Aging, body composition, and lifestyle: the Fels Longitudinal Study[1–3]

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ABSTRACT

Background: Changes in body composition in men and women occur with age, but these changes are affected by numerous covariate factors.

Objective: The study examined patterns of change in body composition and determined the effects of long-term patterns of change in physical activity in older men and women and in menopausal status and estrogen use in women.

Design: Serial measures of height, weight, body mass index (BMI), total body fat (BF), percentage BF, and fat-free mass (FFM) from underwater weighing of 102 men and 108 women enrolled in the Fels Longitudinal Study were analyzed. Physical activity levels and menopausal status were included as covariates.

Results: There were significant age-related decreases in FFM and height and increases in total BF, percentage BF, weight, and BMI. Physical activity was associated with decreases in total BF, percentage BF, weight, and BMI in men and were associated with increases in FFM and decreases in total BF and percentage BF in women. Postmenopausal women had significantly higher total BF and percentage BF than did pre- and perimenopausal women. The longer the time since menopause the greater were the increases in weight, BMI, total BF, and percentage BF; however, estrogen use attenuated these increases.

Conclusions: Low FFM can be improved by increased physical activity. The effects of an intervention program on body composition can be masked if only body weight or BMI is measured. The effects of physical activity were more profound in postmenopausal than in premenopausal women, and estrogen use had beneficial effects on body composition. *Am J Clin Nutr* 1999;70:405–11.

KEY WORDS Body composition, aging, physical activity, menopause, the Fels Longitudinal Study, fat-free mass

INTRODUCTION

The amounts of fat and fat-free mass (FFM) in adults change with increasing age as a function of a variety of factors, from physical activity to menopausal status to nutrition and disease. The status of the fat and FFM compartments is associated with and serves as established risk factors for a variety of chronic diseases from middle to old age. Body composition can also be used in assessments of functional status, disability, and mortality. Understanding the scope of the age-related changes in body composition and the factors associated with them in healthy adults will help to improve our knowledge and understanding of these processes and assist in the prevention of functional limitation and in the management of health status into old age.

Numerous studies have reported age-related increases in body weight and fatness and decreases in FFM after young adulthood (1, 2). Age-related decline in physical activity is associated with increased body weight and body fatness as reported in cross-sectional studies (3). In women, age-related changes in body composition, ie, an increase in body weight and body fat and a decrease in FFM, have been observed after menopause (2, 4–6). Most of these previous reports used cross-sectional data; the few longitudinal studies were only short-term follow-ups of a limited number of subjects (5, 6). In most instances the important covariates, such as level of physical activity, were measured only once. In postmenopausal women, the time passed since the onset of menopause and estrogen use were not considered. More importantly, some studies examined only body weight or body mass index (BMI; weight/height^2). Body weight consists of body fat, lean tissue, bone, and other constituents. Changes in these individual components will not be detected if only body weight or BMI is studied.

The present study made use of the unique data available from the Fels Longitudinal Study to examine the pattern of age-related changes in body composition and their relations with current levels of physical activity in men and women. In addition, the changes in body composition were compared with the timing of the transition through the menopausal period. The age range of subjects in the study spans middle age to the onset of old age. The changes that occur during this period set the stage for the changes that will occur during old age. Those who enter old age with an adequate body composition should have a better health status than those with an inadequate body composition. However, the body composition of middle-aged adults and the effects of physical activity and menopause on the changes that occur

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during this period are not well documented. To address this deficiency, we asked 4 questions. First, what are the age- and sex-specific patterns of change in body composition from 40 to 66 y of age? Second, what is the effect of long-term physical activity on these patterns of change? (Serial levels of physical activity were incorporated into this analysis to evaluate these effects.) Third, what changes occur in body composition from premenopause through perimenopause to postmenopause? Fourth, are these body-composition changes related to the time since menopause and estrogen use? This report presents a picture of the process of change in body composition over time in the same adults as they approach old age and includes associated modifiable risk factors. The information from this picture should help to facilitate the development and timing of preventive health measures that reduce the loss of FFM or the gain in body fatness during middle age, thus setting the stage for a healthy old age.

SUBJECTS AND METHODS

Study sample

The data for this study were collected from 102 men and 108 women, all of whom were participants in the Fels Longitudinal Study (7) and were white. Subjects were not selected because of any known criteria related to their body composition. All procedures were approved by the Institutional Review Board of Wright State University.

Individual serial measures of weight, height, BMI, total body fat (BF), percentage BF, and FFM from 40 to 66 y of age were included in the analysis. These data were collected biennially near each participant's birthday from 1976 to 1996. Because of the timing of scheduled visits and the ages of the participants at the beginning and the end of the data collection period, some participants did not have total BF, percentage BF, or FFM data within the age range of the analysis. Also, some participants were >40 y old in 1976 and some were <66 y old when the most recent data for the present analysis were recorded. The absence of some values is due to the nature of the design of the Fels Longitudinal Study and does not alter the descriptions of the changes that occurred.

Body-composition assessment methods

Measures of total BF, percentage BF, and FFM were obtained by using the 2-component body-composition model of Siri (8). Body density was determined from underwater weighing and residual volume was measured with a Gould 2100 computerized spirometer (9). Stature was measured to 0.1 cm with a Holtain stadiometer (Seritex, Carlstadt, NJ), and weight was measured to 0.1 kg on a balance beam scale.

Physical activity

Physical activity questionnaires were administered during the scheduled examinations. and were used to assess occupational and leisure physical activity. Each individual was asked questions such as "compared with your peers, how do you rate your activity at work or leisure?" The scoring ranged from 1 to 5 for each type of activity with the higher number representing a higher level of activity. The average of the occupational and leisure physical activity scores was determined as the level of activity at an examination. On the basis of the average activity scores, individuals were separated into 3 physical activity groups—low, medium, and high—for each examination. Patterns of change over time in the levels of physical activity were examined on the basis of the standardized average scores. The average score at each examination for each participant was standardized by subtracting each individual average score from the mean for the group at that examination and dividing the difference by the corresponding SD. A random-effects model was applied to examine the changes over time in physical activity.

Menopausal status

A self-reported questionnaire was administered to women at each examination for women. Menopausal status was classified as *1*) premenopausal: regular menstrual cycles; *2*) perimenopausal: ≥3 mo without menses, large changes in cycle length, and hot flashes; or *3*) postmenopausal: ≥12 mo without menses or had undergone a hysterectomy.

Estrogen use

Self-reported data on estrogen supplement use were collected at each examination. Whether a woman had or had not used estrogen before each examination was determined. Participants were separated into 4 groups as follows: those who had not used estrogen, those who had used estrogen for <5 y, those who had used estrogen for ≥5 y, and those for whom estrogen information was not available.

Statistical analysis

Univariate statistics

Means and SDs for length of follow-up, age at first examination, age at last examination, age at onset of menopause, time since menopause, and duration of estrogen use were computed. Means and SDs were also calculated for weight, height, BMI, total BF, percentage BF, and FFM for men and women separately within 2-y age segments, ie, 40–42, 42–44, 44–46, 46–48, 48–50, …, 64–66, and >66 y.

Random-effects model

This model was applied to the serial data of each participant for weight, height, BMI, total BF, percentage BF, and FFM separately, each of which were response variables; age was the independent variable. A subsample of serial data for individuals was plotted by age to determine the general pattern of change with age for each of these response variables. From these plots, low-degree polynomials such as linear or quadratic models were chosen to describe the age-related changes of the variables (10, 11). In the low-degree polynomials, concurrent serial measures for physical activity in each sex and serial measures for menopausal status and estrogen use in women were included as possible covariates. In the linear and quadratic models, the parameters describing the effects of age, ie, the intercept and slope, could be considered as random components or fixed components. The random components account for individual variability. For example, a model with a random slope implied that the rates of change in the response variable differed from individual to individual, whereas the fixed component assumes that there are no differences in the rates of change from individual to individual.

Therefore, for each response variable there were 4 types of models, ie, a model with or without covariates as well as a model with or without random components. These models were evaluated by using likelihood ratio tests and the statistical significance of the parameter estimates ($P < 0.05$). In the random-effects mod-

TABLE 1
Number of participants by duration of follow-up and follow-up measurements for Fels Longitudinal Study subjects

Follow-up data	Men (n = 102)	Women (n = 108)
≥20 y	1 (0.9)[1]	0 (0)[1]
15–20 y	25 (25.5)[1]	20 (18.5)[1]
10–15 y	17 (42.2)[1]	27 (43.5)[1]
5–10 y	39 (80.4)[1]	32 (73.1)[1]
1–5 y	20 (100.0)[1]	29 (100.0)[1]
Length of follow-up (y)	9.25 ± 5.39 (1–20)[2]	8.95 ± 5.21 (2–19)
Age at first exam (y)	44.43 ± 3.81 (40–58)	44.52 ± 4.22 (40–64)
Age at last exam (y)	53.53 ± 6.94 (42–66)	53.59 ± 6.69 (42–66)
Age at onset of menopause (y)[3]	—	45.69 ± 7.24 (25–58)
Natural menopause	—	49.60 ± 4.75 (40–58)
Surgical menopause	—	41.77 ± 7.24 (25–58)
Time since menopause (y)	—	10.23 ± 8.29 (0–29)
Duration of estrogen use (y)[4]	—	2.78 ± 5.25 (0–25)
Estrogen use (<5 y)	—	2.16 ± 1.23 (0.25–4.7)
Estrogen use (>5 y)	—	11.62 ± 6.49 (5–25)

[1] n; percentage in parentheses.

[2] $\bar{x}$ ± SD; range in parentheses.

[3] Thirty-five women experienced natural menopause; 35 women experienced surgical menopause.

[4] Twenty-four women used estrogen for <5 y; 18 women used estrogen for ≥5 y.

els, age was calculated as "age − 40," and a response variable, such as FFM, was calculated as the individual's FFM value minus the mean FFM value at age 40 y. In addition, the general patterns of change in body composition were examined in postmenopause, with years since menopause as an independent variable and estrogen use and physical activity as covariates. These computations were performed by using the SAS PROC MIXED program (12).

RESULTS

The number of participants, by length of follow-up and sex, are given in **Table 1**. There were a total of 102 men and 108 women with examination data. More than 70% of these participants had a follow-up period >5 y and ≈20% had >15 y of follow-up. The average length of follow-up was ≈9 y with the mean ages at first and last examinations being ≈44 and 53 y.

For women, the age at onset of natural menopause was ≈50 y but ranged from 40 to 58 y. Among these menopausal women, the average duration of follow-up after menopause was ≈10 y, ranging from those who had just reached menopause to ≈29 y after menopause. The women were separated into 3 menopausal groups on the basis of their last examination. Eleven women remained premenopausal during the follow-up examinations; 14 women were perimenopausal and 65 were postmenopausal; 35 women had undergone surgical menopause.

There was estrogen use data for 94 women; 52 did not use estrogen and 42 used supplemental estrogen. The duration of estrogen use as hormone replacement therapy was ($\bar{x}$ ± SD) ≈2 ± 1.2 y (range: <1–4.7 y) for women taking estrogen for <5 y, and ≈11.6 ± 6.5 y (range: 5–25 y) for women taking estrogen for ≥5 y.

Sex-specific means and SDs for weight, height, BMI, total BF, percentage BF, and FFM are presented in **Table 2** for each 2-y age segment. The men were significantly heavier, taller, and had more FFM than the women at all ages ($P < 0.05$). The women had significantly greater percentage BF than the men at all ages. The men also had larger mean BMIs than the women at all but 4 age segments. There were no sex differences in total BF.

The final model selected for each response variable for men and women is presented in **Table 3**. There was an age-related, increasing trend in body weight in the men of ≈0.3 kg/y. Total BF values also increased with age in men by ≈0.37 kg/y, whereas the average annual increase in percentage BF was 0.32%/y. BMI in men increased with age at an average annual rate of ≈0.11 $kg \cdot m^{-2} \cdot y^{-1}$. Low physical activity levels in the men were associated with higher body weight. Men with high physical activity levels had significantly lower body weights than did those with low physical activity levels, by ≈2.76 kg. Physical activity level was also associated with BMI in men; those who were physically active tended to have lower BMI values. Physically active men also tended to have smaller total BF values than did those with low physical activity levels, by ≈2.53 kg. The results for percentage BF were similar to those for total BF; lower physical activity levels were associated with higher percentage BF values. In men, FFM decreased with age at an annual average rate of ≈0.07 kg/y and there were no associations with physical activity. The changes in body fatness with age as reflected by total BF, percentage BF, or BMI were mediated by physical activity levels. However, physical activity levels did not affect FFM.

The women also gained body weight as they became older, at an annual rate of ≈0.55 kg/y. There was also a significant age-related increase in BMI. Total BF also increased with age by an average of ≈0.41 kg/y. Unlike men, the women lost FFM as they become older at an average rate of ≈0.11 kg/y. There was no apparent effect of physical activity or menopause on body weight in the women, and neither physical activity nor menopausal status significantly affected BMI values. Like the men, however, women who were physically active had significantly lower total BF values than did women who had low physical activity levels. The effects of age and physical activity on percentage BF in women were similar to those on total BF. Low levels of physical activity were associated with large values for total BF and percentage BF. Unlike in the men, high levels of physical activity in the women were associated with higher levels of FFM, by ≈3.55 kg. The differences in FFM between women with high and medium levels of physical activity were small. Menopausal status also had significant effects on total BF and percentage BF (Table 3). At the same age, postmenopausal women had significantly higher total BF and percentage BF values than did premenopausal women. There were no apparent effects of menopausal status on FFM. Thus, the transition period in menopausal status in women affected body-composition values. There were significant effects of changes in menopausal status on FFM. Women who had used estrogen for >5 y had significantly higher FFM than nonusers but there were no differences in FFM values between women who had used estrogen for <5 y and nonusers.

The findings related to the time since menopause are presented in **Table 4**. With the inclusion of the time since menopause, age-related effects were not significant. Time since menopause appeared to be an important factor. Body weight and BMI increased significantly as a function of time since menopause but height decreased with time since menopause. The effects of time since menopause on FFM were not significant, but FFM values were associated with time since menopause and estrogen use

TABLE 2
Height, weight, BMI, and body composition measured by using underwater weighing by age for men and women aged 40–66 y in the Fels Longitudinal Study[1]

	Anthropometry				Underwater weighing			
Age (*y*)	*n*	Weight	Height	BMI	*n*	TBF	BF	FFM
		kg	*cm*	*kg/m²*		*kg*	*%*	*kg*
Men								
40	25	86.86 ± 14.26	181.04 ± 8.29	26.51 ± 4.20	15	21.12 ± 7.88	23.64 ± 6.46	66.10 ± 8.95
42	47	85.01 ± 12.78	180.59 ± 9.00	26.15 ± 4.20	35	19.59 ± 6.86	23.30 ± 5.89	62.96 ± 7.53
44	47	83.50 ± 12.24	179.24 ± 9.10	26.01 ± 3.51	41	20.84 ± 8.44	24.56 ± 7.66	62.07 ± 7.93
46	34	85.21 ± 13.02	180.58 ± 9.37	26.13 ± 3.55	32	22.30 ± 8.10	25.46 ± 6.89	63.69 ± 8.40
48	42	84.05 ± 12.76	179.55 ± 8.48	26.12 ± 4.03	41	21.40 ± 9.22	24.72 ± 7.61	62.31 ± 6.20
50	31	86.02 ± 15.58	177.83 ± 6.35	27.19 ± 4.81	29	24.81 ± 9.81	27.93 ± 7.49	61.19 ± 8.71
52	26	86.74 ± 13.86	176.33 ± 4.44	27.92 ± 4.62	23	24.54 ± 9.20	28.10 ± 6.68	60.88 ± 7.85
54	25	90.64 ± 18.00	178.73 ± 6.80	28.27 ± 5.04	22	26.71 ± 12.13	28.10 ± 7.74	64.78 ± 9.11
56	34	87.60 ± 16.52	175.62 ± 5.87	28.42 ± 5.37	27	25.96 ± 10.11	28.56 ± 7.13	62.22 ± 9.42
58	20	89.24 ± 14.37	176.82 ± 4.65	28.50 ± 4.26	16	25.89 ± 9.47	28.18 ± 6.74	63.44 ± 7.83
60	18	92.50 ± 13.26	177.53 ± 6.30	29.46 ± 4.87	13	28.34 ± 9.32	29.34 ± 5.79	66.05 ± 5.24
62	20	90.21 ± 15.20	175.46 ± 5.39	29.42 ± 5.71	18	30.09 ± 12.17	31.96 ± 7.15	61.25 ± 5.37
64	12	94.43 ± 16.32	178.20 ± 7.69	30.13 ± 7.26	6	31.35 ± 14.79	33.19 ± 11.22	59.91 ± 6.30
66	10	95.48 ± 18.30	178.71 ± 7.44	30.38 ± 8.19	6	22.90 ± 5.62	26.65 ± 4.28	62.28 ± 5.46
Women								
40	30	64.87 ± 13.66	165.56 ± 5.14	23.58 ± 4.41	16	22.95 ± 9.88	33.45 ± 8.34	43.25 ± 5.56
42	47	66.69 ± 15.09	165.95 ± 5.38	24.17 ± 5.06	37	23.19 ± 10.40	33.03 ± 7.40	44.68 ± 7.41
44	42	66.39 ± 12.73	165.03 ± 5.48	24.43 ± 4.91	37	22.92 ± 9.10	33.59 ± 8.54	43.32 ± 4.99
46	62	67.59 ± 13.31	165.29 ± 5.49	24.74 ± 4.74	53	23.11 ± 9.46	33.23 ± 8.85	44.33 ± 6.01
48	39	71.13 ± 18.62	166.78 ± 6.21	25.56 ± 6.52	32	25.41 ± 13.73	34.53 ± 9.50	44.88 ± 6.75
50	43	70.46 ± 15.02	165.76 ± 5.37	25.61 ± 5.11	36	26.21 ± 9.63	36.00 ± 7.08	44.70 ± 5.84
52	36	68.36 ± 13.24	165.87 ± 5.82	24.83 ± 4.54	27	25.15 ± 9.95	35.41 ± 8.67	43.71 ± 6.14
54	30	68.77 ± 12.30	164.06 ± 5.31	25.57 ± 4.50	23	25.61 ± 9.44	36.57 ± 7.74	42.48 ± 4.39
56	26	72.29 ± 13.36	164.36 ± 5.32	26.70 ± 4.48	18	29.13 ± 8.18	40.04 ± 6.15	43.03 ± 9.08
58	27	66.78 ± 11.26	164.44 ± 6.32	24.63 ± 3.49	22	25.22 ± 7.35	37.93 ± 6.42	40.20 ± 4.99
60	18	66.00 ± 10.40	163.79 ± 6.82	24.61 ± 3.74	12	25.61 ± 7.04	37.89 ± 5.47	40.92 ± 3.94
62	20	62.42 ± 10.47	162.29 ± 6.23	23.73 ± 4.09	12	21.49 ± 6.56	35.03 ± 5.83	38.76 ± 3.56
64	18	63.73 ± 11.99	162.78 ± 7.41	24.05 ± 4.32	13	22.57 ± 8.02	35.99 ± 7.21	38.56 ± 3.88
66	7	69.01 ± 11.75	166.44 ± 7.07	24.89 ± 3.83	6	27.71 ± 8.62	39.38 ± 5.23	41.47 ± 4.89

[1] $\bar{x}$ ± SD. TBF, total body fat; BF, body fat; FFM, fat-free mass. Values for men and women are significantly different at all ages except 48, 50, 56, and 66 y for BMI; 40–60, 64, and 66 y for TBF; and 62–64 y for percentage BF, $P < 0.05$.

(Table 4). Total BF and percentage BF increased significantly with time since menopause for both estrogen users and nonusers; however, a more profound effect of time since menopause on the increase in total BF and percentage BF was noted for estrogen nonusers. All terms in the total BF and percentage BF models were significant at the $P < 0.05$ level. At the same age and same physical activity level, there was a decrease in FFM of ≈0.16 kg/y after menopause for estrogen nonusers and a decrease of 0.08 kg/y after menopause for estrogen users. Level of physical activity remained significantly and positively related to FFM and negatively related to total BF and percentage BF after adjustment for time since menopause. Independent of physical activity level, estrogen use was a significant factor in FFM only during the transition through menopause.

DISCUSSION

Numerous studies on changes in body composition from middle to old age and on the many factors associated with these changes were summarized well by Heymsfield et al (13). Several other studies investigated the association between weight gain and menopause (1, 14, 15). Some reported no changes in weight or body composition in relation to menopause (2), whereas others reported significant age-related weight gains (1, 14). This divergence in findings may be due to several factors. Most of the reports are based on cross-sectional data (14, 16, 17), and it is difficult to use such data to infer age-related changes. Differences in individuals due to secular changes in the cross-sectional data may overshadow age-related changes. Even if there are age-related differences in the cross-sectional studies, such differences may be due to individual differences or selective mortality and not truly age-related changes.

Only a few studies have used longitudinal data to analyze changes in body composition, and the findings from these studies differ from those from cross-sectional studies (18). However, previous longitudinal studies had small sample sizes and the duration of follow-up was, in general, short (1, 2, 19). As a result, these follow-up studies calculated changes in body composition as differences between 2 points in time. Measures of body composition have inherent variations that can be caused by measurement errors or biological variation. Changes measured from follow-up data collected at short intervals will be biased as a result of these errors and biological variations, and the SEs of the estimated changes will be inflated (20). Changes in body composition during adulthood occur at a slow rate and many years of observation are necessary to document real changes and the pattern of these changes.

TABLE 3
Parameter estimates from the selected random-effects models[1]

Variables	Weight	Height	BMI	TBF	BF	FFM
	kg	*cm*	*kg/m^2*	*kg*	*%*	*kg*
Men (*n* = 102)						
Intercept	−6.43 ± 1.53[2]	−0.89 ± 0.77[2]	−1.81 ± 0.46[2]	−3.40 ± 1.13[2]	−2.48 ± 1.05[2]	−2.71 ± 0.78[2]
Age	0.30 ± 0.06[2]	—	0.11 ± 0.02[2]	0.37 ± 0.06[2]	0.32 ± 0.04[2]	−0.07 ± 0.04[3]
Age^2	—	−0.003 ± 0.0003[2]	—	—	—	—
Physical activity[4]						
Low	2.76 ± 1.28[2]	—	0.83 ± 0.39[2]	2.53 ± 1.21[2]	2.49 ± 1.08[2]	—
Medium	1.79 ± 1.08[3]	—	0.58 ± 0.33[3]	1.33 ± 0.97	1.73 ± 0.86[3]	—
Women (*n* = 108)						
Intercept	−0.77 ± 1.24	−0.31 ± 0.52	−0.38 ± 0.43	−4.74 ± 1.71[2]	−4.95 ± 1.70[2]	4.09 ± 1.07[2]
Age	0.55 ± 0.06[2]	—	0.22 ± 0.02[2]	0.41 ± 0.08[2]	0.33 ± 0.08[2]	−0.11 ± 0.03[2]
Age^2	—	−0.003 ± 0.0002[2]	—	—	—	—
Menopausal status[5]						
Premenopausal	—	—	—	−2.43 ± 1.10[2]	−3.10 ± 1.14[2]	—
Perimenopausal	—	—	—	−1.93 ± 1.00[2]	−2.76 ± 1.04[2]	—
Physical activity[4]						
Low	—	—	—	7.50 ± 1.58[2]	8.85 ± 1.61[2]	−3.55 ± 1.05[2]
Medium	—	—	—	3.52 ± 1.30[2]	4.65 ± 1.33[2]	−2.34 ± 0.83[2]
Duration of estrogen use[6]						
≥5 y	—	—	—	—	—	−3.25 ± 1.42[2]
<5 y	—	—	—	—	—	−1.43 ± 1.27

[1]Estimate ± SE. TBF, total body fat; BF, body fat; FFM, fat-free mass.
[2]$P < 0.05$.
[3]$0.05 < P < 0.10$.
[4]Values are in reference to the group with high levels of physical activity.
[5]Values are in reference to the postmenopausal group.
[6]Values are in reference to those who did not use supplemental estrogen.

Long-term, serial body-composition data from underwater weighing and concurrent measures of physical activity and, for women, menopausal status and estrogen use, were analyzed for 210 adults aged 40–66 y. The maximum length of follow-up was 20 y with a mean follow-up of 9 y. A random-effects model was used to determine the patterns of change over time in body composition and the parameters of the model were used to characterize individual differences. The advantage of this model was described elsewhere (21). This model analyzed the complete set of serial data simultaneously, handled the occurrence of missing values, and included measurements made at various time intervals. The random-effects model also allowed the inclusion of time-varying and non-time-varying covariates, such as physical activity levels, menopausal status, and estrogen use. These covariates were included in the model as time-varying covariates to investigate changes in the dependent variable as affected by concurrent values in another variable.

In general, there were age-related increases in weight, BMI, total BF, and percentage BF in both men and women from 40 to 66 y of age; however, but FFM decreased in both men and women over this same age range. The variability was greater for fat than for FFM. There are several factors to which these age-

TABLE 4
Parameter estimates from the selected random-effects models including time since menopause (TSM) for women[1]

Variables	Weight	Stature	BMI	TBF	BF	FFM
	kg	*cm*	*kg/cm^2*	*kg*	*%*	*kg*
Intercept	0.54 ± 1.58	−0.30 ± 0.67	0.04 ± 0.59	−7.82 ± 2.24[2]	−7.40 ± 2.12[2]	2.94 ± 1.60[2]
TSM (y)						
All	0.46 ± 0.09[2]	−0.04 ± 0.02[2]	0.18 ± 0.03[2]	0.45 ± 0.10[2]	0.34 ± 0.08[2]	—
Estrogen users	—	—	—	0.50 ± 0.15[2]	0.37 ± 0.11[2]	−0.16 ± 0.09[3]
Estrogen (non-users)	—	—	—	0.32 ± 0.13[2]	0.29 ± 0.09[2]	−0.08 ± 0.07[2]
Physical activity level[4]						
Low	—	—	—	14.17 ± 2.47[2]	14.19 ± 2.38[2]	−4.20 ± 1.77[2]
Medium	—	—	—	7.99 ± 2.08[2]	8.60 ± 2.00[2]	−3.42 ± 1.50[2]

[1]Estimate ± SE. TBF, total body fat; BF, body fat; FFM, fat-free mass.
[2]$P < 0.05$.
[3]$0.05 < P < 0.10$.
[4]Values are in reference to the group with high levels of physical activity.

related changes in body composition can be attributed. In the present study, changes in body composition were mediated by individual physical activity levels. Individuals with higher physical activity levels had smaller total BF and percentage BF values. This agrees with the findings of others (22, 23). Despite the association between low physical activity level and increased body weight and BMI in men, there was no apparent effect of physical activity on weight and BMI in women. Variability in body weight was due largely to the variation in body fat content (18). In men, differences in physical activity level affected body fat content significantly but not FFM ($P < 0.05$). As a result, the effects of physical activity were seen in body weight and BMI. In women, increased levels of physical activity were associated with reduced body fat and increased FFM. As a result, the effects of physical activity on body weight and BMI were diminished.

The sex-associated differences in the effects of physical activity on body weight, BMI, and body composition were due, in part, to the differences in FFM between the sexes. The FFM if women is approximately two-thirds that of men (18). Consequently, differences in physical activity can noticeably affect the amount of FFM in women but not in men. In men, higher physical activity levels were associated with lower body weight, BMI, and body fat values but were not associated with FFM values. This was partly due to the fact that men already had larger FFM values and, possibly, the differences between the 3 levels of physical activity were not large. This finding implies that a low FFM value can be improved by an increased level of physical activity, and that the effects of an intervention program on body composition can be masked if only body weight or BMI is measured.

In addition to physical activity level, falling estrogen concentration in women after menopause was a major risk factor for increased body fat and decreased FFM. The transition in menopausal status also played an important role in body fatness for women. Although there was no apparent difference in weight, BMI, or FFM between the 3 menopausal groups of women, the effects of menopausal status on total BF and percentage BF were clear. The postmenopausal women had greater total BF and percentage BF values than did the premenopausal women. Similarly, the perimenopausal women had greater total BF and percentage BF values than did the premenopausal women. These findings indicate the importance of measuring body composition in studies of effects of menopausal status and highlights the important point made by Heymsfield et al (13) that “weight change alone is an inadequate guide to the underlying changes in body composition that occur during menopause.”

Time since menopause also played an important role in the changes that occurred in body composition. Postmenopausal women who used estrogen had lost less FFM since the onset of menopause than did those who had not used estrogen. Postmenopausal women who used estrogen also had smaller gains in total BF and percentage BF since the onset of menopause than did those who did not use estrogen.

The present findings show the importance of measuring body composition in clinical programs aimed at altering health risk. There were effects of physical activity on both fat and FFM, but not on body weight or BMI in women. Thus, body composition should be measured in clinical management programs or in epidemiologic and clinical studies of aging, even perhaps at older ages than those studied in the present investigation.

We conclude that a significant decrease in FFM and increases in total BF, percentage BF, body weight, and BMI occur with age. Significant positive effects of physical activity are increases in FFM and decreases in total BF and percentage BF, but body weight and BMI in women are not affected. In men, there are significant positive effects of physical activity on total BF, percentage BF, body weight, and BMI but no effects on FFM. In addition, the longer the time since menopause, the greater the loss in FFM and height and the greater the gain in total BF and percentage BF; estrogen use alleviates the extent of losses in FFM and gains in fat. The present results imply that *1*) a low FFM can be improved by an increased level of physical activity, *2*) the effects of an intervention program on body composition can be masked if only body weight or BMI are measured, *3*) the effects of physical activity are more profound after menopause than from pre- to postmenopause, and *4*) estrogen use has beneficial effects on body composition.

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