Relation between body fat and age in 4 ethnic groups[1–3]

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ABSTRACT

Background: Previous studies of the relation between age and body fat reached differing conclusions concerning the question of whether body fat is lower in the elderly than in middle-aged persons.

Objective: The objectives of this study were to characterize the relation between age and body fat in 4 ethnic groups and test the hypothesis that body fat is lower in the elderly than in middle-aged persons.

Design: Body fat was measured in a sample of 1324 volunteers aged 20–94 y by using a 4-component model of body composition. Four ethnic groups were studied: Asians, blacks, Puerto Ricans, and whites. Regression models were developed for fat mass and fat percentage as functions of age.

Results: In all but one of the groups, a highly significant curvilinear relation between age and body fat was found, indicating a peak amount of body fat in late middle age and lower amounts of body fat at younger and older ages ($P < 0.001$). The age at which maximum body fat was predicted in the various groups ranged from 53 to 61 y for fat mass and from 55 to 71 y for fat percentage. In Puerto Rican men there was no significant relation between age and fat mass, and the relation between age and fat percentage was linear and positively correlated.

Conclusions: This study provided data on the relation between age and body fat in 4 ethnic groups and supported the hypothesis that body fat is lower in the elderly than in middle-aged persons. *Am J Clin Nutr* 1999;69:1007–13.

KEY WORDS Aging, elderly, middle age, old age, fat, fat mass, fat percentage, body fat, adiposity, body composition, obesity, sex, ethnicity, multicomponent models

INTRODUCTION

A growing awareness of the health toll attributable to obesity in modern, industrialized nations has added importance to efforts to understand the causes and natural history of obesity. Part of understanding obesity is determining what a normal body fat content is and how this may change with age. Previous studies of the relation between body fat and aging found 1 of 2 patterns: either an increase in body fat until early old age, followed by a decrease, or a pattern of steadily increasing body fat with aging (1, 2). Some previous studies of the relation between age and fatness used methods such as measurement of skinfold thicknesses (3) or bioimpedance analysis (2) that had problems with reliability. Others used 2-component models of body composition based on hydrodensitometry (4) or measurement of total body potassium (5). These models are dependent on assumptions such as a constant density or potassium concentration in the fat-free mass, but these assumptions have been shown to be incorrect (6, 7). In fact, both the density and the potassium content of the fat-free mass have been shown to change with age (6, 8).

More recently, 4-component models of body composition that do not rely on major assumptions about constant composition of the fat-free mass have been developed (9). Thus, 4-component models offer the opportunity to determine the relation between age and body-composition components such as fat in a more accurate and unbiased way. Although several reports of the relation between fat and age based on 4-component models have been published, these studies were limited to certain ethnic or sex groups. The research of Ellis (10) included predominantly white subjects and too few black subjects for analysis of age effects in blacks, and the studies of Aloia et al (11, 12) included black and white women only. Several studies showed that body-composition variables such as fat mass vary significantly among ethnic groups (10, 13). Thus, there is a need for reliable data regarding other ethnic populations. The aims of the current study were to characterize the relation between age and body fat in a large, ethnically diverse population and to test the hypothesis that the relation between age and body fat is curvilinear, with the greatest amount of body fat in middle-aged persons and lower amounts in both the young and the elderly.

SUBJECTS AND METHODS

Study design

Fat mass was determined once in a large sample of healthy volunteers by using a 4-component model that required measurement of body volume, total body water (TBW), total-body bone mineral mass (TBBM), and body weight (9). The relation

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between age and body fat was explored by using several different statistical methods, including multiple regression both with and without adjustment for body size and multiple regression with fat mass expressed as a percentage of body weight.

Subjects

The 1324 volunteers aged 20–94 y were recruited for this study through posters, local community centers, local newspapers, radio stations, and a commercially available mailing list in the New York City area. Because of these recruitment methods, virtually all subjects were residents of the New York City metropolitan area. Studies were performed between 1986 and 1997. Information on self-reported ancestry was used to classify subjects as black, white, Asian, or Puerto Rican, with subjects who did not fit into one of these categories excluded from the analysis. To be included in the study, each potential subject needed to have all 4 grandparents concordant for racial or ethnic group. Potential subjects were also screened with a medical history questionnaire and a brief physical exam; those with evidence of cancer, chronic use of steroid medication, renal failure, liver disease, drug abuse, or alcoholism were not studied. Overweight by itself was not a reason for exclusion. All subjects were ambulatory. The study was approved by the St Luke's–Roosevelt Hospital Institutional Review Board and each subject gave his or her informed consent.

Body composition

After subjects had fasted overnight, body weight was measured to ±0.2 kg by using a standard balance scale with subjects wearing a hospital gown without shoes. Height was measured to ±0.5 cm by using a stadiometer (Holtain, Crosswell, United Kingdom). For each subject, all body-composition measurements were performed on the same day.

Total body water

TBW was measured by ^3H_2O dilution (14) with 5% correction for hydrogen loss to the nonaqueous phase (15). The within-person day-to-day CV for the TBW method is 1.7% in our laboratory (16).

Hydrodensitometry

Body density and volume were determined by hydrodensitometry by using the method described by Akers and Buskirk (17). Each subject wore a bathing suit and performed 5–10 submersions with maximal exhalation. The greatest weight recorded twice was considered the underwater weight. Before submersion, residual lung volume was estimated by using the closed-circuit oxygen-dilution technique (18) and body volume was adjusted accordingly. The within-person day-to-day CV in our laboratory is 0.33% for body volume (9).

Dual-photon absorptiometry and dual-energy X-ray absorptiometry

TBBM was measured by using a ^{153}Gd system for dual-photon absorptiometry (DPA) (Lunar DPA; Lunar Corp, Madison, WI) between 1986 and 1989 and by dual-energy X-ray absorptiometry (DXA) (Lunar DPX; Lunar Corp) from 1989 to the present. Previous results from our laboratory showed a mean difference of 0.7% and a high correlation (r = 0.98) for TBBM measured by DPA compared with DXA in 81 subjects (19). TBBM values derived from the DPA system were converted to DXA values by using the following regression equation (19):

$$TBBM_{DXA} = 0.0430 + (0.96 \times TBBM_{DPA}) \quad (1)$$

All measurements were analyzed with LUNAR software (version 3.4; Lunar Corp). The within-person day-to-day CV for TBBM is 1.0% by DPA and 0.5% by DXA (19).

Calculations and statistical analysis

Total body fat was calculated in all subjects by using a 4-component model (9) that required measurement of body volume, TBW, TBBM, and body weight. This method provides estimates of body fat that are independent of major age-, sex-, and ethnicity-related assumptions (9). We used the following equation (20):

$$\text{Fat mass} = (2.513 \times \text{body volume}) - (0.739 \times \text{TBW}) + (0.947 \times \text{TBBM}) - (1.79 \times \text{body weight}) \quad (2)$$

where fat mass, TBBM, and body weight are in kg and body volume and TBW are in L. The propagated measurement error for this method is estimated to be 1.6% of body weight (9). Friedl et al (21) investigated the reliability of a similar 4-component model by conducting 3 determinations of body fat in each of 10 subjects and found an average within-subject SD of 0.8 kg (1.1% of body weight).

Statistics

For descriptive purposes, subjects were divided into age groups by decade and the mean and SD of fat mass and fat percentage for each age group were calculated. This analysis was performed independently for each ethnic and sex group. For inferential purposes, linear regression analysis was performed independently for each ethnic and sex group, with fat mass or fat percentage as the dependent variable and age as the independent variable. Age^2 was tested for significance as a predictor. Coefficients were compared across groups by using the F test (22). For fat mass, this analysis was performed both with and without adjustment for body size (height and weight). Statistical analysis was performed by using SPSS for WINDOWS, release 8.0 (SPSS Inc, Chicago).

RESULTS

In **Table 1** the number of subjects in each sex, ethnic, and age group is shown. To determine how representative our sample was of the US population, we compared the body mass index (BMI; in kg/m^2) of subjects in our study with BMI data from phase 1 of the third National Health and Nutrition Examination Survey (NHANES III), a nationally representative, cross-sectional survey conducted by the National Center for Health Statistics between 1988 and 1991 (23). In **Table 2** the mean BMIs by decade from NHANES III and from our sample are shown, irrespective of ethnicity. The subjects in our study, particularly the women, tended to have a lower mean BMI than the NHANES III sample at all ages. However, in both populations the relation between age and BMI was similar. The pattern was characterized by a relatively low BMI in the youngest age groups; a relatively high BMI in middle-aged persons, with peak BMI occurring in either the 40–49-y-old group or the 50–59-y-old group; and a progressively lower BMI in the older age groups.

The similarity between the 2 studies was tested by performing multiple regression analysis. Multiple regression models were developed with BMI as the dependent variable and age group, study, and their interaction term as independent vari-

TABLE 1
Number of subjects by age, sex, and ethnicity

	Age							
	20–29 y	30–39 y	40–49 y	50–59 y	60–69 y	70–79 y	≥80 y	All ages
Women								
Asian	17	22	16	21	31	9	4	120
Black	16	36	31	31	27	15	6	162
Puerto Rican	17	19	15	25	15	6	1	98
White	56	73	47	70	55	44	15	360
Men								
Asian	17	14	15	16	25	14	1	102
Black	18	24	29	20	17	15	2	125
Puerto Rican	17	20	22	24	21	7	0	111
White	40	61	36	41	33	22	13	246
Total	198	269	211	248	224	132	42	1324

ables. In both sexes, the interaction term was not significant. This indicates that there was no significant difference between the 2 studies in the relation between age and BMI.

In **Figure 1** the mean fat mass by decade in each of the groups is shown. In most groups there was a pattern of increasing fat mass with increasing age until 50–59 or 60–69 y, followed by a declining fat mass in the older age groups. A similar pattern was seen for fat percentage (data not shown).

Regression models: fat mass

In all of the population groups except for the Puerto Rican men, age was a significant predictor of fat mass, explaining 7–22% of the variance. In Puerto Rican men there was no significant relation between age and fat mass. In the other groups the relation was quadratic, with positive linear and negative quadratic coefficients. This model predicts the largest fat mass in middle-aged persons, with a smaller fat mass in both older and younger persons. The regression models are presented in **Table 3** and **Figure 2** and **Figure 3**. The age at which fat mass was maximum as predicted by the models ranged from 49 to 61 y. By using a lack-of-fit test, it was determined that none of the groups differed significantly from a quadratic model. Coefficients were compared across groups. For women, the models for Asians, blacks, and whites were parallel; that is, the differences among the coefficients were not significant but the constant terms were significantly different. The model for Puerto Rican women was significantly different in that it predicted a significantly lower age at which fat mass was maximum ($P < 0.001$). For men, the models for blacks and whites did not differ significantly, and the model for Asians was parallel to these models. The model for Puerto Rican men was significantly different ($P < 0.05$).

Adjustment for body size

Regression models were developed for predicting fat mass as a function of body size (height and weight). Height and weight were strong determinants of fat mass in all groups, explaining between 53% and 90% of the among-individual variance in fat mass. After adjustment for body size, age and age^2 remained significant predictors of fat mass in all groups except the Puerto Rican men, in whom age alone was significant. The regression models are shown in **Table 4**. In all groups the age coefficient was positive and the age^2 coefficient was negative, consistent with the curvilinear pattern of difference in fat mass with age that was seen in the model not adjusted for body size. In all groups except the Puerto Rican men, the age and age^2 coefficients were less in the model that was adjusted for body size than in the model that was not. This is to be expected because weight is a strong predictor of fat mass ($r^2 = 0.46$ in all subjects combined). Interestingly, in the Puerto Rican men, adjustment for body size revealed a significant relation between age and fat mass that was not present in the unadjusted data.

Fat percentage

Regression models were developed to predict body fat per-

TABLE 2
Mean BMI by age in the current study and the third National Health and Nutrition Examination Survey (NHANES III), phase 1[1]

	Men		Women	
Age	Current study	NHANES III	Current study	NHANES III
		kg/m²		
20–29 y	24.8 ± 0.42 [92]	24.9 ± 0.21 [858]	23.4 ± 0.48 [106]	24.1 ± 0.29 [755]
30–39 y	25.8 ± 0.44 [119]	26.1 ± 0.29 [759]	23.3 ± 0.44[2] [150]	26.4 ± 0.39 [771]
40–49 y	26.4 ± 0.41 [102]	27.3 ± 0.36 [643]	25.9 ± 0.48 [109]	26.7 ± 0.29 [624]
50–59 y	26.2 ± 0.40[2] [101]	27.6 ± 0.16 [493]	26.8 ± 0.50[2] [147]	28.5 ± 0.41 [464]
60–69 y	26.2 ± 0.39 [96]	26.9 ± 0.22 [588]	25.4 ± 0.36[2] [128]	27.3 ± 0.27 [595]
70–79 y	24.5 ± 0.37[2] [58]	26.5 ± 0.29 [495]	24.5 ± 0.54[2] [74]	26.7 ± 0.29 [446]
≥80 y	25.2 ± 0.67 [16]	24.7 ± 0.24 [373]	23.3 ± 0.52 [26]	24.6 ± 0.23 [396]
All ages	25.7 ± 0.17 [584]	26.3 ± 0.13 [4209]	24.9 ± 0.19[2] [740]	26.3 ± 0.14 [4051]

[1] $\bar{x}$ ± SE; *n* in brackets. NHANES III data are from reference 23.
[2] Significantly different from NHANES III, $P < 0.05$.

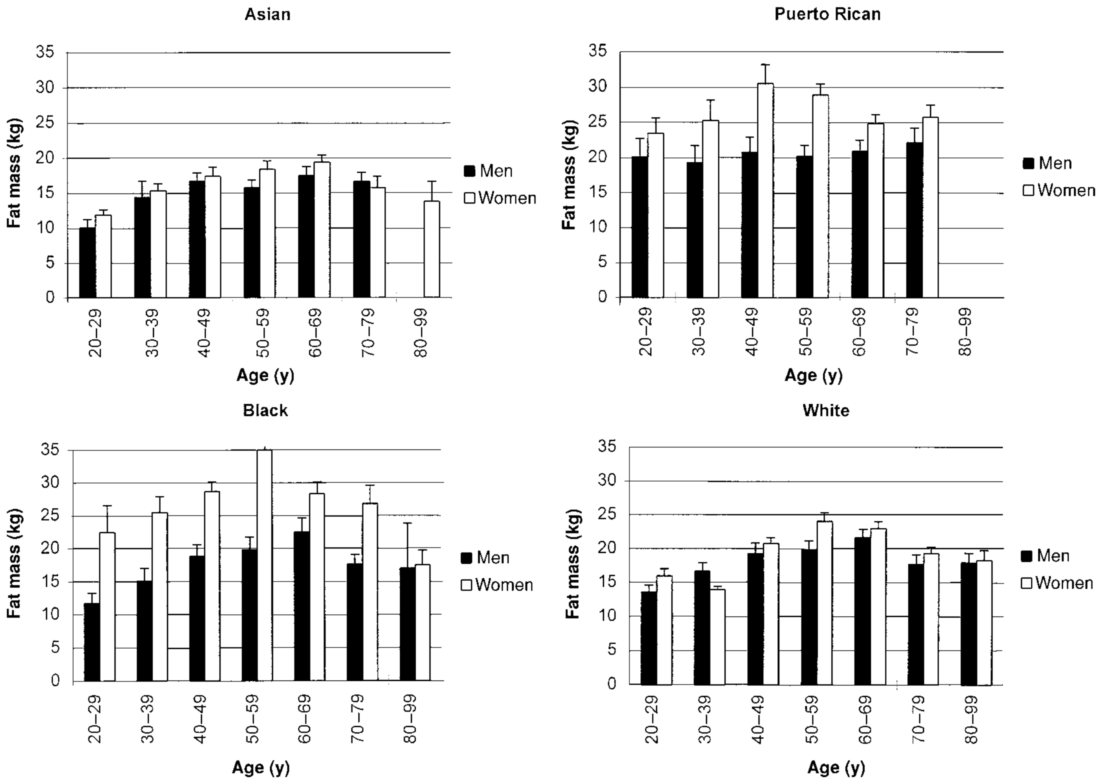

FIGURE 1. Mean (±SE) fat mass by decade of age in 4 ethnic groups. The number of subjects in each group is reported in Table 1.

centage as a function of age and age^2; these are presented in **Table 5**. In all of the population groups, age was a significant predictor of body fat percentage, explaining 8–31% of the variance in fat percentage. In all population groups except Puerto Rican men, the relation was quadratic with positive linear and negative quadratic coefficients. This model predicts the highest fat percentage in middle-aged persons, similar to the pattern seen when fat mass was the dependent variable. In Puerto Rican men the relation was linear, indicating that fatness increased steadily as age increased. In all population groups, age accounted for a larger proportion of the variance in fat percentage than the variance in fat mass. Furthermore, in all population groups, the age at which fat percentage was maximum as predicted by the model was greater than the age at which fat mass was maximum.

DISCUSSION

The primary goals of the present study were to characterize

TABLE 3
Results of linear regression with fat mass in kg as the dependent variable and age in y as the independent variable

Group	Constant	Coefficient: Age	Coefficient: Age^2	R^2	SEE	AgeMax[1]
					kg	*y*
Women						
Asian (n = 120)	−2.1	0.7 (0.2)[2,3]	−0.006 (0.002)[3]	0.18	5.0	58.3
Black (n = 162)	−3.0	1.3 (0.4)[3]	−0.012 (0.003)[3]	0.08	11.8	53.3
Puerto Rican (n = 98)	5.1	1.0 (0.4)[3]	−0.010 (0.004)[3]	0.08	9.0	49.0
White (n = 360)	−3.6	0.9 (0.1)[3]	−0.007 (0.001)[3]	0.15	7.6	60.5
Men						
Asian (n = 102)	−8.4	0.9 (0.2)[3]	−0.008 (0.002)[3]	0.22	5.5	57.0
Black (n = 125)	−10.3	1.1 (0.3)[3]	−0.009 (0.003)[3]	0.14	8.3	58.0
Puerto Rican (n = 111)	20.2	0.0 (0.4)	0.001 (0.004)	0.01	9.1	—[4]
White (n = 246)	0.4	0.7 (0.2)[3]	−0.005 (0.002)[3]	0.08	8.2	60.7

[1] AgeMax, age at which fat mass was maximum as predicted by the model.
[2] SE in parentheses.
[3] Significantly different from zero, $P < 0.01$.
[4] AgeMax was not calculated for this group because the coefficients were not significantly different from zero.

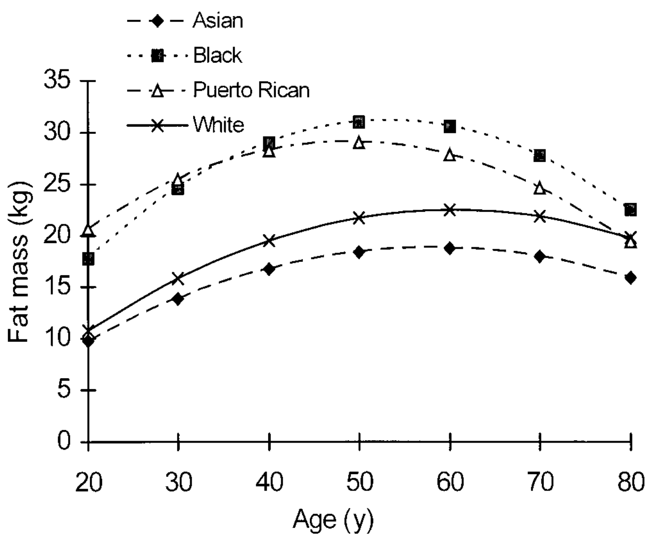

FIGURE 2. Plot of regression models for fat mass as a function of age in women. Details of the models are presented in Table 3. The number of subjects in each group is reported in Table 1.

the relation between age and body fat in a large, multiethnic population and to test the hypothesis that there is a curvilinear relation between age and body fat such that the greatest amount of body fat occurs in middle age. Most investigators believe that body fat increases from young adulthood to middle age; the relation between age and body fat in older individuals is less clear (1).

Findings

The first finding was that the relation between BMI and age in the current study was similar to that found in phase 1 of NHANES III, a nationally representative, cross-sectional survey of the US population. The population we studied had a lower mean BMI than the NHANES population; however, in both populations there was a clear pattern of increasing BMI as age increased until the fifth or sixth decade of life, followed by declining BMI in the older age groups. Although BMI is an indirect indicator of fatness, there is no reason to believe that the relation between BMI and body fat is systematically different in these 2 populations. Therefore, this finding provides some evidence that the relation between age and body fat in the population we studied is similar to the relation in the NHANES population.

The second finding was a curvilinear relation between age and body fat in all but one of the groups studied. This relation was present regardless of whether body fat was expressed as fat mass, fat percentage, or fat mass adjusted for height and weight. The age at which fat mass was maximum as predicted by the regression models varied among the groups, but was ≈55–60 y.

Comparison between the fat mass and fat percentage models

There are some important differences between the models. In the fat mass model, the amount of variation explained by age was relatively modest, but highly significant. In no group did age account for >22% of the variance in fat mass. Age accounted for a greater proportion of the variance in fat percentage. This can be explained by the fact that the use of fat percentage as the dependent variable eliminated some of the variation that was due to differences in body weight. The decline in lean body mass with age explains the difference observed between the age at which fat percentage was maximum and the age at which fat mass was maximum (1).

Ethnic differences

In general, there was notable homogeneity among the different ethnic groups in the relation between age and body fat, despite significant differences in absolute amounts of fat (Figures 2 and 3). The pattern in Puerto Rican men was strikingly different, however, in that the relation between age and body fat was either weak or nonexistent. We do not have an explanation for this interesting finding; further investigation in this population with analysis of lifestyle factors such as dietary intake and physical activity could be a rewarding area for future research.

Previous cross-sectional studies

Several previous cross-sectional studies also showed a curvilinear relation between body fat and age. Aloia et al (11) used neutron activation to measure body composition in 155 white women and found the relation between age and fat mass to be curvilinear, with the peak fat mass at ≈57.5 y, close to the age of 60.5 y in the current study. Ellis (10) measured body fat mass in 175 white men and 1134 white women by using neutron activation. He found a biphasic pattern of body fat in the women, with peak fat mass occurring in the age range of 50–59 y, but a pattern of steadily increasing fat mass as age group increased in the men. The power of the study to detect a lower fat mass in older men was limited, however, because there were only 8 men aged >74 y. Baumgartner et al (24) studied 316 elderly white subjects (aged 60–95 y) by DXA and isotope dilution and found progressive decreases in fat mass and fat percentage with age in women. In men, there was a trend toward decreasing fat mass with age that was not significant.

In contrast, some studies found a pattern of steadily increasing body fat with age. Rico et al (25) measured body fat by DXA in 815 healthy Spanish subjects aged 15–83 y and found a pat-

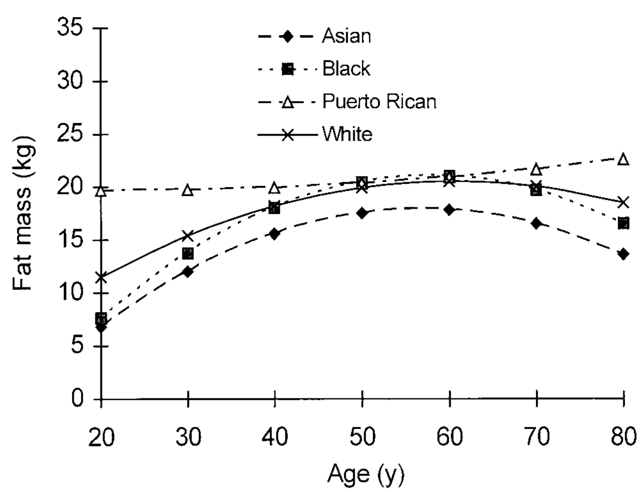

FIGURE 3. Plot of regression models for fat mass as a function of age in men. Details of the models are presented in Table 3. The number of subjects in each group is reported in Table 1.

TABLE 4
Results of linear regression with fat mass in kg as the dependent variable and age in y, height in cm, and weight in kg as the independent variables

Group	Constant	Coefficient				R^2	SEE
		Height	Weight	Age	Age^2		
							kg
Women							
Asian (*n* = 120)	−4.3	−0.15 (0.05)[1,2]	0.60 (0.04)[3]	0.44 (0.09)[3]	−0.004 (0.001)[3]	0.78	2.6
Black (*n* = 162)	6.9	−0.24 (0.05)[3]	0.68 (0.02)[3]	0.31 (0.12)[2]	−0.002 (0.001)[4]	0.90	3.9
Puerto Rican (*n* = 98)	22.4	−0.31 (0.06)[3]	0.66 (0.02)[3]	0.27 (0.12)[4]	−0.003 (0.001)[4]	0.91	2.9
White (*n* = 360)	10.0	−0.26 (0.03)[3]	0.70 (0.02)[3]	0.26 (0.06)[3]	−0.002 (0.001)[2]	0.86	3.1
Men							
Asian (*n* = 102)	−7.1	−0.14 (0.08)	0.47 (0.05)[3]	0.52 (0.18)[2]	−0.004 (0.002)[4]	0.62	3.9
Black (*n* = 125)	24.0	−0.37 (0.07)[3]	0.55 (0.03)[3]	0.52 (0.17)[2]	−0.004 (0.002)[4]	0.73	4.7
Puerto Rican (*n* = 111)	29.7	−0.36 (0.06)[3]	0.59 (0.03)[3]	0.10 (0.02)[3]	NS	0.84	3.7
White (*n* = 246)	6.2	−0.26 (0.05)[3]	0.59 (0.02)[3]	0.32 (0.09)[3]	−0.002 (0.001)[4]	0.76	4.3

[1] SE in parentheses.
[2–4] Significantly different from zero: [2] $P < 0.01$, [3] $P < 0.001$, [4] $P < 0.05$.

tern of increasing fat mass with age. However, in their analysis the investigators grouped all persons >60 y of age together, and so would have been unable to detect a decrease in body fat at older ages. Poehlman et al (26) measured body fat by using hydrodensitometry in 720 healthy white subjects (427 men and 293 women) and found a pattern of steadily increasing body fat with age. However, as the authors acknowledged, the hydrodensitometry method assumes a constant bone mineral density with aging and therefore could lead to an overestimation of body fat in older subjects. Also, the report does not indicate how many subjects were older than 65 y, and an inadequate number of older subjects would diminish the power of the study to detect changes at older ages. Aloia et al (12) measured body fat mass in 112 black women by using a 4-component model and found a linear increase in fat mass with age. However, small numbers of older subjects (10 >60 y, none >70 y) limited the power of this study to detect a decrease in fat mass at older ages.

Explanations for the pattern

There are several possible explanations for the findings of lower fat mass and lower fat percentage after ≈60 y of age. Explanations that represent limitations of the study will be discussed first.

Because this study was not population based, the possibility exists that our sample was not representative. Although this possibility cannot be excluded, the marked similarity between our sample and the NHANES population in the relation between age and BMI suggests that selection bias was not the cause of our findings.

A second potential explanation is that undiagnosed disease caused a change in fat mass, most likely a loss of fat mass. Although subjects were recruited as healthy individuals and screened for conditions known to affect body composition through a medical history questionnaire and physical exam, it is possible that some had as yet undiagnosed conditions that caused a decrease in body fat. If these conditions were more common in the older subjects, this could have accounted for some or all of the decrease in body fat that occurred after age 60 y. Longitudinal studies with careful clinical follow-up could help resolve this issue.

Other well-known limitations of cross-sectional studies could have influenced our findings as well. For example, obesity is associated with increased premature mortality (27). Thus, the death of obese individuals would have removed them from the

TABLE 5
Results of linear regression with fat percentage as the dependent variable and age in y as the independent variable

Group	Constant	Coefficient		R^2	SEE	AgeMax[1]
		Age	Age^2			
					%	*y*
Women						
Asian (*n* = 120)	2.6	1.03 (0.20)[2,3]	−0.008 (0.002)[3]	0.28	5.9	60.8
Black (*n* = 162)	4.7	1.20 (0.24)[3]	−0.010 (0.002)[3]	0.16	8.1	57.5
Puerto Rican (*n* = 98)	18.5	0.76 (0.28)[4]	−0.007 (0.003)[5]	0.10	7.0	55.6
White (*n* = 360)	7.0	0.78 (0.13)[3]	−0.006 (0.001)[3]	0.24	7.2	69.5
Men						
Asian (*n* = 102)	−7.5	1.11 (0.26)[3]	−0.009 (0.003)[3]	0.31	6.1	60.2
Black (*n* = 125)	−7.8	1.06 (0.25)[3]	−0.009 (0.002)[3]	0.23	7.1	61.8
Puerto Rican (*n* = 111)	18.4	0.15 (0.05)[6]	NS	0.09	7.1	—[7]
White (*n* = 246)	3.2	0.63 (0.14)[3]	−0.004 (0.001)[3]	0.19	6.9	70.9

[1] AgeMax, age at which fat percentage was maximum as predicted by the model.
[2] SE in parentheses.
[3–6] Significantly different from zero: [3] $P < 0.001$, [4] $P < 0.01$, [5] $P < 0.02$, [6] $P < 0.005$.
[7] AgeMax was not calculated for this group because the model predicts a steadily increasing fat percentage with age.

population before the study, making the older population thinner. This phenomenon undoubtedly did cause some, and could have caused all, of our finding of a decrease in body fat after middle age. A potential secular or cohort effect is another limitation of cross-sectional studies, and such an effect restricts the potential to derive conclusions about change with age from such studies.

The possibility exists that there is a physiologic tendency for body fat to decrease during old age. This could be caused by a physiologic anorexia of aging (28) or by some other process. It is not possible within the confines of the current study to definitively determine the relative importance of these alternative explanations. Large-scale, longitudinal studies of body composition in aging populations would be useful in clarifying the kinetics of age-related changes in body fat.

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