Influence of Body Fatness on the Coronary Risk Profile of Physically Active Postmenopausal Women

Hirofumi Tanaka, Christopher M. Clevenger, Pamela P. Jones, Douglas R. Seals, and Christopher A. DeSouza

We have shown previously that endurance-trained postmenopausal runners demonstrate more favorable coronary heart disease (CHD) risk factors compared with age-matched sedentary women. However, the runners exhibited higher levels of physical activity and lower levels of body fatness, both of which can influence CHD risk factors. To gain insight into the influence of body fatness per se, we studied 38 postmenopausal healthy women: 10 swimmers, 10 runners, and nine obese and nine leaner sedentary subjects matched for age, hormone replacement use, and years postmenopause. Swimmers and runners were further matched for exercise training volume (4.5 ± 0.2 *v* 4.6 ± 0.6 h/wk) and relative competitive performance (79% ± 5% *v* 77 ± 3% of age-adjusted world record). Maximal oxygen consumption ($\dot{V}O_2max$) on the treadmill was lower ($P < .01$) in swimmers versus runners. Body mass (65.0 ± 2.0 *v* 59.0 ± 1.3 kg), percent body fat (29% ± 2% *v* 23% ± 2%), and waist circumference (79 ± 3 *v* 71 ± 1 cm) were greater ($P < .01$) in swimmers than in runners. There were no significant differences in total caloric intake or dietary composition between swimmers and runners. Insulin sensitivity (via Bergman's minimal model) and fasting plasma concentrations of total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), triglyceride (TG), glucose, and plasminogen activator inhibitor-1 (PAI-1) activity were not different between the groups. However, plasma high-density lipoprotein cholesterol (HDL-C), HDL_2-C, HDL-C/TC, insulin, fibrinogen, fibrin D-dimer, PAI antigen, tissue plasminogen activator (t-PA) activity, and t-PA antigen levels all were less favorable ($P < .05$) in swimmers versus runners. Daytime, nighttime, and 24-hour systolic blood pressure (SBP) was 6 to 10 mm Hg higher in swimmers compared with runners, but resting blood pressure, 24-hour blood pressure load, and blood pressure variability were not significantly different. Stepwise regression showed that measures of body fatness were the primary independent determinants of most of the metabolic CHD risk factors. When analysis of covariance (ANCOVA) was performed with body fatness as a covariate, differences in CHD risk factors between swimmers and runners were abolished ($P = .18$ to $.90$). We conclude that among endurance-trained postmenopausal women matched for training volume and competitive eliteness, higher total and abdominal body fatness is, in general, associated with a less favorable metabolic CHD risk profile. Thus, high levels of habitual aerobic exercise do not appear to negate the deleterious effects of adiposity on the coronary risk profile of healthy middle-aged and older women.

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THE INCIDENCE OF CORONARY heart disease (CHD) increases with age in women, with the rate of increase being particularly marked after menopause.[1,2] It is estimated that one in nine women aged 45 to 64 years and one in three aged 65 and older have some form of cardiovascular disease.[2] With the marked increase in the number of postmenopausal women predicted for the future, cardiovascular disease, especially CHD, is likely to be even more of a public health problem.

Several epidemiological studies have found that physically active postmenopausal women have a lower incidence of CHD compared with their sedentary peers.[3,4] Although the exact mechanisms underlying this cardioprotection are not fully understood, our recent investigation indicates that postmenopausal women who regularly perform endurance running exercise demonstrate more favorable systolic blood pressure (SBP) and plasma metabolic, androgenic, and hemostatic CHD risk factors than sedentary postmenopausal women.[5,6] However, total body and abdominal fatness, which are independently related to these risk factors, were much lower in the runners than in the sedentary women.[5] Therefore, it is not clear whether physical activity, lower body fatness, or both are associated with the favorable CHD risk factor profile observed in postmenopausal female distance runners.

Accordingly, the experimental aim of the present study was to determine the relation of body fatness to the coronary risk profile of physically active postmenopausal women. To address this, we studied groups of postmenopausal runners and swimmers carefully matched for endurance exercise training volume and age-adjusted competitive performance but differing in abdominal and total body fat levels.

SUBJECTS AND METHODS

Subjects

Thirty-eight healthy postmenopausal women were studied: 10 endurance-trained swimmers, 10 distance runners, nine obese sedentary, and nine leaner sedentary subjects. All women were at least 2 years postmenopausal. The women in the four groups were similar with respect to age, use of hormone (estrogen) replacement therapy, and years postmenopausal.

The swimmers and runners were further matched according to their respective age-adjusted world-best performance times and endurance exercise training volume (ie, training duration × training frequency; Table 1). Swimmers and runners had been performing their respective types of endurance exercise training for at least the past 2 years, and

From the Human Cardiovascular Research Laboratory, Center for Physical Activity, Disease Prevention, and Aging, Department of Kinesiology and Applied Physiology, University of Colorado at Boulder, Boulder; and Department of Medicine, Divisions of Cardiology and Geriatric Medicine, University of Colorado Health Sciences Center, Denver, CO.

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Address reprint requests to Hirofumi Tanaka, PhD, University of Colorado at Boulder, Department of Kinesiology, Campus Box 354, Boulder, CO 80309-0354.

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Table 1. Subject Characteristics

Variable	Sedentary		Endurance-Trained	
	Obese (n = 9)	Leaner (n = 9)	Swimmers (n = 10)	Runners (n = 10)
Age (yr)	61 ± 2	62 ± 2	59 ± 2	58 ± 2
Height (cm)	166 ± 3	160 ± 3	167 ± 2†	168 ± 1†
Body mass (kg)	77.3 ± 2.3	64.6 ± 3.8*	65.0 ± 2.0*‡	59.0 ± 1.3*
BMI (kg/m^2)	28.2 ± 1.2	25.0 ± 0.9*	23.3 ± 0.9*	21.0 ± 0.2*†
$\dot{V}O_2$max (L/min)	1.6 ± 0.1	1.5 ± 0.1	2.0 ± 0.1*†‡	2.4 ± 0.1*†
$\dot{V}O_2$max (mL/kg/min)	21.1 ± 1.6	22.8 ± 1.4	30.7 ± 2.1*†‡	40.0 ± 1.9*†
Current HRT use (%)	44	44	50	50
Years postmenopausal	13 ± 2	8 ± 2	10 ± 3	8 ± 2
Years of training	NA	NA	13 ± 2	18 ± 2
Training (h/wk)	NA	NA	4.5 ± 0.2	4.6 ± 0.6
Relative performance (%)	NA	NA	79 ± 5	77 ± 2

Abbreviation: HRT, hormone replacement therapy; relative performance, % of age-adjusted world-best performance time for respective events; NA, not applicable.

*$P < .05$ *v* obese sedentary women.

†$P < .05$ *v* leaner sedentary women.

‡$P < .05$ *v* runners.

were actively competing in swimming meets and running road races, respectively. The swimmers and runners were recruited from age-group top 10 finishers in the US Masters Swimming National Championships and a local, national-class road race (Bolder Boulder 10-km race), respectively. It should be emphasized that although most swim events last less than 2 minutes, swimming training per se is considered endurance exercise training due to its sustained nature.[7]

The women in the sedentary groups had performed no regular endurance exercise for at least 1 year. The sedentary groups were divided into obese (body fat >40%) and leaner (<40%) groups. In the present study, sedentary subjects were included solely to represent "reference" values for key outcome variables in our region of the United States.

All subjects were free of overt cardiovascular disease as assessed by medical history questionnaire, physical examination, and resting and maximal exercise electrocardiograms. None of the subjects smoked or took medications other than hormone replacement. Before participation, a verbal and written explanation of the procedures and potential risks was administered. All subjects provided written informed consent to participate. The study was reviewed and approved by the Human Research Committee of the University of Colorado at Boulder.

Body Mass and Composition

Body mass was measured with a balanced laboratory scale (Detecto, Webb City, MO) to the nearest 0.1 kg. The body mass index (BMI) was calculated according to the formula, body mass (kg)/height (m^2). Body composition was determined by the hydrostatic weighing technique as previously described in detail.[8] Immediately before hydrostatic weighing, residual lung volume was determined outside the weighing tank by the oxygen dilution method. Body fat percentage was subsequently estimated from body density using the equations of Brozek et al.[9] Fat mass was calculated as the product of body fat percentage and body mass. Lean body mass was calculated as body mass minus fat mass. The waist to hip ratio was determined using a nonelastic tape (Lafayette Instruments, Lafayette, IN) to the nearest 1 mm with the subject in a standing position. The waist circumference was measured at the umbilicus, and hip circumference was determined at the maximum circumference of the buttocks. The measurement was obtained at each circumference site in duplicate by the same investigator.

Maximal Oxygen Consumption

Maximal oxygen consumption ($\dot{V}O_2$max) was assessed with on-line computer-assisted open-circuit spirometry during incremental treadmill exercise as described in detail previously.[10] Briefly, after a 6- to 10-minute warm-up period, each subject ran or walked at a comfortable speed that corresponded to 70% to 80% of age-predicted maximal heart rate. The treadmill grade was increased 2.5% every 2 minutes until volitional exhaustion. To ensure that each subject attained a valid $\dot{V}O_2$max, at least three of the following four criteria were met by each subject: (1) plateau in $\dot{V}O_2$ with increasing exercise intensity, (2) respiratory exchange ratio of at least 1.15, (3) achievement of age-predicted maximal heart rate (±10 bpm), and (4) rating of perceived exertion of at least 18 U.[11]

Dietary Intake

Dietary data were collected using 3-day food intake records (2 weekdays and 1 weekend day). Subjects were instructed to continue their customary eating habits during these 3 days. Foods were weighed and recorded in household measures. The dietary records were analyzed for nutrient content by a registered dietitian using the Nutritionist IV analysis program (N-Squared Computing, Salem, OR).

Metabolic Risk Factors

An intravenous glucose tolerance test (IVGTT) and measurements of plasma lipid and lipoprotein, fibrinogen, glucose, and insulin concentrations were obtained in the General Clinical Research Center at the University of Colorado Health Sciences Center as described previously in detail by our laboratory.[5] Briefly, a blood sample was drawn from an antecubital vein after abstinence from caffeine and an overnight fast of at least 12 hours. In addition, all measurements were performed 24 to 48 hours after the last exercise session to avoid the immediate effects of a single bout of exercise. Plasma total cholesterol (TC) and triglyceride (TG) levels were analyzed with conventional enzymatic methods. Plasma high-density lipoprotein cholesterol (HDL-C) and HDL_3-C concentrations were determined by the dextran precipitation technique. Plasma HDL_2-C was calculated as the arithmetic difference between plasma HDL-C and HDL_3-C. Low-density lipoprotein cholesterol (LDL-C) was subsequently determined from the following equation: LDL = TC − HDL − TG/5.[12] No subject had a TG value greater than 4.5 mmol/L.

After a blood sample for plasma lipids, lipoproteins, and fibrinogen was obtained, a frequently sampled IVGTT was performed according to the method of Bergman.[13] Briefly, glucose (0.3 g/kg) was injected intravenously at time 0, and insulin (0.025 U/kg) was injected at 20 minutes. Twenty-eight blood samples were obtained between 0 and 180 minutes for glucose and insulin measurements. Indices of insulin sensitivity (S_I) and glucose effectiveness (S_G) were calculated by computer analysis using Bergman's minimal model of insulin action.[13] Plasma glucose was determined using a hexokinase/glucose-6-phosphate dehydrogenase method. Plasma insulin was determined by a solid-phase radioimmunoassay.

Blood samples for tissue-type plasminogen activator (t-PA) and plasminogen activator inhibitor type-1 (PAI-1) were drawn with minimal venostasis between 8 and 11 AM to avoid diurnal variation in fibrinolytic variables as described in detail previously.[14] Total t-PA antigen, total PAI-1 antigen, and fibrin D-dimer were determined by an enzyme-linked immunosorbent assay (American Bioproducts, Parsippany, NJ). Total t-PA activity and PAI-1 activity were determined by an amidolytic method (Chromogenix, Franklin, OH). Plasma fibrinogen levels were determined using the Clauss method for clottable fibrinogen.[15]

Blood Pressure

Casual blood pressure was measured by a conventional mercury sphygmomanometer after at least 10 minutes of rest under quiet, comfortable laboratory conditions. All casual blood pressure measurements were taken according to guidelines established by the American Heart Association[16] while subjects were in the sitting position. To eliminate the effects of postexercise hypotension,[17] all casual blood pressure measurements in trained subjects were obtained about 20 hours after the last bout of exercise.

Arterial blood pressure throughout a 24-hour period of normal activity was measured using a noninvasive ambulatory blood pressure monitor (model 90207; Spacelabs, Redlands, WA) as described in detail previously.[18] The ambulatory system was programmed to inflate automatically every 15 minutes between 6 AM and 11 PM and every 20 minutes between 11 PM and 6AM. To reduce noise, subjects were instructed to pause momentarily at the time of each measurement and to relax their arm. Data from the ambulatory monitors were analyzed using the Spacelabs analysis software package as described previously.[18] SBP and diastolic blood pressure (DBP) variabilities were assessed as the standard deviations of the individual BP recordings, and SBP load (percent of SBP recordings exceeding 140 mm Hg) and DBP load (percent of DBP recordings exceeding 90 mm Hg) were also determined. Ambulatory blood pressure recordings for the trained women were made on a nonexercise day.

Statistics

Data were analyzed using one-way ANOVA. When indicated by a significant F value, a post hoc test using the Newman-Keuls method was performed to identify significant differences among group means. To gain insight into the influence of body fatness on cardiovascular risk factors among endurance-trained subjects (swimmers and runners), we performed univariate and stepwise multiple regression analyses. Moreover, analysis of covariance (ANCOVA) was performed using body fatness measures (BMI, percent body fat, waist circumference, or waist to hip ratio) or $\dot{V}O_2$max as covariates among endurance-trained subjects. The probability level of statistical significance was set at P less than .05 in all comparisons. Descriptive statistics are expressed as the mean ± SE.

RESULTS

Subject Characteristics

Table 1 describes the physical characteristics of the four subject groups. The four groups were not different in age, years postmenopause, or use of hormone replacement therapy. The body mass of swimmers and sedentary controls was higher ($P < .05$) than that of runners. Obese sedentary women had a higher body mass than leaner sedentary women. $\dot{V}O_2$max was lower in swimmers than in runners, but both were higher than in either obese or leaner sedentary women ($P < .001$). There were no significant differences in the percent of age-adjusted world-best times of respective events, training volume, or years of training between swimmers and runners. When the subjects were divided into users (n = 18) and nonusers (n = 20) of hormone replacement, there were no significant group differences in any CHD risk factors except plasma fibrinogen (2.86 ± 0.08 *v* 2.51 ± 0.09 g/L in users *v* nonusers, $P < .01$).

Body Composition

Table 2 shows the body composition and body fat distribution of the four groups. The percent body fat was higher in swimmers than in runners but lower than in the obese sedentary women. The body fat mass of the swimmers was about 40% higher ($P < .05$) than that of the runners, but was lower than that of the obese sedentary women ($P < .01$). Swimmers and runners had higher ($P < .05$) fat-free mass compared with either obese or leaner sedentary controls. Waist circumference and the waist to hip ratio of the swimmers were higher than those of the runners ($P < .05$). Body composition and body fat distribution were similar in the swimmers and leaner sedentary women, except for the fat-free mass and waist to hip ratio.

Estimated Dietary Intake

Total caloric intake was higher in swimmers and runners compared with leaner sedentary controls (Table 3). Absolute levels of carbohydrate intake were higher in runners than in leaner sedentary women ($P < .05$). The protein and fat intake of the swimmers were higher than that of the leaner sedentary subjects ($P < .05$). There were no significant differences in total caloric intake and dietary composition between swimmers and runners.

Metabolic Risk Factors

Plasma TC and LDL-C concentrations of the swimmers, runners, and leaner sedentary controls were similar, but were lower ($P < .05$) than levels in obese sedentary controls (Fig 1). Plasma HDL-C levels for swimmers were lower ($P < .05$) than for runners, and were not different from the sedentary controls. The lower total HDL-C levels in swimmers versus runners were associated with lower ($P < .05$) HDL_2-C and HDL_3-C concentrations. The plasma HDL-C to TC ratio of the swimmers was lower (less favorable) than that of the runners, but higher

Table 2. Body Composition and Body Fat Distribution of the Four Groups

Variable	Sedentary		Endurance-Trained	
	Obese (n = 9)	Leaner (n = 9)	Swimmers (n = 10)	Runners (n = 10)
Body fat (%)	46 ± 2	34 ± 1*	29 ± 2*‡	23 ± 2*†
Fat mass (kg)	35.5 ± 1.9	22.5 ± 2.0*	19.5 ± 2.2*‡	13.8 ± 1.1*†
Fat-free mass (kg)	41.8 ± 1.8	42.2 ± 2.0	45.5 ± 0.8*†	45.2 ± 1.3*†
Waist circumference (cm)	93.5 ± 2.5	84.7 ± 2.5*	78.7 ± 2.8*‡	71.4 ± 1.1*†
Hip circumference (cm)	112.3 ± 2.7	100.6 ± 3.0*	99.8 ± 1.6*	96.8 ± 1.6*
Waist to hip ratio	0.83 ± 0.02	0.85 ± 0.02	0.79 ± 0.02†‡	0.74 ± 0.01*†

*$P < .05$ *v* obese sedentary women.

†$P < .05$ *v* leaner sedentary women.

‡$P < .05$ *v* runners.

Table 3. Estimated Dietary Intake of the Four Groups

Variable	Sedentary		Endurance-Trained	
	Obese (n = 9)	Leaner (n = 9)	Swimmers (n = 10)	Runners (n = 10)
Calories				
kcal	1,906 ± 66	1,613 ± 102	2,206 ± 153*	2,143 ± 191*
kcal/FFM	44.1 ± 2.2	39.4 ± 3.1	48.2 ± 2.7	47.6 ± 4.4
Carbohydrate				
kcal	1,065 ± 106 (55)	933 ± 44 (57)	1,084 ± 57 (49)	1,234 ± 123 (58)*
kcal/FFM	24.7 ± 2.8	22.6 ± 1.1	23.8 ± 1.1	27.3 ± 2.7
Protein				
kcal	291 ± 13 (15)	254 ± 16 (16)	358 ± 46 (16)*	326 ± 24 (15)
kcal/FFM	6.8 ± 0.5	6.1 ± 0.4	7.8 ± 0.9	7.2 ± 0.6
Fat				
kcal	572 ± 55 (30)	443 ± 60 (27)	711 ± 60 (32)*	587 ± 50 (27)
kcal/FFM	13.1 ± 1.3	11.1 ± 1.7	15.6 ± 1.2	13.2 ± 1.4

NOTE. Parentheses show the % of total calories.
Abbreviation: FFM, fat-free mass.
*$P < .05$ *v* leaner sedentary women.

($P < .05$) than that of the obese sedentary controls. There was no significant difference in the ratio between swimmers and leaner sedentary women. Plasma TG levels of the swimmers, runners, and leaner sedentary controls were similar, but were lower ($P < .05$) than those of the obese sedentary women.

Fasting concentrations of plasma insulin were about 65% higher ($P < .05$) in swimmers than in runners (Fig 2). The runners had lower ($P < .05$) plasma insulin levels than both sedentary groups. There were no significant group differences in fasting plasma glucose concentrations. There was no significant difference in S_I between swimmers and runners. Both swimmers and runners had a higher ($P < .05$) S_I than both sedentary groups, whereas S_G was not significantly different among the four groups. When ANCOVA was performed using body fatness measures as covariates, the differences in metabolic risk factors between swimmers and runners were no longer significant ($P = .18$ to $\sim.90$). In contrast, when these metabolic factors were covaried for $\dot{V}O_2$max, group differences remained significant ($P < .05$).

Plasma Hemostatic Risk Factors

Plasma fibrinogen levels in the swimmers were higher ($P < .05$) than in the runners, and were not different from the leaner sedentary controls (Fig 3). Plasma fibrin D-dimer levels for swimmers were about 25% higher ($P < .05$) than for runners, and were similar to values in the sedentary women. Both swimmers and runners had similarly lower ($P < .05$) plasma PAI-1 activity and PAI-1 antigen concentrations than the obese sedentary women; however, PAI-1 antigen was about 150% higher ($P < .05$) in swimmers than in runners. The mean plasma t-PA activity was about 40% lower ($P < .05$) in swimmers than in runners, but was not different from the sedentary controls. Total plasma t-PA antigen concentrations were about 55% higher ($P < .05$) in swimmers than in runners, but were lower ($P < .05$) than in obese sedentary controls. The group differences in plasma hemostatic risk factors between swimmers and runners were no longer significant ($P = .25$ to $\sim.47$) when ANCOVA was performed using body fatness measures as covariates. In contrast, when these plasma hemostatic factors were covaried for $\dot{V}O_2$max, group differences remained significant ($P < .05$).

Blood Pressure

Casual resting blood pressure and 24-hour ambulatory blood pressure are presented in Table 4. Blood pressure at rest was not significantly different among the four groups, although SBP tended to be lower in runners versus obese sedentary women. Daytime, nighttime, and 24-hour SBP levels were 5 to 8 mm Hg higher in swimmers and both sedentary groups compared with runners. Blood pressure variability and blood pressure loads did not differ among the four groups (not presented).

Relation of CHD Risk Factors to Body Fatness

In the physically active women (pooled swimmers and runners), significant ($P < .05$) univariate correlations were observed for BMI versus plasma concentrations of HDL-C ($r = -.53$), TG (.52), HDL-C/TC (−.72), fasting insulin (.70), t-PA activity (−.47), and t-PA antigen (.78); percent body fat versus LDL-C (.45), HDL-C/TC (−.45), fasting insulin (.64), t-PA antigen (.73), and fibrinogen (.56); waist circumference versus TG (.44), HDL-C/TC (−.59), fasting insulin (.89), t-PA antigen (.85), and fibrinogen (.44); and waist to hip ratio versus HDL-C/TC (−.49), insulin (.80), and t-PA antigen (.66).

The results of the stepwise multiple regression analysis are presented in Table 5. Among the physically active women, percent body fat and BMI were the primary independent determinants of plasma levels of HDL-C, HDL_2-C, TG, LDL-C, HDL-C/TC ratio, fibrinogen, and t-PA activity. Abdominal fatness, as estimated by waist circumference, was the primary predictor of fasting insulin and t-PA antigen levels, explaining greater than 70% of the variability in each case. The waist to hip ratio was the primary, albeit modest, determinant of nighttime SBP variability ($R^2 = .28$), DBP variability ($R^2 = .15$), and SBP load ($R^2 = .22$). No body fatness measures entered for the other blood pressure variables. Similar relations between body fatness and cardiovascular risk factors were observed in the overall pooled population (active women plus sedentary controls).

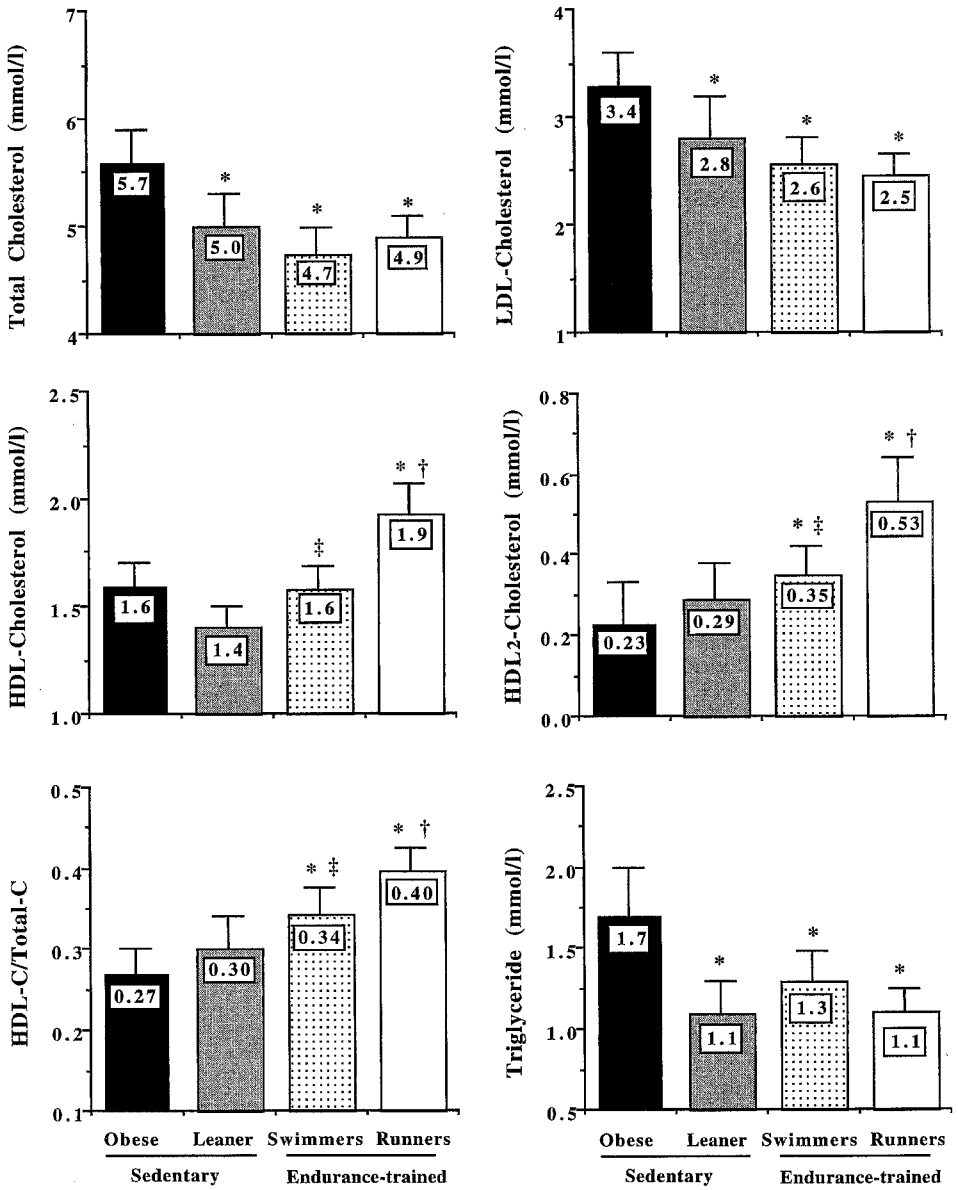

Fig 1. Fasting plasma concentrations of lipids and lipoproteins in the 4 groups. *$P < .05$ *v* obese sedentary control; †$P < .05$ *v* leaner sedentary control; ‡$P < .05$ *v* runners.

DISCUSSION

To our knowledge, this is the first study to determine the relation between body fatness and CHD risk factors among physically active postmenopausal women. We were successful in matching our two groups of endurance-trained women for age, fat-free mass, hormone replacement use, years postmenopause, competitive performance ranking, and endurance exercise training volume. This allowed us to isolate, as much as possible in a cross-sectional study design, the influence of adiposity in that the runners and swimmers differed significantly in both total body and abdominal fat levels. The primary finding from the present study is that higher total and abdominal body fatness is associated with a less favorable metabolic CHD risk profile even among highly physically active postmenopausal women.

Dyslipidemia, elevated fasting plasma glucose and insulin concentrations, hypercoaguability and hypofibrinolysis, and elevated arterial blood pressure all are known to contribute to the age-related increase in CHD risk in women.[2,19-22] In our recent studies,[5,6] we demonstrated that in general, these elements of the CHD risk profile are more favorable in highly active (runners) compared with sedentary but healthy postmenopausal women. However, in addition to high levels of physical activity, the runners also had much lower levels of total and abdominal body fatness, and these measures of adiposity were consistently correlated with the other CHD risk factors in our pooled population analyses. As such, the influence of body fatness on the CHD risk profile of the active women, independent of habitual exercise, could not be determined. The present findings extend our previous observations by demonstrating that among regularly exercising postmenopausal females, higher total and abdominal adiposity is associated with a less favorable CHD risk factor profile, particularly for metabolic and hemostatic risk factors. Interestingly, when we compared swimmers with leaner sedentary controls who had similar body fatness, the CHD risk factor profile was similar despite the highly active

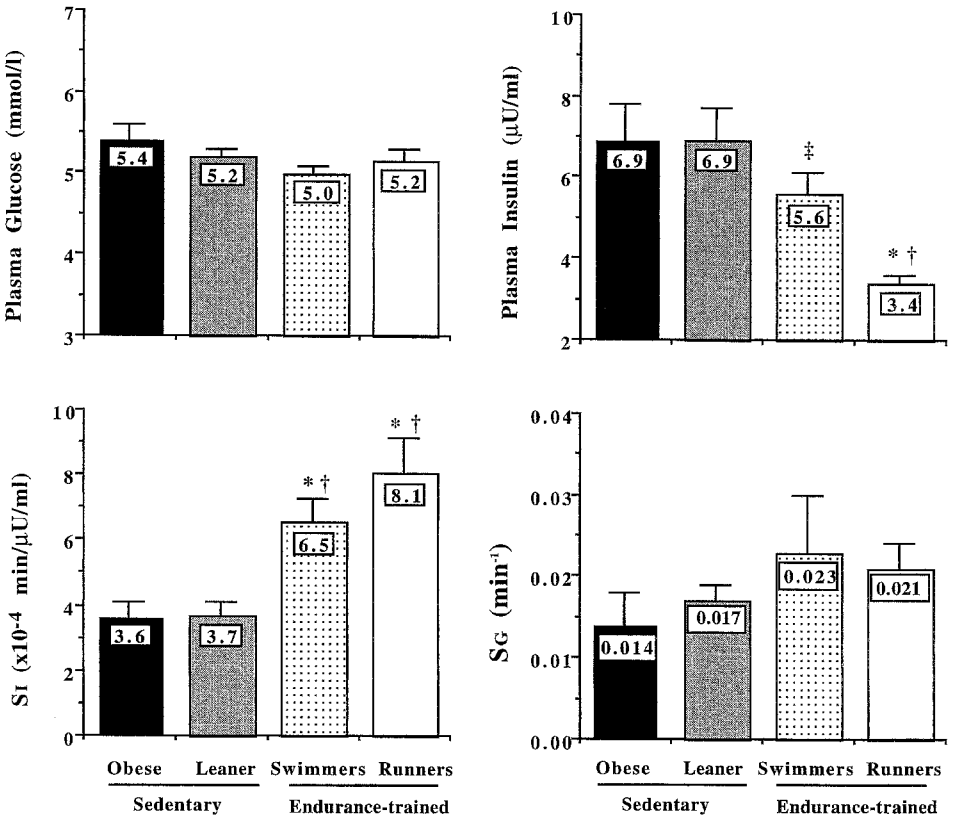

Fig 2. Fasting plasma concentrations of glucose and insulin, S_I, and S_G in the 4 groups. *$P <$ .05 *v* obese sedentary control; †$P <$ .05 *v* leaner sedentary control; ‡$P <$ .05 *v* runners.

life-style of swimmers. Taken together, our data support a strong relation of body fatness to the coronary risk profile among healthy postmenopausal women.

In the present study, the higher adiposity in swimmers was associated with lower plasma HDL-C and HDL_2-C concentrations and a lower HDL-C/TC (atherogenic risk) ratio compared with the runners. Moreover, the fasting plasma insulin concentration, insulin sensitivity index (S_I), and hemostatic risk factors were less favorable in swimmers. Multiple regression analysis showed that total body and/or abdominal adiposity was the primary predictor(s) of these risk factors among the active women. Furthermore, when ANCOVA was performed using body fatness measures as covariates, these group differences were no longer significant. Taken together, these observations are consistent with those previously reported in sedentary populations,[23-25] and demonstrate that the physiological relations between body fatness and these metabolic and hemostatic risk factors for CHD are maintained even in the presence of high habitual levels of endurance exercise. Stated another way, at least in healthy postmenopausal women, high levels of habitual aerobic exercise do not appear to negate the deleterious effects of adiposity on the coronary risk profile.

Caloric intake and dietary composition have been reported to influence the CHD risk factor profile.[26] Therefore, it is reasonable to speculate that dietary intake, in addition to body fatness, may have contributed to the less favorable CHD risk factors in swimmers compared with runners. However, no significant group differences were observed in total caloric intake and the absolute level or percent of carbohydrate, fat, and protein intake. In addition, stepwise multiple regression showed that the dietary factors did not explain a significant portion of the variance in CHD risk factors. Although food intake records are a relatively crude measure, these results suggest that dietary factors did not contribute significantly to group differences in CHD risk factors observed in the present study.

In contrast, plasma TC, LDL-C, and glucose concentrations were not different between the two endurance-trained groups, nor did arterial blood pressure–related CHD risk factors consistently differ, although there was a tendency for 24-hour SBP to be higher in the swimmers. The results of our univariate and multiple regression analyses support these findings, showing at most only weak relations between these risk factors and body fatness among the active women. These observations are consistent with previous findings in sedentary subjects suggesting that body fatness is at best a weak correlate of these CHD risk factors in women.[6,25,27-29]

Epidemiological studies have demonstrated that higher body fatness is strongly associated with impaired insulin sensitivity in sedentary women.[25] As such, we hypothesized that body fatness would be associated with insulin sensitivity in physically active postmenopausal women. Our results fail to support this hypothesis. Rather, our data support and extend previous findings in young adult males suggesting that adiposity is not the determining factor for the increased insulin sensitivity among endurance-trained men.[30] Thus collectively, the present findings and the previous report in men[30] suggest that insulin sensitivity is not strongly related to body fatness among endurance-trained adult humans.

There are at least two possible limitations in the present study that should be emphasized. First, despite our substantial efforts to match the two endurance-trained groups for potential con-

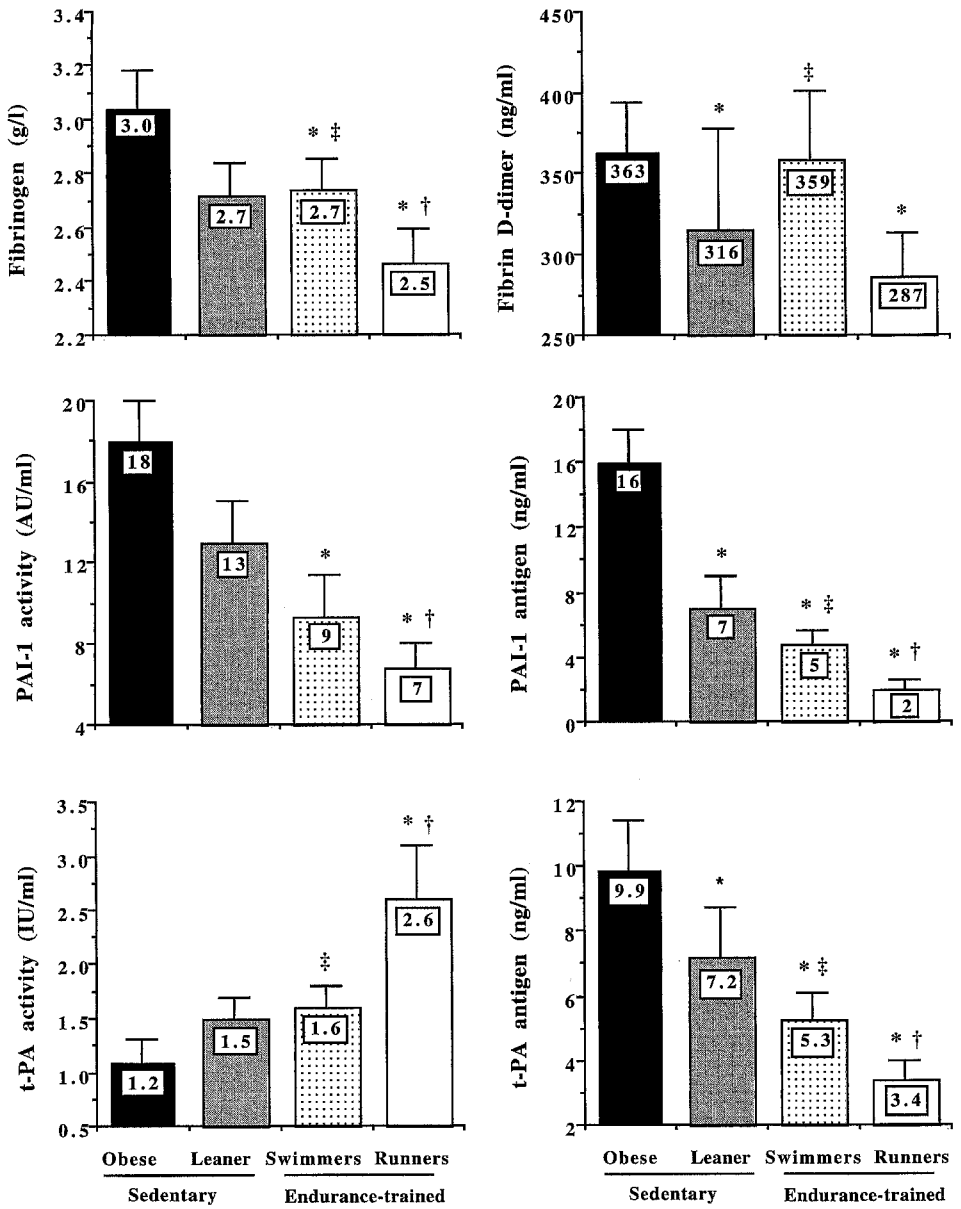

Fig 3. Fasting plasma concentrations of hemostatic risk factors in the 4 groups. *$P < .05$ *v* obese sedentary control; †$P < .05$ *v* leaner sedentary control; ‡$P < .05$ *v* runners.

Table 4. Casual Resting and Ambulatory Blood Pressure (mm Hg) of the Four Groups

Variable	Sedentary		Endurance-Trained	
	Obese (n = 9)	Leaner (n = 9)	Swimmers (n = 10)	Runners (n = 10)
Resting blood pressure				
Sitting SBP	118 ± 4	113 ± 5	115 ± 6	111 ± 4
DBP	77 ± 3	74 ± 2	75 ± 3	73 ± 3
24-Hour blood pressure				
24-hour SBP	123 ± 3	122 ± 3	123 ± 4	115 ± 2
DBP	69 ± 2	72 ± 2	72 ± 2	71 ± 2
Daytime SBP	128 ± 3	125 ± 3	127 ± 4	120 ± 3
DBP	73 ± 2	75 ± 3	75 ± 2	76 ± 3
Nighttime SBP	112 ± 3	112 ± 4	110 ± 3	104 ± 3
DBP	60 ± 1	64 ± 3	62 ± 2	62 ± 3

founds, inherent in the cross-sectional nature of our design is the possibility that genetic or other constitutional factors may have influenced one or more of the CHD risk factors studied, independent of body fatness. Second, in addition to differences in body fatness, the swimmers had a lower $\dot{V}O_2$max, which could have been related to their less favorable CHD risk factor profile compared with the runners. However, we think this unlikely because (1) there is no obvious physiological link between $\dot{V}O_2$max and the CHD risk factors in question—any such relation observed in pooled sedentary and active populations is likely due to the higher exercise levels of subjects with a high $\dot{V}O_2$max, which is not the case in the present study; (2) $\dot{V}O_2$max failed to explain a significant amount of the variability in most of the risk factors among endurance-trained women; and (3) previous investigations, including our own,[5,6,31,32] have

Table 5. Stepwise Multiple Regression Analysis Depicting Independent Predictors of CHD Risk Factors in the Overall Population and in the Subpopulation Using Swimmers and Runners

CHD Risk Factors	Swimmers and Runners		Pooled Subjects	
	No. 1 Predictor (R^2)	No. 2 Predictor (R^2)	No. 1 Predictor (R^2)	No. 2 Predictor (R^2)
TC	*		BMI (.18)	Weight (.31)
HDL-C	BMI (.28)		WHR (.21)	CHO (.33)
HDL_3-C	WHR (.34)		WHR (.32)	
HDL_2-C	BMI (.20)		*	
TG	BMI (.27)	% Body fat (.44)	*	
LDL-C	% Body fat (.20)		% Body fat (.23)	
HDL-C/TC	BMI (.52)		WHR (.27)	CHO (.35)
Fasting glucose	CHO (.32)		BMI (.20)	
Fasting insulin	Waist (.79)		BMI (.45)	WHR (.56)
SI	$\dot{V}O_2$max (.35)		$\dot{V}O_2$max (.34)	
SG	*		*	
Fibrinogen	% Body fat (.32)		% Body fat (.24)	
Fibrin D-dimer	*		*	
PAI activity	*		$\dot{V}O_2$max (.41)	
PAI antigen	$\dot{V}O_2$max (.33)		BMI (.44)	CHO (.51)
t-PA activity	BMI (.22)		BMI (.34)	
t-PA antigen	Waist (.73)		BMI (.64)	

NOTE. R^2 for no. 2 predictor is the cumulative variance explained by all significant predictors.
Abbreviations: WHR, waist to hip ratio; CHO, dietary carbohydrate intake.
*No significant predictors.

failed to demonstrate that $\dot{V}O_2$max, independent of body fatness, is consistently correlated with these CHD risk factors; rather, exercise training volume appears to be a much stronger predictor.[33] Nevertheless, we cannot dismiss the possibility that high levels of $\dot{V}O_2$max and favorable levels of these CHD risk factors are part of the same phenotype among active postmenopausal women and therefore may have influenced our results.

We believe that the present findings have at least two important physiological and clinical implications. First, our results suggest that vigorous and prolonged endurance exercise training alone does not ensure the most favorable levels of CHD risk factors in the present population; rather, body fatness and possibly other influences can be associated with a less favorable risk profile among equally active postmenopausal women. Second, our findings provide further support for the concept of "metabolic fitness" as described previously by Despres et al.[34,35] This concept proposes in part that improvements in metabolic risk factors for CHD associated with the physically active state are dependent on reductions in body fatness. For example, among previously sedentary obese middle-aged women who exercised for 14 months, reductions in total and abdominal body fat were significantly and consistently correlated with exercise training–induced improvements in carbohydrate and lipid metabolism, whereas increases in $\dot{V}O_2$max were not.[36] The present results extend this idea to regularly exercising postmenopausal women.

In conclusion, the present findings indicate that among endurance-trained postmenopausal women matched for training volume and age-adjusted competitive eliteness, higher total and abdominal body fatness is, in general, associated with a less favorable metabolic CHD risk profile. Thus, high levels of habitual aerobic exercise do not appear to negate the deleterious effects of adiposity on the coronary risk profile of healthy middle-aged and older women.

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