effect of acute[10] and chronic[22–24] resistance training on lipid metabolism has been studied less than aerobic training, but there are reports of improved lipid profiles in both men and women after high intensity resistance training.[22–24] However, there is a dearth of well controlled studies on the effect of resistance training on lipid metabolism in premenopausal women. Reductions in total and LDL cholesterol have been reported in premenopausal women after resistance training at 70% of one repetition maximum (1-RM).[23] We are aware of only one mixed study of men and women[24] that reported favourable changes in lipid metabolism after a more intense (>80% of 1-RM) resistance training regimen. The results of some studies are difficult to interpret owing to design weaknesses, inadequate control of factors known to influence lipid metabolism, and lack of statistical power. Therefore, the purpose of this investigation was to study the effects of a supervised, intensive (85% of 1-RM) 14 week resistance training regimen on lipid profile and body composition in healthy, sedentary, premenopausal women.

Methods

SUBJECTS
Subjects were recruited by advertising in the campus newspaper and by word of mouth. Fifty women expressed an interest in the study, with 40 of these meeting the criteria for participation. Thirty healthy, sedentary, non-smoking premenopausal women took part in the study. Subjects completed health history and exercise questionnaires. Criteria for inclusion were sedentary lifestyle (no planned physical activity for the previous nine months) and normal menstrual function (10–12 menstrual cycles a year). Each subject was informed of the procedures of the study and gave their informed consent in accordance with the Institutional Review Board of Old Dominion University, Norfolk, VA, USA.

DESIGN
About one week before the start of the 14 week resistance training programme, height and mass were measured, together with skinfold measurements for estimation of the percentage of body fat. A blood sample was obtained by venepuncture for measurement of lipid profile. Baseline strength was assessed by estimated 1-RM resistance exercise stations. Subjects submitted details of their diet over three days for nutritional analysis. They were then matched according to baseline body mass, height, and age and randomly assigned to either the resistance exercise training or sedentary control group. After completion of training, height, mass, body fat percentage, and strength were again measured. Blood samples and three day dietary records were also obtained at this time.

HEIGHT AND BODY MASS
The body mass and height of subjects in exercise clothes without shoes were measured to the nearest 0.1 kg and 0.5 cm, respectively, with a Continental 159.0 kg capacity scale/stadiometer (Continental Scale Corporation, Chicago, IL, USA).

SKINFOLDS
Triceps, suprailium, and anterior thigh skinfolds were measured three times on the right side of the body to the nearest 0.5 mm with a Lange caliper (Cambridge Scientific Instruments, Cambridge, MD, USA). All skinfolds were measured by the same technician (BP). A reliability criterion of 2 mm was established for triplicate measures, and the mean of these measurements was used for analytical purposes. To minimise experimenter bias the technician was unaware of baseline measurements and subsequent calculations until all the data were collected. Body density was estimated by the equation of Jackson, Pollock, and Ward,[25] with subsequent calculation of body fat percentage by the Siri equation.[26]

LIPID PROFILE
Subjects reported to the human performance laboratory between 7 00 am and 10 30 am, 12 hours after eating a meal. Subjects were asked to refrain from strenuous physical activity before blood sampling. Further blood samples were drawn after the study, three days after the last exercise bout, to measure the chronic effect of exercise. Blood samples (10 ml) were collected by venepuncture from an antecubital vein with serum separator tubes (Becton Dickinson, Franklin Lanes, NJ, USA). Samples were centrifuged at 1500 g for 10 minutes, with serum extracted and stored in polypropylene vials at $-20°$C. Before and after training serum total cholesterol, HDL and LDL cholesterol, and triglycerides were measured by enzymatic assay procedures (Laboratory Corporation of America, Norfolk, VA, USA). Interassay coefficients of variation (2.3% and 2.1% for low and high total cholesterol controls, respectively, and 6.5% on an HDL cholesterol control (mean 1.27 mmol/l)) comply with National Cholesterol Education Programme recommendations.[27] Very low density lipoprotein (VLDL) cholesterol and LDL cholesterol were calculated using the following equations[28]:

$$[VLDL\text{-}C] = [TG] \div 5$$
$$[LDL\text{-}C] = [T\text{-}CHOL] - [HDL\text{-}C] - [VLDL\text{-}C]$$

where C = cholesterol; TG = triglycerides.

NUTRITIONAL ANALYSIS
Subjects were instructed not to alter their diets during the study and shown how to maintain a three day dietary record, including a weekend day. They were given instructions about portion size. Dietary data were analysed (Food Processor, Salem, OR, USA) for total calories and fat calories.

MEASUREMENT OF 1-RM
Several familiarisation sessions were carried out for both control and exercise groups before estimation of baseline 1-RM. Each subject took part in only one of the several familiarisation sessions. From the resistance mass and number of repetitions performed, 1-RM was estimated with Power 5.1 software (LJC, Carone Corp, Hudson, FL, USA) before and after training to assess strength in each of eight resistance exercises: leg press, leg extension, leg curl, latissimus dorsi pull, bench press, military press, biceps curl, and triceps extension. Validity coefficients for this software are 0.99 (reported by the manufacturer) and 0.93 (measured in our laboratory). For each exercise a resistance was selected, based on the subject's capability, which would result in fatigue after 8–15 repetitions. If more than 15 repetitions of a resistance could be performed, the resistance mass was increased.

EXERCISE PROTOCOL
The resistance exercise training group took part in a supervised, progressive, 14 week strength training programme, with 45–50 minute sessions three times a week. Subjects were informed that attendance was required at more than 80% of sessions in order to remain in the study. They were asked to refrain from any other physical activity throughout the study. The control group was instructed to avoid structured exercise or activities other than those required for normal daily living throughout the study.

Table 1   Baseline measurements of physical characteristics, and energy intake. Results are shown as means (SD)

Variable	Controls (n=12)	RT* (n=12)
Age (years)	26.0 (6.0)	28.0 (6.0)
Height (cm)	165.0 (7.0)	162.5 (7.0)
Weight (kg)	65.5 (17.3)	66.8 (7.3)
Total calories (kJ)	6699 (1510)	7297 (1774)
Fat calories (kJ)	2067 (644)	2427 (724)

*RT = resistance training.

EXERCISE TRAINING

Training comprised exercises to load the major muscle groups (legs, arms, trunk, and lower back) performed at 85% of 1-RM; 45–50 minute sessions three times a week. Subjects performed two sets of eight repetitions and went to exhaustion on the third set. The rest interval between sets was 30 seconds to one minute. Before training, all subjects were shown the proper technique. The principal investigator (BP) suggested the initial resistance for a given subject based on the subject's body mass. Subjects performed bench press; leg press, extension, and curl; and latissimus dorsi pull using a circuit training machine (DVF, Newport News, VA, USA). Bicep curls, military press, and triceps extension exercises were performed using free weights. A standardised warm up of eight repetitions at 60% of 1-RM for each exercise preceded each training session. Subjects were given an exercise log sheet each week on which was recorded the number of repetitions completed during the third set for each exercise. At the end of each week these data were assessed using Power 5.1 software to generate a new estimated 1-RM for each exercise. Resistance was then increased as necessary to maintain 85% of estimated 1-RM in each muscle group throughout the study. During the course of the study, training resistance was increased two or three times for triceps extension and leg curls; and five or six times for leg press and extension, bench press, latissimus dorsi pull, military press, and biceps curl.

STATISTICAL ANALYSIS

The effects of resistance training on total cholesterol, HDL and LDL cholesterol, triglycerides, body fat percentage, body mass, and estimated 1-RM for each exercise station were analysed by repeated measures analysis of variance using SAS 6.09 PROC GLM.[29] The criterion for main (group, trial) and interaction (group × trial) effects was $\alpha=0.05$, with a Bonferroni adjustment for appropriate post hoc comparisons.

Results

BASELINE CHARACTERISTICS OF THE SUBJECTS

Thirty subjects took part in the study, but the results of six were excluded—one subject from the control group reduced her estimated energy intake compared with baseline; two other control subjects failed to report for blood collection after the study; and three subjects in the resistance exercise training group failed to attend the required 80% of the total exercise sessions. The results are based on the remaining 24 subjects (12 control subjects; 12 from the resistance exercise training group) who
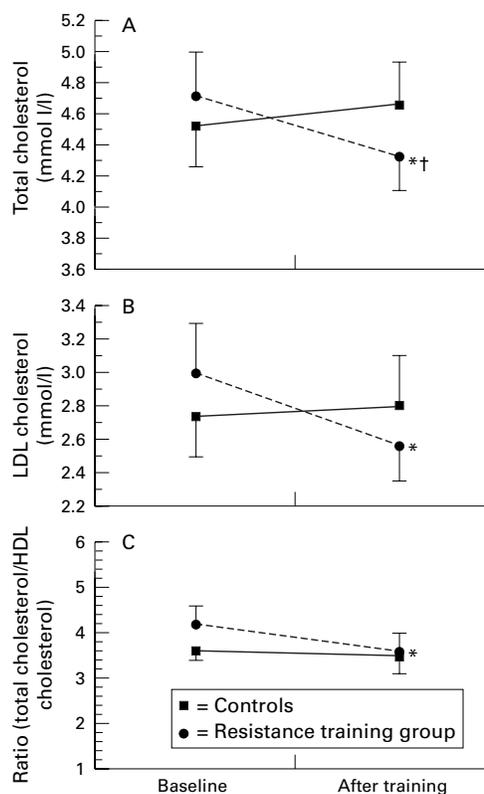

*Figure 1   Effect of resistance training on total cholesterol (A), LDL cholesterol (B), and the total cholesterol/HDL cholesterol ratio (C). *RT-after < RT-baseline; p<0.05; †RT-after < controls after; p<0.05. To convert total cholesterol and LDL cholesterol to mg/dl multiply mmol/l by 38.46.*

completed the study. Table 1 shows the baseline characteristics of the subjects. There were no differences at baseline between the groups in age, body composition, lipids, estimated 1-RM measurements, or intake of total and fat calories.

COMPLIANCE WITH TRAINING

Subjects showed a high degree of compliance with training, completing 39 (1) (mean (SD) 94 (3)%) of the 42 training sessions.

EFFECT OF RESISTANCE TRAINING ON LIPID PROFILE

Fourteen weeks of resistance training resulted in a 9% decrease in total cholesterol (4.68 (0.31) v 4.26 (0.23) mmol/l; p<0.05; fig 1A), 14% decrease in LDL cholesterol (2.99 (0.29) v 2.57 (0.21) mmol/l; p<0.05; fig 1B), and a 14.3% decrease in the total cholesterol/HDL cholesterol ratio (4.20 (0.42) v 3.66 (0.42); p<0.05; fig 1C).

At the end of training the total cholesterol was significantly lower (p<0.05) in the resistance exercise training group than in the control group. In addition, a strong trend towards a

- To convert total cholesterol, LDL cholesterol, and HDL cholesterol to mg/dl, multiply mmol/l by 38.46.
- To convert triglycerides to mg/dl, multiply mmol/l by 87.72.

significant decrease in the LDL to HDL cholesterol ratio (p=0.057, table 2) was seen in the resistance exercise training group. Triglycerides and HDL cholesterol were not significantly changed by training (table 2). No changes were seen in any of these variables in the control group.

EFFECT OF RESISTANCE TRAINING ON BODY MASS AND COMPOSITION

Body mass was not significantly changed in either group. A small, but significant decrease in the body fat percentage was seen in the resistance exercise training group (27.9 (2.09) *v* 26.5 (2.15)%; p<0.05), but was unchanged in the control group. Although resistance training did not significantly change HDL cholesterol, there was a significant correlation (r = −0.77, p=0.0034) between the percentage change in estimated body fat and the percentage change in HDL cholesterol. For all subjects, there was a trend towards a significant association between percentage change in body fat and the percentage change in total cholesterol (r=0.36, p=0.08) and a significant association between percentage change in body fat and the percentage change in HDL cholesterol (r= −0.41, p=0.05).

EFFECT OF RESISTANCE TRAINING ON STRENGTH

After 14 weeks of resistance exercise training, significant increases (p<0.05) in the estimated 1-RM were seen for all eight strength exercises. Total strength, defined as the sum of the estimated 1-RM for eight exercises (Σ1-RM$_{est}$), increased by 27% (mean (SE) sum before training 239 (15.3) kg; mean (SE) sum after training 303 (20.6) kg; p<0.05). Estimated 1-RM in the control group either remained unchanged (leg press and extension, latissimus dorsi pull, bench press, military press, biceps curl) or significantly decreased (leg curl, triceps extension; p<0.05), with a decrease of 5% (−12 (8) kg; p<0.05) in total strength. A significant association was found between the percentage change in total cholesterol and the percentage change in total strength for all subjects (percentage change in Σ1-RM$_{est}$) (r= −0.59, p=0.0026).

NUTRITIONAL INTAKE

Nutritional analysis showed no difference between groups in their intake of total (p=0.40) and fat calories (p=0.22) at baseline. After training, dietary records were returned by only eight subjects in the resistance exercise training group. There was no difference in the intake of total and fat calories between baseline and after training in these eight subjects.

Discussion

The key finding of this study was that 14 weeks of high intensity resistance training significantly decreased total cholesterol, LDL cholesterol, and the total cholesterol/HDL cholesterol ratio in previously sedentary, premenopausal, eumenorrhoeic women. This finding is in agreement with reports of previous resistance training studies. Boyden *et al*[23] reported similar decreases in these variables in

Table 2 Effect of 14 weeks of resistance training on lipid profile and body fat percentage. Results are shown as means (SE)

Variable	Before training	After training	% Change
[T-CHOL] (mmol/l)			
Controls	4.47 (0.29)	4.60 (0.29)	3 ⇑
RT*†	4.68 (0.31)	4.26 (0.23)*†	9 ⇓
[LDL-C] (mmol/l)			
Controls	2.73 (0.23)	2.81 (0.26)	2.5 ⇑
RT*	2.99 (0.29)	2.57 (0.21)*	14 ⇓
[HDL-C] (mmol/l)			
Controls	1.27 (0.05)	1.33 (0.08)	4.7 ⇑
RT	1.20 (0.10)	1.27 (0.10)	5.9 ⇑
[TG] (mmol/l)			
Controls	0.99 (0.10)	1.01 (0.10)	2 ⇑
RT	1.06 (0.13)	0.90 (0.10)	14 ⇓
[LDL-C]/[HDL-C] ratio			
Controls	2.13 (0.20)	2.10 (0.20)	1.4 ⇓
RT‡	2.68 (0.36)	2.26 (0.37)‡	15.7 ⇓
[T-CHOL]/[HDL-C] ratio			
Controls	3.55 (0.22)	3.52 (0.22)	0.8 ⇓
RT*	4.20 (0.42)	3.66 (0.42)*	14.3 ⇓
Body fat percentage			
Controls	25.64 (1.97)	25.65 (2.02)	0.03 ⇓
RT*	27.90 (2.09)	26.51 (2.15)*	5 ⇓

RT = resistance training; T-CHOL = total cholesterol; LDL-C = low density lipoprotein cholesterol; HDL-C = high density lipoprotein cholesterol; TG = triglycerides.
*RT- after < RT-baseline; p<0.05.
†RT- after < controls-after; p<0.05.
‡RT- after < RT-baseline; p=0.057.
To convert [T-CHOL], [LDL-C], and [HDL-C] to mg/dl, multiply mmol/l by 38.46.
To convert [TG] to mg/dl, multiply mmol/l by 87.72.

premenopausal women after resistance training at 70% of 1-RM, a lower intensity than that used in this study. Goldberg *et al*[24] studied a single group of men and women and reported decreased total cholesterol, LDL cholesterol, triglycerides, and decreased ratios of LDL/HDL cholesterol and total/HDL cholesterol after 16 weeks of resistance training at 84% of 1-RM, an intensity similar to that used in this study. The results of this study lend additional support to the hypothesis that chronic resistance training can favourably affect serum lipid profiles in apparently healthy, premenopausal women.

In our study the training was monitored, well controlled, and progressive. Training resistance was increased several times (two or three increases for triceps extension and leg curls; five or six increases for leg press and extension, bench press, latissimus dorsi pull, military press, and biceps curl) over 14 weeks. By comparison, Boyden *et al* increased training resistance only twice over the entire five month study.[23] In contrast with the study of Goldberg *et al*,[24] our study featured a larger sample size, randomised group assignment with a sedentary control group, and focused exclusively on women. Control and training subjects were well matched at baseline for demographic, body composition, lipid, and strength variables. Estimated 1-RM increased significantly in all eight resistance exercises after training while strength decreased in control subjects. For all subjects, a significant association between the percentage change in 1-RM and the percentage change in total cholesterol was found (r= −0.59, p=0.0026). An even stronger association between these variables was found for subjects in the resistance training group (r= −0.86, p=0.0003) compared with the control subjects, where no correlation was found

(r= −0.08, p=0.81). The mean (SD) percentage change in total cholesterol seen in resistance training subjects (−8 (9)%) was similar to that reported in young women after 24 weeks of "brisk walking" (6.4 km/h) which produced a 9% increase in $\dot{V}O_2MAX$.[30]

Most of the research on this issue has concerned the effect of aerobic exercise on lipid profiles. Although $\dot{V}O_2MAX$ was not measured in this study, high intensity resistance training has been reported to have no significant effect on cardiorespiratory fitness in men[7 22] and women.[8 21] These results support the efficacy of resistance training as a stimulus which is effective and comparable with cardiovascular training in favourably altering lipid profiles in previously sedentary, premenopausal, eumenorrhoeic women.

It has been reported that young to middle aged women have higher serum HDL cholesterol and lower LDL cholesterol and triglycerides than their male counterparts.[15 16] These differences between men and women may be due to endogenous or exogenous hormones, or both.[31–33] Although increased serum HDL cholesterol has been reported in men after resistance training,[22] it was not significantly increased in response to the training stimulus used in this study or other studies of female subjects.[23 24] Resistance training regimens of five months at 70% of 1-RM[23] and 16 weeks at 84% of 1-RM[24] failed to increase serum HDL cholesterol in female subjects who had baseline values of 53 mg/dl (1.38 mmol/l) and 77 mg/dl (2.0 mmol/l), respectively. Baseline HDL cholesterol of subjects in our study ((47 mg/dl) 1.27 mmol/l) was greater than the HDL cholesterol after training for the men in the study of Hurley *et al*.[22] Possibly, resistance training is not an effective stimulus to increase HDL cholesterol in women or other subjects with high baseline values.

Decreased body mass and body fat have also been associated with decreased total cholesterol, decreased LDL cholesterol, and increased HDL cholesterol. Body mass was not significantly changed in this study. Other studies have reported no change in body fat after resistance training,[22–24] but the estimated body fat percentage was decreased after resistance training in this study. The lack of a significant association between the percentage change in total cholesterol and the percentage change in body fat (r=0.36, p=0.08) suggests that our finding of decreased total cholesterol after resistance training was not confounded by the modest, but significant decrease in body fat percentage. Although no significant change was observed in HDL cholesterol in this study, the percentage change in HDL cholesterol was significantly associated with a change in body fat percentage (r= −0.41, p=0.05). However, the percentage change in HDL cholesterol was not significantly associated with a percentage change in 1-RM (r= −0.11, p=0.061). In the resistance trained subjects, high correlations were found between the percentage change in HDL cholesterol and the percentage change in body fat (r= −0.77, p=0.003), and the percentage change in total cholesterol and the

percentage change in 1-RM (r= −0.86, p=0.0003). These associations suggest that increased strength may exert a greater influence on decreasing total cholesterol in young women, whereas a decreased percentage body fat may exert a greater influence on any observed increase in HDL cholesterol, a variable which appears to be resistant to change in this group.

Serum triglycerides were not affected by the resistance training in this study, a finding which is in agreement with similar studies of male[34] and female[35] subjects after high intensity resistance training, as well as a study of women after aerobic exercise training.[4] The observed 14% decrease in triglycerides after high intensity resistance training was not significant owing to the large variance in triglycerides. In addition, the percentage change in triglycerides was not significantly associated with the percentage change in body fat (r=0.16, p=0.61) in the resistance exercise training group.

Serum lipids have been reported to vary during the menstrual cycle, with increased total, LDL, and HDL cholesterol during the late follicular phase compared with the late luteal phase.[36–38] These fluctuations are thought to be related in part to cyclical changes in progesterone concentration.[39 40] In our study it was not feasible to obtain samples during the same phase of each subject's menstrual cycle. Although this may be a possible limitation, we believe that the effect of cyclical menstrual fluctuations in lipid profiles, which might be seen as a threat to the validity of our study, was controlled, in part, by the presence of a well matched sedentary control group, in whom there was no change in lipid profile. Recommendations for future studies include within-subject control of the menstrual phase and a resistance training regimen of longer duration.

In summary, significant decreases in total cholesterol, LDL cholesterol, and the total/HDL cholesterol ratio were observed in previously sedentary, eumenorrhoeic, premenopausal women after 14 weeks of well controlled, intense (85% of estimated 1-RM) resistance training which elicited significant increases in strength. HDL cholesterol and triglycerides were not significantly changed after training. Training was also associated with a small, but significant, decrease in estimated body fat percentage, but no change in body mass. In conclusion, intense resistance training appears to be an effective stimulus for favourably altering lipid profiles in this group.

Contributors

Bharathi Prabhakaran was the principal investigator, who trained the subjects, organised the collection of data, and assisted in statistical analysis of the data and preparation of the manuscript. Elizabeth A Dowling assisted in the design of the study, data collection, and manuscript preparation. J David Branch assisted in the collection and statistical analysis of the data, as well as in manuscript preparation. David P Swain and Brian C Leutholtz assisted in the preparation and editing of the manuscript.

1 Castelli WP. Epidemiology of coronary heart disease: the Framingham study. *Am J Med* 1984;**27**:4–12.

2 Thom TJ. Cardiovascular disease mortality in U.S. women. In: Eaker E, Packard B, Wenger N, *et al,* eds. *Coronary heart disease in women.* New York: Haymarket Doyna, 1987:33–41.

3 Adner MM, Castelli WP. Elevated high-density levels in marathon runners. *JAMA* 1980;**243**:534–6.

4 Despres JP, Tremblay A, Moorjani S, *et al.* Long-term exercise training with constant energy intake. 3: Effects on plasma lipoprotein levels. *Int J Obes* 1989;**14**:85–94.

5 Frick MH, Elo O, Haapa K, *et al.* Helsinki heart study: primary-prevention trial with gemfibrozil in middle-aged men with dyslipidemia. *N Engl J Med* 1987;**317**:1237–45.

6 Lamarche B, Despres JP, Poulit MC, *et al.* Is body fat loss a determinant factor in the improvement of carbohydrate and lipid metabolism following aerobic exercise training in obese women? *Metabolism* 1992;**41**:1249–56.

7 Smutok MA, Reece C, Kokkinos PF, *et al.* Aerobic versus strength training for risk factor intervention in middle-aged men at high risk for coronary heart disease. *Metabolism* 1993;**42**:177–84.

8 Blumenthal JA, Matthews K, Fredrikson M, *et al.* Effects of exercise training on cardiovascular function and plasma lipid lipoprotein, and apolipoprotein concentrations in premenopausal and postmenopausal women. *Arterioscler Thromb* 1991;**11**:912–17.

9 Kantor MA, Cullinane EM, Sady SP, *et al.* Exercise acutely increases high density lipoprotein-cholesterol and lipoprotein lipase activity in trained and untrained men. *Metabolism* 1987;**36**:188–92.

10 Wallace MB, Moffatt RJ, Haymes EM, *et al.* Acute effects of resistance exercise on parameters of lipoprotein metabolism. *Med Sci Sports Exerc* 1991;**23**:199–204.

11 Pronk NP, Crouse SF, O'Brien BC, *et al.* Acute effects of walking on serum lipids and lipoproteins in women. *J Sports Med Phys Fitness* 1995;**35**:50–8.

12 Berger GMB, Griffiths MP. Acute effects of moderate exercise on plasma lipoprotein parameters. *Int J Sports Med* 1987;**8**:336–41.

13 Gordon PM, Goss FL, Visich PS, *et al.* The acute effects of exercise intensity on HDL-C metabolism. *Med Sci Sports Exerc* 1994;**26**:671–7.

14 Angelopoulos TJ, Robertson RJ, Goss FL, *et al.* Effect of repeated exercise bouts on high density lipoprotein-cholesterol and its subfractions HDL_2-C and HDL_3-C. *Int J Sports Med* 1993;**14**:196–201.

15 Fulwood R, Kalsbeek W, Rifkind B *et al.* Total serum cholesterol levels of adults 20–74 years of age. *Vital Health Stat 11* 1986:1–59. (United States, 1976–80. National Center for Health Statistics, Series 11, No.236, DHHS publication No (PHS) 86–168, Washington DC, US Government Printing Office.)

16 Wenger N. Hypertension and other cardiovascular risk factors in women. *Am J Hypertens* 1995;**8**:94–9S.

17 Santiago MC, Leon AS, Serfass RC. Failure of 40 weeks of brisk walking to alter body lipids in normolipemic women. *Can J Appl Physiol* 1995;**20**:417–28.

18 Chilibeck PD, Calder AW, Sale DG, *et al.* Twenty weeks of weight training increases lean tissue mass but not bone mineral mass or density in healthy, active young women. *Can J Physiol Pharmacol* 1996;**74**:1180–5.

19 Chilibeck PD, Calder AW, Sale DG, *et al.* A comparison of strength and muscle mass increases during resistance training in young women. *Eur J Appl Physiol* 1998;**77**:170–5.

20 Cullinen K, Caldwell M. Weight training increases fat-free mass and strength in untrained young women. *J Am Diet Assoc* 1998;**98**:414–18.

21 Nakao M, Inoue Y, Murakami H. Longitudinal study of the effect of high intensity weight training on aerobic capacity. *Eur J Appl Physiol* 1995;**70**:20–5.

22 Hurley BF, Hagberg JM, Goldberg AP, *et al.* Resistive training can reduce coronary risk factors without altering VO_2MAX or percent body fat. *Med Sci Sports Exerc* 1988;**20**:150–4.

23 Boyden TW, Pamenter RW, Going SB, *et al.* Resistance exercise training is associated with decreases in serum low-density lipoprotein cholesterol levels in premenopausal women. *Arch Intern Med* 1993;**153**:97–100.

24 Goldberg L, Elliot DL, Schutz RW, *et al.* Changes in lipid and lipoprotein levels after weight training. *JAMA* 1984;**252**:504–6.

25 Jackson AS, Pollock ML, Ward A. Generalized equations for predicting body density of women. *Med Sci Sports Exerc* 1980;**12**:175–82.

26 Siri WE. *Body composition from fluid spaces and density: analysis of methods and techniques for measuring body composition.* Washington DC: National Academy of Science National Research Council, 1961:223–44.

27 National Heart, Lung and Blood Institute. *Current status of blood cholesterol measurement in clinical laboratories in the United States.* (A report from the Laboratory Standardization Panel of the National Cholesterol Education Program, USGPO 88-2928, 1998, Bethesda, MD, USA.)

28 Friedwald WT, Levy RI, Fredrickson DS. Estimation of the concentration of low density lipoprotein cholesterol in plasma without use of the preparation of ultracentrifuge. *Clin Chem* 1972;**18**:499–502.

29 SAS Institute. *SAS/STAT user's guide: the GLM procedure.* Version 6, 4th ed, Vol 2. Cary, NC: SAS Institute, 1989:891–996.

30 Duncan JJ, Gordon, NF, Scott, CB. Women walking for health and fitness. *JAMA* 1991;**266**:3295–9.

31 Wahl P, Walden C, Knopp R, *et al.* Effect of estrogen/progestin potency in lipid/lipoprotein cholesterol. *N Engl J Med* 1985;**308**:862–7.

32 Krauss RM, Lindgren FT, Wingerd J, *et al.* Effects of estrogens and progestins on high density lipoproteins. *Lipids* 1979;**14**:113–18.

33 Srinivasan SR, Sundaram GS, Williamson GD, *et al.* Serum lipoprotein and endogenous sex hormones in early life: observations in children with different lipoprotein profiles. *Metabolism* 1985;**34**:861–7.

34 Kokkinos PF, Hurley BF, Vaccaro P, *et al.* Effects of low- and high-repetition resistive training on lipoprotein-lipid profiles. *Med Sci Sports Exerc* 1988;**20**:50–4.

35 Manning JM, Dooly-Manning CR, White K, *et al.* Effects of a resistive training program on lipoprotein-lipid levels in obese women. *Med Sci Sports Exerc* 1991;**23**:1222–6.

36 Muesing RA, Forman MR, Graubard BI, *et al.* Cyclic changes in lipoprotein and apolipoprotein levels during the menstrual cycle in healthy premenopausal women on a controlled diet. *J Clin Endocrinol Metab* 1996;**81**:3599–603.

37 Cullinane EM, Yurgalvitch SM, Saritelli AL, *et al.* Variations in plasma volume affect total and low-density lipoprotein cholesterol concentrations during the menstrual cycle. *Metabolism* 1995;**44**:965–71.

38 Schijf CP, van der Mooren MJ, Doesburg WH, *et al.* Differences in serum lipids, lipoproteins, sex hormone binding globulin and testosterone between the follicular and the luteal phase of the menstrual cycle. *Acta Endocrinol* 1993;**129**:130–3.

39 Tonolo G, Ciccarese M, Brizzi P, *et al.* Cyclical variation of plasma lipids, apolipoproteins, and lipoprotein(a) during menstrual cycle of normal women. *Am J Physiol* 1995;**269**: E1101–5.

40 Lussier-Cacan S, Xhignesse M, Desmarais JL, *et al.* Cyclic fluctuations in human serum lipid and apolipoprotein levels during the normal menstrual cycle: comparison with changes occurring during oral contraceptive therapy. *Metabolism* 1991;**40**:849–54.

Take home message

Many women engage in resistance (weight) training as a supplement or alternative to aerobic exercise. A high intensity resistance training programme which increased strength was also effective in decreasing total cholesterol and low density lipoprotein cholesterol in premenopausal, apparently healthy women. This type of exercise training appears to be an effective strategy to improve blood lipids and reduce the risk of cardiovascular disease.