Journal of Gerontology: MEDICAL SCIENCES
2000, Vol. 55A, No. 10, M607–M612

Determinants of Body Composition in Postmenopausal Women

James M. Hagberg,[1,2] Joseph M. Zmuda,[1] Steve D. McCole,[1,3] Kathleen S. Rodgers,[2] Kenneth R. Wilund,[2] and Geoffrey E. Moore[1]

[1]Division of Cardiology, University of Pittsburgh Medical Center, Pennsylvania.
[2]Department of Kinesiology, University of Maryland, College Park.
[3]Department of Human Kinetics, University of Wisconsin–Milwaukee.

Background. Little is known about the effects of different levels of long-term physical activity on total body and regional fat and whether hormone replacement therapy interacts with physical activity level to affect body composition in postmenopausal women.

Methods. We determined the associations between different levels of habitual physical activity, hormone replacement therapy (HRT), and total and regional body composition in postmenopausal women. Twenty sedentary, 20 active nonathletic, and 23 endurance-trained women (approximately half on HRT) had total and regional body composition assessed by dual-energy x-ray absorptiometry. The athletes and active nonathletic women had been active for the same number of years and the same number of hours per week.

Results. The athletes and sedentary women weighed the same, but the active nonathletic groups on and not on HRT weighed 3–12 kg more ($p < .05$). Athletes had less trunk, arm, leg, and total body fat than sedentary and active nonathletic women ($p < .05$). Women on HRT tended to have lower total body ($p = .07$), but not regional, fat values. Linear regression analyses indicated that $\dot{V}O_2$max in ml/kg/min was the major independent determinant of total and regional body fat accounting for 52% to 70% of their variances. Athletes had greater caloric and carbohydrate intake than their less active peers, but all groups had similar protein, fat, saturated fat, monounsaturated fat, and polyunsaturated fat intakes.

Conclusions. Intense training, but not low- to moderate-intensity physical activity, is associated with markedly lower levels of total and regional body fat in postmenopausal women. HRT has less of an effect on body composition than intense exercise training in postmenopausal women.

NUMEROUS systems are affected by the hormonal alterations that occur with menopause in women. One of the more important changes that occurs with menopause is the change in body composition, evident as an increase in total body and trunk fat (1,2). Body fat, especially that located on the trunk, is associated with an increased cardiovascular (CV) disease risk as a result of the direct association between total body and regional fatness and CV disease risk (3,4). Increased total body and regional fatness also have indirect effects on other CV disease risk factors including plasma lipoprotein-lipid profiles, blood pressure, and insulin resistance (1). Some evidence indicates that hormone replacement therapy (HRT) might ameliorate or reverse the increases in body fat that occur following menopause, which might be one mechanism for the cardioprotection afforded by HRT (5).

Increased habitual levels of physical activity can markedly affect a person's daily energy expenditure, energy balance, and, consequently, their body composition. The long-term vigorous exercise training of older endurance-trained men is associated with low levels of body fat (6–8). However, very little data exist on the body composition of endurance-trained postmenopausal women (9–14). Furthermore, only one study has addressed the potential role of HRT in determining body composition in these women (13).

In 1995, the Centers for Disease Control and Prevention and the American College of Sports Medicine concluded that 30 minutes of low- to moderate-intensity exercise on most, if not all, days of the week provides substantial health benefits and results in reduced CV disease mortality (15). Clearly, many more postmenopausal women would choose to initiate and maintain this type of a physical activity program compared to the intense and prolonged training of an endurance athlete. However, to our knowledge, no studies have assessed whether prolonged participation in a low- to moderate-intensity physical activity program is associated with lower levels of total body and trunk fat.

We hypothesized that total body and trunk fat levels would be lower in active nonathletes compared with sedentary postmenopausal women, in endurance-trained compared with active nonathletic postmenopausal women, and in postmenopausal women on HRT compared with those not on HRT. Habitual dietary intake was also measured to assess the potential impact on body composition in these women.

Methods

Postmenopausal women were recruited based on their physical activity habits (sedentary, active nonathlete, or endurance-trained athlete) and HRT status. All subjects provided their written consent to participate in the study. The study was approved by the Institutional Review Board of the

University of Pittsburgh Medical Center. Postmenopausal status was initially identified by self-report as the lack of menses for more than 2 years and later confirmed by elevated luteinizing and follicle-stimulating hormone levels. Sedentary women had not participated in regular physical activity for more than 2 years. Active nonathletic women were taking part in low- to moderate-intensity physical activity (walking, aerobics, swimming, etc.) more than 90 minutes per week and more than 3 days per week, but not training for endurance-based competitive events. Subjects for these two groups were recruited from the Pittsburgh metropolitan area. Women athletes were distance runners from across the United States who were training intensely for competitive endurance-based events. The final study population consisted of 20 sedentary women (9 on HRT, 11 not on HRT), 20 active nonathletic women (9 on HRT, 11 not on HRT), and 23 endurance-trained athletes (11 on HRT, 12 not on HRT). Approximately one third of the women on HRT were taking only estrogen. Two thirds of the women on HRT were taking combined estrogen and progestin with roughly half of them on continuous and half on cyclic progestin programs. Each subject's physical activity and HRT program had been constant for 2 years or more preceding this study. Three (27%) of the active nonathletic women not on HRT and 4 (44%) of the active nonathletic women on HRT included some resistive or upper body exercise in their physical activity program. Four (33%) of the women athletes not on HRT and 5 (45%) of the women athletes on HRT included some resistive or upper body exercise in their training.

Sedentary and active nonathletic women completed a Bruce exercise test to screen for CV disease; women with no evidence of CV disease underwent a second maximal exercise treadmill test to measure $\dot{V}O_2$max (16). Women athletes underwent a single test to screen for CV disease and to assess $\dot{V}O_2$max (16). The $\dot{V}O_2$max data from these women have been published previously (16).

Body Composition Assessments

Body composition was measured by dual-energy x-ray absorptiometry (DEXA; DPX-L, Lunar Corp., Madison, WI) in the morning while the subjects maintained an overnight fast. All women were of the appropriate anteroposterior tissue thickness so that all scans were performed at medium speed. Fat and fat-free soft tissue masses and percent fat were measured for the total body, arms, legs, and trunk using the default Lunar definitions. Software version 1.3z was used to obtain and analyze all scans. All scans were performed and analyzed by one investigator, thus eliminating interobservor error. Details of the DEXA procedure and analysis have been published elsewhere (17). The total body composition data (percent of fat, lean body mass) from these women have been published previously (16).

Dietary Assessments

We also sought to assess whether dietary habits might confound our interpretation of the associations between habitual physical activity levels, HRT status, and body composition. Subjects completed a 3-day food record that consisted of 2 weekdays and 1 weekend day. The food records were analyzed for daily kcal, protein, fat, carbohydrate, and saturated, monounsaturated, and polyunsaturated fat intake as factors that could affect overall energy intake and body composition. All records were analyzed by a registered dietitian using Computrition, Inc., software (Chatsworth, CA).

Statistics

All data are reported as mean ± standard deviation. Multivariate analyses of variance (ANOVAs) were performed as an initial step to assess the differences in overall body composition profiles and dietary habits among the different subject groups. ANOVA and analysis of covariance (ANCOVA) with post hoc analyses were then used to compare groups in terms of body composition at specific anatomical sites. Bivariate correlations and multiple linear regressions were used to assess the independent determinants of total and regional body composition. $P < .05$ was accepted as statistically significant.

Results

Subject Characteristics

As shown in Table 1, all six subject groups were of similar age and had been postmenopausal the same number of years. The three groups of subjects on HRT had been taking hormones

Table 1. Physical Characteristics of the Subjects

	Sedentary		Active Nonathletes		Endurance Athletes	
	No HRT (n = 11)	HRT (n = 9)	No HRT (n = 11)	HRT (n = 9)	No HRT (n = 12)	HRT (n = 11)
Age, years	66 ± 6	62 ± 5	64 ± 6	61 ± 4	65 ± 4	65 ± 4
Years PM	16 ± 8	11 ± 4	15 ± 9	12 ± 6	16 ± 5	22 ± 13
HRT history, years	—	8 ± 4	—	10 ± 7	—	11 ± 10
PA history, years	—	—	12 ± 6	12 ± 8	16 ± 5	14 ± 4
PA, hours/week	—	—	5.1 ± 2.5	6.0 ± 2.8	5.5 ± 1.9	5.5 ± 1.3
Running mileage, miles/week	—	—	—	—	29 ± 9	32 ± 10
$\dot{V}O_2$max						
L/min	1.4 ± 0.2†	1.4 ± 0.3†	1.7 ± 0.2*	1.6 ± 0.2†	2.1 ± 0.2*	2.2 ± 0.4*
ml/kg/min	23 ± 2†	24 ± 5†	26 ± 2†	26 ± 3†	38 ± 6*	39 ± 5*

Notes: HRT = hormone replacement therapy; PM = postmenopausal; PA = physical activity. Values are expressed as mean ± *SD*. Years PM is the number of years the women had been postmenopausal. HRT history is the number of continuous years those women on HRT had been taking HRT. PA history is the number of continuous years at the current level of physical activity. PA hours/week is the number of hours of physical activity per week. * and † indicate values within the same variable significantly different at $p < .05$.

for the same length of time. In addition, the athletic and active nonathletic women had been undergoing their physical activity programs for the same number of years and hours per week. The athletes on and not on HRT were running the same number of miles per week in training. $\dot{V}O_2$max was higher in the athletes than in the sedentary and active nonathletic groups, whether expressed as l/min or ml/kg/min. $\dot{V}O_2$max in l/min was higher in the active nonathlete than in the sedentary women, but $\dot{V}O_2$max in ml/kg/min did not differ between these two groups. $\dot{V}O_2$max was not affected by HRT status.

Overall Body Composition

As shown in Table 2, height did not differ among the six groups of women. The athletic and sedentary women were of similar body weight; however, the active nonathletic women were 3–12 kg heavier than the sedentary and athletic groups. Physical activity status significantly affected total body percent fat, which was significantly and markedly lower in the athletes compared with the sedentary and active nonathletic women, who both had similar percent body fat values. Fat mass was also significantly and markedly lower in the athletes, with the sedentary and active nonathletic women again having similar fat mass values. The effect of HRT status on total body percent fat approached significance ($p = .07$) as women on HRT tended to have lower total body percent fat values. HRT status had less of an effect on fat mass with women on HRT who tended to have slightly lower total body fat mass ($p = .12$).

There was a significant effect of physical activity status on total body lean mass ($p = .01$); the active nonathletic and athletic women had higher lean mass than the sedentary women. However, the active nonathletic women had higher lean mass than the sedentary women as a result of their increased body weight, because the percent of total body weight that was lean mass was the same in these two groups. On the other hand, the higher lean mass in the athletes compared with the sedentary women was the result of a greater percentage of their total body weight being lean mass as both groups had the same body weight. HRT status did not have an effect on lean mass. There also were no significant interaction effects of physical activity and HRT status on total body composition variables.

Regional Body Composition

As shown in Tables 2 and 3, when trunk, arm, and leg percent fat values were included in multivariate ANOVAs, the athletic women had significantly lower overall regional body fat percentages compared with both the sedentary and active nonathletic women. Furthermore, ANOVAs on each individual region also indicated that the women athletes had lower trunk, arm, and leg percent body fat than both the sedentary and active nonathletic women. Multivariate and individual ANOVAs both indicated that sedentary and active nonathletic women did not differ in terms of percent fat overall or at individual regions. Although most regional fat percentages were lower in women on HRT compared with those of the same physical activity status not on HRT, these differences were not significant.

Determinants of total and regional body composition: $\dot{V}O_2$max, in ml/kg/min, was significantly and inversely correlated with all measures of body fat including percent total body fat, fat mass, and regional fat percentages ($r = -.74$ to $-.84$, all $p < .0001$), and was significantly and positively correlated with lean body mass ($r = .32$, $p = .01$). Years of physical activity also correlated significantly and inversely with all measures of total and regional body fat ($r = -.24$ to $-.36$, $p = .01$ to $.07$), but not lean mass ($r = .21$, $p = .11$). HRT duration also correlated significantly and inversely with all measures of total and regional body fat ($r = -.25$ to $-.29$, $p = .02$ to $.05$), except leg percent fat ($r = -.18$, $p = .18$); HRT duration did not correlate with lean mass ($r = -.05$, $p = .68$). Age, years postmenopausal, and HRT status did not correlate significantly with any of the body composition variables.

In multiple linear regressions, $\dot{V}O_2$max, years of activity, and HRT duration were independent determinants of total body percent fat, accounting for 70%, 3%, and 2% of the to-

Table 2. Body Composition of the Subjects

	Sedentary		Active Nonathletes		Endurance Athletes	
	No HRT (n = 11)	HRT (n = 9)	No HRT (n = 11)	HRT (n = 9)	No HRT (n = 12)	HRT (n = 11)
Height, cm	158 ± 6	158 ± 5	160 ± 6	159 ± 6	161 ± 6	159 ± 8
Weight, kg	59 ± 5†	59 ± 8†	66 ± 8*	62 ± 10*	57 ± 8†	54 ± 8†
Total body						
Percent fat	37 ± 3†	36 ± 7†	38 ± 3†	37 ± 6†	28 ± 8*	22 ± 5*
Fat mass	22 ± 4†	22 ± 7†	25 ± 5†	23 ± 7†	16 ± 7*	12 ± 3*
Percent lean	63 ± 3†	64 ± 6†	62 ± 4†	63 ± 5†	72 ± 7*	78 ± 6*
Lean mass	37 ± 2†	38 ± 4†	41 ± 4	39 ± 4†	41 ± 4*	42 ± 7*
Trunk						
Percent fat	37 ± 4†	35 ± 8†	39 ± 4†	37 ± 5†	27 ± 9*	21 ± 6*
Percent lean	63 ± 5†	65 ± 7†	61 ± 4†	63 ± 5†	73 ± 8*	79 ± 5*
Arms						
Percent fat	36 ± 4†	30 ± 9†	34 ± 4†	32 ± 7†	24 ± 7*	21 ± 5*
Percent lean	64 ± 5†	70 ± 8†	66 ± 5†	68 ± 8†	76 ± 6*	79 ± 4*
Legs						
Percent fat	41 ± 3†	41 ± 8†	39 ± 5†	41 ± 7†	31 ± 8*	24 ± 5*
Percent lean	59 ± 4†	59 ± 5†	61 ± 4†	59 ± 6†	69 ± 7*	76 ± 4*

Notes: HRT = hormone replacement therapy. Values are expressed as mean ± *SD*. * and † indicate values within the same variable significantly different at $p < .05$.

Table 3. Probability Values for the Differences Between Groups Within a Multivariate ANOVA Framework Comparing Trunk, Arm, and Leg Fat Percentages

	Sedentary		Active Nonathletes		Endurance Athletes	
	No HRT	HRT	No HRT	HRT	No HRT	HRT
Sedentary						
No HRT	—	0.17	0.19	0.25	0.00	0.00
HRT		—	0.23	0.85	0.08	0.00
Active nonathletes						
No HRT			—	0.52	0.01	0.00
HRT				—	0.00	0.00
Endurance athletes						
No HRT					—	0.20
HRT						—

Note: HRT = hormone replacement therapy.

tal variation, respectively. $\dot{V}O_2max$, years of activity, and HRT duration were also independent determinants of trunk percent fat, accounting for 64%, 5%, and 3% of the total variation, respectively. $\dot{V}O_2max$ and years of activity were the only independent determinants of total body fat mass and accounted for 52% and 5% of the total variation, respectively. $\dot{V}O_2max$ was the only independent determinant of both leg and arm percent fat and accounted for 62% and 57% of their total variances, respectively. $\dot{V}O_2max$ was the only independent determinant of lean mass, accounting for 9% of the total population variance in total body lean mass.

Dietary Composition

As seen in Table 4, the women athletes had greater daily caloric and carbohydrate intake than both the sedentary and active nonathlete women. The sedentary and active nonathletic women had similar daily intake of total calories and carbohydrates. The six groups of women did not differ in overall intake of protein, fat, saturated fat, monounsaturated fat, and polyunsaturated fat.

Discussion

The results of this study indicate that the years of intense training that postmenopausal women athletes had undergone was associated with lower total body and regional percent fat values. However, the same number of hours per week and years of low- to moderate-intensity physical activity completed by the active nonathletic women was not associated with lower total body or regional percent fat values compared with sedentary women. In the present study, HRT had minimal effects on body composition.

The present data clearly indicate that the intense endurance training programs of the postmenopausal women athletes were associated with significantly and markedly lower total body and regional percent fat values. Six previous studies—two that used underwater weighing, two that used skinfold measures, and two that used DEXA—reported that 50–70-year-old endurance-trained women athletes had lower total body percent fat than, or that would be expected in, sedentary women of the same age (9–14). Five of these investigations studied women athletes with average ages between 53 and 57 years (9,11–14). The study in the oldest athletes (mean age, 62 years) included only 7 women (10). Thus, our results extend the findings of these previous studies indicating that prolonged high-intensity endurance training in 60+-year-old women athletes, as in older men (6–8), is associated with lower levels of total body percent fat.

The present data also extend the results of these previous studies of overall body composition in postmenopausal women, because they provide strong evidence that older endurance-trained women have lower levels of trunk fat. In one previous study, endurance-trained women averaging 57 years of age had lower umbilicus subcutaneous skinfolds than sedentary women of the same age (12). In a second study, women runners averaging 55 years of age had a lower waist circumference than their sedentary peers (9). The same general findings also were evident in two recent studies of women athletes with average ages of 56 to 58 years; however, in one study, sedentary women of the same age were not studied as a comparison group, and in the other, the sedentary women weighed over 25% more than the women athletes (13,14). In the present study, the postmenopausal women athletes had significantly and markedly lower trunk percent fat values than sedentary and active nonathletic women of the same age. This finding is especially important as trunk fat is an independent CV disease risk factor (1,4).

Although the intense training of the athletes in the present study was associated with lower levels of total and regional percent fat values, women who had undergone the same number of years and hours per week of low- to moderate-intensity physical activity had the same total and regional body composition as sedentary women. These differential

Table 4. Dietary Compositions of the Subjects Related to Body Composition

	Sedentary		Active Nonathletes		Endurance Athletes	
Dietary Intake	No HRT	HRT	No HRT	HRT	No HRT	HRT
Energy, kcal/day	1503 ± 227†	1426 ± 281†	1451 ± 239†	1446 ± 348†	1630 ± 412*	1697 ± 391*
Protein, g/day	9 ± 3	9 ± 4	9 ± 4	8 ± 4	10 ± 6	10 ± 3
CHO, g/day	192 ± 49†	208 ± 28†	211 ± 45†	192 ± 68†	226 ± 71*	319 ± 123*
Fat, g/day	54 ± 20	40 ± 15	46 ± 15	45 ± 24	50 ± 22	51 ± 18
Saturated fat, g/day	19 ± 9	13 ± 6	15 ± 6	15 ± 10	15 ± 8	15 ± 6
Monounsaturated fat, g/day	19 ± 8	14 ± 5	16 ± 6	16 ± 8	18 ± 9	17 ± 7
Polyunsaturated fat, g/day	9 ± 3	9 ± 4	9 ± 4	8 ± 4	10 ± 6	10 ± 3

Notes: HRT = hormone replacement therapy; CHO = carbohydrates. Values are expressed as mean ± *SD*. * and † indicate values within the same variable significantly different at $p < .05$.

effects of low- to moderate- compared with higher-intensity endurance training on body composition are also evident in previous longitudinal training studies in older men and women. We previously found that 6 months of approximately 40% of $\dot{V}O_2$max training in sedentary 60- to 69-year-old men and women did not alter body weight or composition, whereas an additional 6 months of 70%–85% $\dot{V}O_2$max training in these same men and women resulted in significant percent body fat and body weight reductions (18). In another study in 60- to 69-year-old hypertensive men, 9 months of training at 70%–85% $\dot{V}O_2$max decreased body weight, but 9 months of training at 50% $\dot{V}O_2$max did not (19). We also found that 6 months of 75%–85% $\dot{V}O_2$max training in healthy 70- to 79-year-old men and women resulted in a significant decrease in body fat (20). On the other hand, 6 months of 46% $\dot{V}O_2$max training followed by another 6 months of 57% $\dot{V}O_2$max training did not change body weight or composition in 50+-year-old hypertensive men and women (21). However, these longitudinal intervention studies generally employed exercise programs that lasted only 6–12 months, and they did not address the possibility that more prolonged periods of low- to moderate-intensity training might have altered body composition. Our data extend these findings substantially because they indicate that the much longer (12 years) low- to moderate-intensity physical activity program still was not associated with lower levels of total body or regional percent fat values.

It is also clear from these data that $\dot{V}O_2$max expressed in ml/kg/min is the primary determinant of all body composition variables. For total and regional body fat measures, $\dot{V}O_2$max independently accounted for 52%–70% of the interindividual variability. $\dot{V}O_2$max was the only independent determinant of two of the five total and regional body fat measures. The number of years of physical activity also was an independent determinant of fat mass, but accounted for substantially less of the variance than $\dot{V}O_2$max. Years of physical activity and duration of HRT were also significant independent determinants of percent total body and percent trunk fat; however, again $\dot{V}O_2$max accounted for, by far, the largest portion of their variances. These results lend further support to the conclusion that exercise programs that are associated with higher levels of $\dot{V}O_2$max (only the high-intensity prolonged training of the athletes in the present study) are associated with lower levels of total body, trunk, arm, and leg fat.

The estrogen deficiency that is evident following menopause in women is generally associated with an increase in total body and, more importantly, trunk fat (1,2). A number of cross-sectional and longitudinal studies indicate that estrogen replacement in postmenopausal women generally blunts the total body and trunk fat gains evident after menopause (5). In the present study, HRT was associated with nonsignificant trends for lower total body and regional percent fat values. The lack of statistical significance for the effect of HRT on body composition in the present study is undoubtedly due to the relatively small number of subjects in each group; previous studies reporting significant effects of HRT on body composition in postmenopausal women had substantially larger sample sizes. However, because the same sample sizes were available to assess the association between different habitual physical activity levels and total and regional body fat values, perhaps the most appropriate interpretation of these results is that the many years of prolonged high-intensity training the women athletes had completed clearly had a greater effect on total and regional body fat values than HRT.

Although the weaknesses inherent with food records are well documented, they still represent the most valid and least intrusive means of quantifying dietary habits in a free-living population. Bearing in mind the limitations of food records, it is clear that the different groups of women had similar daily intakes of dietary constituents that could influence body fat and lean body mass stores. Further, the athletes had higher daily energy and carbohydrate intakes, differences that clearly would not result in lower total body or regional fat stores. Thus, our data provide no evidence that habitual dietary intakes contributed substantially to the body composition differences evident between these groups of women.

In summary, high-intensity endurance exercise training in postmenopausal women is associated with lower total body and regional percent fat values, including the trunk region, compared with sedentary women of the same age. However, women taking part in low- to moderate-intensity exercise had total and regional body compositions no different from those of sedentary women. HRT use exhibited a nonsignificant tendency to be associated with lower total body and regional percent fat values, perhaps most importantly indicating that numerous years of high-intensity endurance training had a greater effect on total and regional body fat values than HRT. Dietary constituents known to affect body composition did not differ among the groups, which suggests that dietary habits did not play a substantive role in the body composition differences among the groups.

Acknowledgments

This research was supported by grants to James Hagberg from the Andrus Foundation of the American Association of Retired Persons and from the Pennsylvania Affiliate of the American Heart Association. Geoffrey Moore was supported by the National Institutes of Health (NIH Grant K08 HL03029). This work was also supported by the University of Pittsburgh General Clinical Research Center (NIH/NCRR/GCRC Grant 5M01 RR00056).

Address correspondence to James Hagberg, PhD, Department of Kinesiology, University of Maryland, College Park, MD 20742-2611. E-mail: jh103@umail.umd.edu

References

1. Stefanick ML. The roles of obesity, regional adiposity, and physical activity in coronary heart disease in women. In: Wenger NK, Packard B, eds. *Cardiovascular Health and Disease in Women*. Greenwich, CT: Le Jacq Communications; 1993:149–156.
2. Wing RR, Matthews KA, Kuller LH, et al. Waist to hip ratio in middle-aged women: associations with behavioral and psychological factors and with changes in cardiovascular risk factors. *Arterioscler Thromb.* 1991;11:1250–1257.
3. Schroll M. A longitudinal epidemiologic survey of relative weight at age 25, 50, and 60 in Glostrup population of men and women born in 1914. *Dan Med Bull.* 1981;28:106–116.
4. Kannel WB, Cupples LA, Ramaswami R, et al. Regional obesity and risk of cardiovascular disease: the Framingham Study. *J Clin Epidemiol.* 1991;44:183–190.
5. Hassager C, Christiansen C. Estrogen/gestagen therapy changes soft tissue body composition in postmenopausal women. *Metabolism.* 1989;38:662–665.
6. Hagberg J, Allen W, Seals D, et al. A hemodynamic comparison of

young and older endurance athletes during exercise. *J Appl Physiol.* 1985;58:2041–2046.
7. Seals D, Hagberg J, Allen W, et al. Glucose tolerance in young and older athletes and sedentary men. *J Appl Physiol.* 1984;56:1521–1525.
8. Seals D, Allen W, Hurley B, et al. Elevated high-density lipoprotein cholesterol levels in older endurance athletes. *Am J Cardiol.* 1984;54: 390–393.
9. Stevenson E, Davy K, Seals D. Hemostatic, metabolic, and androgenic risk factors for coronary heart disease in physically active and less active postmenopausal women. *Arterioscler Thromb.* 1995;15:669–677.
10. Wells CL, Boorman MA, Riggs DM. Effect of age and menopausal status on cardiorespiratory fitness in masters women runners. *Med Sci Sports Exerc.* 1992;24:1147–1154.
11. Green JS, Crouse SF, Rohack JJ, et al. Peak exercise hemodynamics in exercising postmenopausal women taking versus not taking supplemental estrogen. *Med Sci Sports Exerc.* 1998;30:158–164.
12. Kohrt WM, Malley MT, Dalsky GP, et al. Body composition of healthy sedentary and trained, young and older men and women. *Med Sci Sports Exerc.* 1992;24:832–837.
13. Van Pelt RE, Davy KP, Stevenson ET, et al. Smaller differences in total and regional adiposity with age in women who regularly perform endurance exercise. *Am J Physiol.* 1998;275:E626–E634.
14. Ryan AS, Nicklas BJ, Elahi D. A cross-sectional study on body composition and energy expenditure in women athletes during aging. *Am J Physiol Endocrinol Metab.* 1996;34:E916–E921.
15. Pate R, Pratt M, Blair S, et al. Physical activity and public health. *JAMA.* 1995;273:402–407.
16. McCole SD, Brown MD, Moore GE, et al. Enhanced cardiovascular hemodynamics in endurance-trained postmenopausal women. *J Appl Physiol.* 1999;87:2334–2340.
17. Mazess R, Barden H, Bisek J, et al. Dual energy x-ray absorptiometry for total body and regional bone mineral and soft tissue composition. *Am J Clin Nutr.* 1990;51:1106–1112.
18. Seals D, Hagberg J, Hurley B, et al. Endurance training in older men and women. I. Cardiovascular responses to exercise. *J Appl Physiol.* 1984;57:1024–1029.
19. Hagberg J, Montain S, Martin W, et al. Effect of exercise training on 60 to 69 year old persons with essential hypertension. *Am J Cardiol.* 1989;64:348–353.
20. Hagberg J, Graves J, Limacher M, et al. Cardiovascular responses of 70-79 year old men and women to exercise training. *J Appl Physiol.* 1989;66:2589–2594.
21. Seals D, Reiling M. Effect of regular exercise on 24-hour arterial pressure in older hypertensive humans. *Hypertension.* 1991;18:583–592.

Received September 14, 1999
Accepted January 20, 2000
Decision Editor: William B. Ershler, MD