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Total and regional adiposity measured by dual-energy X-ray absorptiometry and mortality in NHANES 1999-2006

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Abstract

Objective—We investigated associations of overall and regional body fat measured by dual-energy X-ray absorptiometry with total and cause-specific mortality in National Health and Nutrition Examination Survey 1999-2006.

Methods—This study included 9,471 participants (≥20 years) free of major chronic diseases at baseline. Death information was obtained from the National Death Index (mean follow-up duration: 8.8 years).

Results—A total of 682 participants died after 12 months since baseline, with 206 and 170 deaths attributed to cardiovascular diseases(CVD) and cancer, respectively. The second quartile of fat mass percentages(FM%) was used as the reference to account for potential non-linearity. In multivariate-adjusted model, participants in the highest quartile of total FM% had increased total mortality: hazard ratio(HR; 95% confidence interval[95%CI]) was 1.48(1.07, 2.04; P<0.05). Higher total and trunk FM%, but not leg FM%, were significantly associated with an increased CVD mortality: HRs(95%CIs) in the highest quartiles of total, trunk, and leg FM% were 2.24(1.17, 4.31), 1.93(1.02, 3.66), and 1.50(0.77, 2.94), respectively.

Conclusions—Higher total body fat is associated with increased total mortality in U.S. adults. Higher total and trunk fat contents are also associated with increased CVD mortality, although fat accumulation in lower body is not an independent predictor of mortality.

Keywords

DXA; Abdominal obesity; Fat Mass; Mortality; NHANES

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Introduction

Excessive body fat accumulation is an established risk factor for a multitude of chronic conditions, including type 2 diabetes, cardiovascular disease (CVD), and certain cancers, that are among the major causes of deaths in U.S. population.(1) Although obese individuals, as defined as body mass index (BMI) above 30 kg/m^2, have unequivocally elevated total and CVD-related mortality, the relationship between body weight and mortality is a matter of debate among other individuals.(2, 3, 4, 5, 6, 7) Methodological challenges in this research may lead to spurious observations, since the inclusion of participants with pre-existing health conditions and residual confounding by smoking could substantially increase mortality risk at a normal BMI.(8, 9)

While BMI is a simple yet valid tool for assessing overall adiposity at population levels, it is subject to obvious limitations when quantifying individuals' body fat contents.(10) Besides, BMI cannot reflect body fat distribution, which is clearly associated with the development of chronic diseases.(11, 12, 13) Trunk fat has been linked to metabolic abnormalities at various BMI levels(14, 15), and several studies have reported a positive association between visceral adipose tissue and CVD incidence.(16, 17, 18) Conversely, the accumulation of leg fat is associated with a largely favorable metabolic profile.(19, 20, 21, 22, 23) Despite these demonstrated distinctive effects of regional body fat, existing findings on body fat distribution and mortality were limited and inconsistent.(18, 24, 25, 26, 27) In particular, the association between regional body fat accumulation and CVD mortality remains to be elucidated.(28)

In the current study, we aimed to evaluate associations of overall and regional (trunk and legs) body fat contents measured by dual-energy X-ray absorptiometry (DXA) with total and cause-specific mortality in a representative sample of U.S. adults participating in the National Health and Nutrition Examination Survey (NHANES).

Methods

Study population

In NHANES, a complex, multistage, probability sampling design was used to randomly select nation-wide representative non-institutionalized U.S. residents.(29) The study protocol was approved by the institutional review board at the Centers for Disease Control and Prevention (Atlanta, Georgia), and written informed consent was obtained from all participants. Between 1999 and 2006, a total of 14,933 adults (≥20 years) completed a whole-body DXA scan for body composition assessment. Within this sample, the following exclusion criteria were applied in the current analysis: 1) self-reported chronic diseases, including diabetes (n=755), CVD (n=974), cancer (n=895), asthma (n=1,161), or chronic obstructive pulmonary diseases (n=995) at baseline; 2) mental or physical limitations at baseline (n=670); 3) missing mortality information (n=12). After these exclusions, 9,471 participants remained in the analysis. A participant flow chart is available in **S-Figure 1**.

DXA measurements

DXA scan was performed using Hologic QDR 4500A fan beam x-ray bone (Hologic, Inc., Bedford, Massachusetts).(29) Original scan results were analyzed using Hologic Discovery software (version 12.1, Hologic, Inc.) to derive fat mass and lean mass. Body regions (head, arms, trunk, and legs) were delineated manually using tools provided by the software. Trunk region was defined as the area from the inferior edge of the chin as the upper borders to the oblique lines that cross the femoral necks and converge below the pubic symphysis as the lower perimeter, with vertical borders lateral to the ribs. The area below the lower borders of the trunk was defined as leg region. Missing values in original dataset were imputed five times and all five datasets were provided, allowing analysts to incorporate the extra variability due to imputation into their analyses.(29) Overall, less than 5% of data points were imputed in the dataset. The current study included 496 participants with 1 or more imputed DXA measurements in the trunk or leg region. Body fat mass percentage (FM%) for the whole body and each region (trunk, legs) was calculated as fat mass divided by total or regional mass times 100. Fat mass index (FMI) and fat free mass index (FFMI) were calculated as total fat mass and fat-free mass (kg) divided by standing height squared (m^2).

Ascertainment of the Cause of Death

Deaths of NHANES participants were identified through linking to the National Death Index by National Center for Health Statistics using a probabilistic matching strategy. A complete description of the methodology is available elsewhere.(30) We obtained detailed mortality data up to December 31st, 2010 from the Research Data Center of CDC. The International Statistical Classification of Diseases and Related Health Problems Tenth Revision was used to identify participants for whom CVD (codes I00-I78) or cancer (codes C00–C97) was listed as the underlying cause of death. Sixteen deaths were recorded within 12 months since DXA measurements, and these participants were censored in the analysis to further minimize the influence of pre-existing conditions on the associations of interest. Excluding these participants from our analysis did not materially change the results (data not shown).

Covariate assessments

Standard survey questionnaires were used to collect information on demography, lifestyle, and prevalent diseases during the in-person interview.(29) Ethnicity was categorized into non-Hispanic White, non-Hispanic Black, Mexican American, other Hispanic group, and other ethnic groups including multi-ethnicity. Educational attainment was classified as high school or below, any college, and college graduate or beyond. Marital status was grouped into never married, married/living with partner, or separated/divorced/widowed. Ratio of family income to poverty was defined as the ratio of the midpoint of observed family income category to the official poverty threshold based on US Census Bureau information and classified into three groups (<1, 1-3, and >3 using the cutoffs of 1 and 3). Smoking status was grouped as nonsmoker, past smoker, current smoker with ≤10 cigarettes per day, current smoker with 11 to 20 cigarettes per day, and current smoker with >20 cigarettes per day. Alcohol consumption was defined as nondrinker, 1-3 drinks/day, or ≥ 4 drinks/day. Regular moderate-to-vigorous physical activity was categorized as yes or no. Family history of chronic diseases was defined if participants reported blood relatives having diabetes, hypertension, stroke, or angina. Trained study technicians measured body weight, and standing height following a standard protocol.(29) BMI was calculated as weight (kg) divided by standing height squared (m^2), and defined as categorical variables (<18.5, 18.5-22.9, 23-24.9, 25-27.4, 27.5-29.9, 30.0-32.4, 32.5-34.9, and ≥35 kg/m^2).

Statistical analysis

We accounted for survey-based design of NHANES in the analysis whenever feasible. (29) Participants were grouped into quartiles according to weighted distribution of FM% at 25, 50, and 75 percentiles. Sex-specified cutoffs were used to account for the differences in body fat between men and women. The second quartile was treated as the reference group to account for the potential non-linear association between body fat and mortality as suggested by studies in earlier NHANES population.(31) Cox proportional hazards regression was used to estimate hazard ratios (HRs) and 95% confidence intervals (CIs) of total and cause-specific mortality according to FM% quartiles. Because of the multiple-imputation procedure, statistics were calculated within each imputed DXA dataset first, and then pooled to derive a single composite estimate in the PROC MIANALYZE procedure. We used 47 (the number of primary sampling units minus the number of sampling strata) as the degree of freedom for complete data.(29) We adjusted for the following covariates: age (in 5-year age groups), sex, ethnicity, education, marital status, family income, ratio of family income to poverty, family history of chronic diseases, alcohol drinking, smoking status, and physical activity. When analyzing regional FM%, we additionally included BMI and mutually adjusted for trunk FM% and leg FM%, to control for potential confounding from overall obesity and other regional body fat. Data were analyzed using SAS 9.4 (SAS Institute, Inc., Cary, North Carolina) and SUDAAN, version 11 (Research Triangle Institute, Research Triangle, North Carolina). All tests were 2-sided, and $P < 0.05$ was considered as statistically significant.

Results

Population characteristics according to quartiles of total FM% are shown in **Table 1**. Participants with higher total FM% were older, more likely to be married, non-smokers, and have a family history of chronic diseases. They also had lower educational attainment, lower alcohol consumption, and lower physical activity than participants who had lower FM%.

A total of 682 participants died over a mean follow-up duration of 8.8 years, with 206 and 170 deaths attributed to CVD and cancer mortality, respectively. Associations of total and regional FM% with all-cause mortality are presented in **Table 2**. In age-adjusted model (model 1), participants in the highest quartile of total FM% had 47% (HR [95%CIs]: 1.47 [1.08, 2.00]) higher risk of death compared with the second quartile, and this association was not changed after multivariate adjustment (model 2). In contrast, the positive association for the lowest total FM% quartile was attenuated after multivariate adjustment of lifestyle and other demographic factor. Neither trunk FM% nor leg FM% was significantly associated with total mortality after multivariate adjustment.

As shown in **Table 3**, higher total FM% and trunk FM% were associated with an increased CVD mortality. Compared with the reference group, HRs (95%CIs) of CVD mortality in the highest groups were 2.24 (1.17, 4.31) for total FM% in multivariate adjusted model (model 2) and 1.93(1.02, 3.66) for trunk FM% with further adjustment of BMI and leg FM% (model 3). The increased CVD mortality among participants in the lowest total FM% and trunk FM % group in age-adjusted model were weakened in model 2, and further attenuated in model 3 for trunk FM%. Leg FM% was not significantly associated with CVD mortality with or without adjustment of covariates. Compared with the reference group, HRs (95%CIs) were 1.42 (0.75, 2.17) for the lowest quartile and 1.50 (0.77, 2.94) for the highest quartile of leg FM% in the fully-adjusted model.

None of these body fat distribution measurements was associated with cancer mortality after multivariate adjustment of covariates (**Table 4**). FMI, FFMI, and the ratio of trunk fat to leg fat were not associated with total or cause-specific mortality after multivariate adjustment (**S-Table 1** and **S-Table 2**).

Discussion

In the current study among 9,471 U.S. adults, higher total body fat contents were associated with increased total and CVD mortality. Moreover, higher trunk FM%, but not leg FM%, was associated with a significantly increased risk of death due to CVD. These findings were independent of established demographic and lifestyle risk factors of mortality. Our study expanded existing literature on obesity and mortality by linking DXA-measured body fat with cause-specific mortality in a general population, and highlighted the importance of body fat contents and distribution on CVD health.

Existing data linking overall adiposity directly measured by DXA or other instruments with mortality were mainly generated from studies among elderly populations. In 4,000 Chinese men and women aged ≥65 years, Auyeung *et al.* found an inverse association between FMI and 5-year survival among men, but in women FMI was not associated with mortality.(27) In contrast, among 921 Swedes aged 65-85 years, total fat mass was monotonically associated with lower mortality in women, whereas a U-shaped association was found in men.(24) Lastly, higher FMI was favorably associated with 17 years survival among 4574 French women aged ≥75 years.(25) These inconsistent findings should be explained with caution as aging process is accompanied by loss of muscle mass and redistribution of body fat.(8, 9) Besides, elderly populations are more likely to have chronic diseases that may result in loss of body mass and premature death, which may lead to reverse causation bias between adiposity and mortality.(8, 9) In a recent large-scale study conducted among Canadian adults aged 40 and ahove, high total FM% was associated with a higher mortality even after adjustment of BMI, clearly suggesting detrimental effects of overall adiposity on longevity.(32)

The increased CVD mortality among participants with the lowest total FM% could be largely due to methodological limitations pertinent to studies of obesity and mortality, such as the inclusion of participants with subclinical diseases and residual confounding by smoking, as well as aging.(8, 9) Although we excluded participants with several types of prevalent diseases and censored deaths within 12 months after baseline, the self-reported disease status may not reflect the true underlying conditions in this general population.(9)

Higher mortality among participants with normal BMI has been mainly observed in smokers,(6, 7) which possibly explained the “obesity paradox” in previous NHANES studies.(33). When repeating the analysis among never smokers, we found no association of FM% with total or CVD mortality due to a lack of statistic power (data not shown).Based on more accurate assessment of obesity status, our findings did not suggest that the increased mortality among normal weight participants could be explained by the inability of BMI in differentiating FM and FFM.

Evidence regarding the association between regional fat distribution and mortality has primarily focused on abdominal fat in relation to total mortality. Since body imaging technology is too expensive and labor-intensive to apply in large-scale studies to examine abdominal fat distribution, simple anthropometric measurements, such as waist circumference (WC) and waist-to-hip ratio (WHR) have been widely used as indirect assessment of central fat distribution. In a meta-analysis of 18 studies that included various anthropometric measurement of obesity, both WC and WHR showed monotonically positive association with total mortality, and these findings remained after adjustment of BMI (for WC, 4 studies with over 491 thousands participants; for WHR, 5 studies with 535 thousands). (13)

In comparison with these large-scale analyses, data regarding DXA- or CT-measured abdominal fat contents/distribution were less consistent. In the aforementioned studies among the elderly populations, Auyeung *et al* reported that DXA-measured trunk-to-total fat ratio was associated with a higher total mortality in Chinese men but not women,(27) whereas Toss *et al.* found a U-shaped association between DXA-measured abdominal fat and total mortality in the elderly Swedes.(24) The latter study also showed that leg fat mass was inversely associated with total mortality in women, with a U-shaped association found in men.(24) Among studies that examined CT-measured visceral fat in relation to mortality, visceral fat accumulation was positively associated with total mortality among 291 middle-aged and older U.S. men.(34) Contrarily, a study that consisted of 5087 Icelandic aged 66-96 years showed CT-measured visceral fat was linearly associated with higher mortality in women but not in men.(35) CT-measured visceral fat was associated with total mortality in 3,086 participants from the Framingham Heart Study or in 733 Japanese Americans.(18, 26) The inconsistencies of these findings may be explained by study participants’ characteristics, such as age and baseline health status, small sample size, short duration of follow-up, and lack of comprehensive adjustment of covariates.

Despite the evidence suggesting strong adverse effects of central obesity and potential benefits or neutral effects of leg fat accumulation as compared to trunk fat on cardiometabolic health,(19, 20, 21, 22, 23) data regarding regional fat depots in relation to CVD mortality are sparse. The only published study that reported no associations between DXA-measured trunk fat with CVD mortality was conducted among 3978 Chinese men and women aged 65 and over, but leg fat was not analyzed.(28) In the current study, we found that increased CVD mortality was associated with high trunk FM%, although neither high nor low leg FM% was associated with CVD mortality. Mechanisms underlying the findings of leg fat remain to be elucidated, although experimental studies have showed that leg fat releases lower levels of pro-inflammatory markers compared with abdominal adipose tissue.

(36, 37) Furthermore, adipocytes in the gluteal or femoral region have greater free fatty acid uptake but lower lipolysis than those in the abdominal region, which collectively lead to a relatively lower circulating free fatty acid level.(38, 39) Consistent with these mechanisms, several studies have reported that leg fat was inversely associated with blood lipids, markers of glucose metabolism, blood pressure, as well as metabolic syndrome which is a collection of these risk factors.(19, 20, 21, 22, 23)

The strength of our study included using a nationally representative cohort of U.S. adult, long duration of follow-up, multivariate adjustment of covariates, and exclusion of participants with existing major chronic diseases. Meanwhile, our study has several limitations. Although the current study is among the largest investigations that examined direct measurements of body fat distribution in relation to total and cause-specific mortality, the moderate number of deaths might render diminished statistical power. This may be particularly of concern for detecting association between body fat distribution and deaths due to cancer, for which the strength of associations with adiposity is less than that for CVD- or diabetes-related death, and thus a larger sample size is required to detect significant associations (40) Similarly, we were unable to perform analyses stratified by age and sex, or a subgroup analysis among never smokers to disentangle the influences of these factors on the associations of interest. In addition, we cannot fully exclude potential residual confounding from misclassified disease status, which is also a plausible reason for an increased CVD mortality among participants with lower total FM%. Third, we cannot exclude the role of chance, especially when certain cases were assigned with a relative-high sampling weight due to the survey-based design of NHANES. Fourth, body fat distribution was only measured at baseline, and the associations between changes in body fat contents during follow-up and mortality cannot be evaluated. Lastly, DXA scan cannot distinguish subcutaneous fat from visceral fat in the trunk region. Therefore, we were unable to explore whether visceral fat will be more strongly associated with mortality than total fat content in the trunk.

Conclusion

In conclusion, higher total body is associated with an increased total mortality, while total and trunk fat accumulation is associated with an increased CVD mortality in this nation-wide representative sample of U.S. adults. In contrast, leg fat accumulation is not associated with total or cause-specific mortality. Our findings further support the adverse effects of overall and central obesity on health and also suggest a neutral effect of leg fat accumulation on health. Clearly, large-scale studies are warranted to replicate these findings.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Study Importance Questions

What is already known about this subject?

1. Anthropometric indices that are indirect measurements of body fatness have been widely used in observational studies to evaluate associations between body fat content and mortality.
2. Trunk fat has been linked to an increased total mortality, although few studies have been conducted to examine regional fat distribution, especially leg fat accumulation that may have different effects compared with trunk fat, in relation to cardiovascular (CVD) mortality.

What does this study add?

1. In a representative sample of Americans, high total body fat content is associated with higher total and CVD mortality.
2. High trunk fat content is associated with a higher CVD mortality, whereas leg fat content is not associated with total, CVD, or cancer mortality.
3. These findings suggest adverse effects of upper body fat accumulation and neutral effects of lower body fat on longevity.

Table 1

Characteristics of Study Participants According to Weighted Quartiles of Total FM% [1]

Variable	Q1	Q2	Q3	Q4
Crude sample	2186	2352	2416	2517
Weighted sample	25.2%	25.2%	24.8%	24.8%
Total FM%, men	19.58(0.08)	25.55(0.04)	29.09(0.03)	34.40(0.07)
Total FM%, women	30.11(0.14)	37.17(0.06)	41.73(0.04)	47.23(0.08)
Men	52%	52%	51%	52%
Age, years	36.2(0.4)	41.8(0.4)	44.9(0.4)	46.9(0.4)
Ethnicity				
Non-Hispanic White	71%	69%	68%	72%
Non-Hispanic Black	13%	10%	10%	10%
Mexican American	6%	10%	9%	10%
Other Hispanic	5%	5%	7%	5%
Other ethnic groups	6%	6%	5%	4%
Education				
High school or below	41%	43%	43%	46%
Any college	30%	30%	30%	31%
College graduate or above	30%	27%	26%	23%
Smoking status				
Never smoked	58%	57%	57%	59%
Past smoker	14%	21%	23%	26%
Current smoker, ≤10 cigarettes per day	10%	8%	7%	6%
Current smoker, 11 to 20 cigarettes per day	13%	11%	9%	6%
Current smoker, >20 cigarettes per day	4%	3%	3%	4%
Alcohol consumption				
Nondrinkers	23%	25%	30%	34%
1-3 drinks/day	55%	56%	54%	51%
4 drinks/day	22%	20%	16%	15%
Family history of chronic diseases	51%	56%	58%	61%
Married	55%	66%	69%	68%
Family income to poverty ratio [2]				
<1	19%	17%	17%	16%
1 to 3	33%	32%	32%	35%
>3	48%	51%	51%	49%
Moderate to vigorous physical activity, yes	75%	70%	66%	59%
Body mass index, kg/m^2, men	23.0(0.1)	26.3(0.1)	28.2(0.1)	32.0(0.2)
Body mass index, kg/m^2, women	21.5(0.1)	24.9(0.1)	28.8(0.2)	34.6(0.2)
Whole body fat mass, kg	15.9(0.1)	22.8(0.1)	28.7(0.2)	38.8(0.2)
Trunk fat mass, kg	6.8(0.1)	10.9(0.1)	14.3(0.1)	19.9(0.1)
Trunk FM%	22.2(0.1)	30.5(0.1)	35.6(0.2)	41.4(0.1)
Leg fat mass, kg	6.2(0.1)	8.1(0.1)	9.8(0.1)	13.1(0.1)

Variable	Q1	Q2	Q3	Q4
Leg FM%	28.2(0.2)	33.2(0.2)	36.5(0.2)	41.2(0.2)

FM%=fat mass percentage;

[1]Data are presented as weighted mean±standard error for continuous variables, and weighted percentages for categorical variables. Sums of percentages may not be 100% because of rounding.

[2]Poverty income ratio is the ratio of the midpoint of observed family income category to the official poverty threshold based on US Census Bureau information.

Table 2

Body Fat Percentages and Hazard Ratios of Total Mortality

		Q1	Q2	Q3	Q4
Total FM%	Weighted sample [1]	25.2%	25.2%	24.8%	24.8%
	FM% range, men	≤23.4	23.5-27.3	27.4-31.0	≥31.1
	FM% range, women	≤34.5	34.6-39.6	39.7-43.8	≥43.9
	Weighted total mortality [2]	3.3%	3.3%	4.5%	6.5%
	Model 1 [3]	1.55(1.08,2.22) [6]	Reference	1.11(0.79,1.55)	1.47(1.08,2.00) [6]
	Model 2 [4]	1.33(0.95,1.87)	Reference	1.13(0.81,1.56)	1.48(1.07,2.04) [6]
Trunk FM%	Weighted sample [1]	25.1%	25.2%	24.9%	24.9%
	FM% range, men	≤23.4	23.5-28.7	28.8-33.2	≥33.3
	FM% range, women	≤30.8	30.9-37.9	38.0-43.4	≥43.5
	Weighted total mortality [2]	3.1%	3.9%	4.4%	6.2%
	Model 1 [3]	1.36(0.96,1.92)	Reference	0.98(0.68,1.42)	1.28(0.92,1.78)
	Model 2 [4]	1.24(0.89,1.73)	Reference	1.04(0.72,1.51)	1.33(0.96,1.86)
	Model 3 [5]	1.05(0.75,1.47)	Reference	1.12(0.75,1.66)	1.36(0.94,1.98)
Leg FM%	Weighted sample [1]	25.0%	25.2%	25.1%	24.7%
	FM% range, men	≤23.05	23.10-26.80	26.85-30.65	≥30.70
	FM% range, women	≤39.05	39.10-43.35	43.40-47.50	≥47.55
	Weighted total mortality [2]	3.8%	3.7%	4.0%	6.1%
	Model 1 [3]	1.41(1.05,1.89) [6]	Reference	0.98(0.74,1.30)	1.30(0.98,1.74)
	Model 2 [4]	1.31(0.98,1.75)	Reference	1.03(0.78,1.36)	1.35(0.99,1.84)
	Model 3 [5]	1.32(0.96,1.82)	Reference	1.03(0.77,1.38)	1.28(0.93,1.77)

FM%=fat mass percentage;

[1] Data are weighted percentages of total study population;

[2] Data are weighted mortality in each group;

[3] Hazard ratios were calculated in survey-based Cox proportional hazards model in each imputed DXA data set first, and then pooled to get single estimates. Model 1, adjusted for age (in 5-year age group);

[4] Model 2, further adjusted for ethnicity (non-Hispanic White, non-Hispanic Black, Mexican American, other Hispanic, or other ethnic groups), education (high school or below, any college, or college graduate or above), marital status (single, married or living with partner, or divorced or widowed or separated), family income to poverty ratio (<1, 1-3, or >3), family history of chronic diseases (diabetes, hypertension, stroke, or angina), regular moderate-to-vigorous physical activity (yes, or no), smoking status (nonsmoker, past smoker, current smoker with ≤10 cigarettes per day, current smoker with 11 to 20 cigarettes per day, or current smoker with >20 cigarettes per day), and alcohol consumption (nondrinker, 1-3 drinks/day, or >4 drinks/day) based on model 1;

[5] Model 3, further adjusted for body mass index (<18.5, 18.5-22.9, 23-24.9, 25-27.4, 27.5-29.9, 30.0-32.4, 32.5-34.9, and ≥35 kg/m^2), and mutually adjusted for trunk FM% and leg FM% (in 10% group) based on model 2.

[6] $P<0.05$.

Table 3

Body Fat Percentages and Hazard Ratios of Cardiovascular Disease Mortality

		Q1	Q2	Q3	Q4
Total FM%	Weighted sample [1]	25.2%	25.2%	24.8%	24.8%
	FM% range, men	≤23.4	23.5-27.3	27.4-31.0	≥31.1
	FM% range, women	≤34.5	34.5-39.6	39.6-43.8	≥43.9
	Weighted total mortality [2]	1.0%	0.7%	1.2%	1.8%
	Model 1 [3]	2.81(1.37,5.73) [7]	Reference	1.63(0.88,3.02)	2.26(1.14,4.46) [6]
	Model 2 [4]	2.43(1.12,5.26) [6]	Reference	1.66(0.89,3.08)	2.24(1.17,4.31) [6]
Trunk FM%	Weighted sample [1]	25.1%	25.2%	24.9%	24.9%
	FM% range, men	≤23.4	23.5-28.7	28.8-33.2	≥33.3
	FM% range, women	≤30.8	30.9-37.9	38.0-43.4	≥43.5
	Weighted total mortality [2]	0.9%	0.9%	1.1%	1.8%
	Model 1 [3]	2.16(1.32,3.54) [7]	Reference	1.19(0.77,1.84)	1.86(1.10,3.13) [6]
	Model 2 [4]	1.95(1.16,3.28) [6]	Reference	1.26(0.80,1.99)	1.95(1.17,3.26) [6]
	Model 3 [5]	1.38(0.75,2.52)	Reference	1.49(0.88,2.52)	1.93(1.02,3.66) [6]
Leg FM%	Weighted sample [1]	25.0%	25.2%	25.1%	24.7%
	FM% range, men	≤23.05	23.10-26.80	26.85-30.65	≥30.70
	FM% range, women	≤39.05	39.10-43.35	43.40-47.50	≥47.55
	Weighted total mortality [2]	1.1%	0.9%	0.9%	1.7%
	Model 1 [3]	1.59(0.86,2.94)	Reference	0.88(0.52,1.50)	1.50(0.85,2.65)
	Model 2 [4]	1.47(0.78,2.79)	Reference	0.85(0.50,1.42)	1.45(0.83,2.53)
	Model 3 [5]	1.42(0.75,2.71)	Reference	0.89(0.49,1.64)	1.50(0.77,2.94)

FM%=fat mass percentage;

[1] Data are weighted percentages of total study population;

[2] Data are weighted mortality in each group;

[3] Hazard ratios were calculated in survey-based Cox proportional hazards model in each imputed DXA data set first, and then pooled to get single estimates. Model 1, adjusted for age (in 5-year age group);

[4] Model 2, further adjusted for ethnicity (non-Hispanic White, non-Hispanic Black, Mexican American, other Hispanic, or other ethnic groups), education (high school or below, any college, or college graduate or above), marital status (single, married or living with partner, or divorced or widowed or separated), family income to poverty ratio (<1, 1-3, or >3), family history of chronic diseases (diabetes, hypertension, stroke, or angina), regular moderate-to-vigorous physical activity (yes, or no), smoking status (nonsmoker, past smoker, current smoker with ≤10 cigarettes per day, current smoker with 11 to 20 cigarettes per day, or current smoker with >20 cigarettes per day), and alcohol consumption (nondrinker, 1-3 drinks/day, or >4 drinks/day) based on model 1;

[5] Model 3, further adjusted for body mass index (<18.5, 18.5-22.9, 23-24.9, 25-27.4, 27.5-29.9, 30.0-32.4, 32.5-34.9, and ≥35 kg/m^2), and mutually adjusted for trunk FM% and leg FM% (in 10% group) based on model 2;

[6] $P<0.05$;

[7]P<0.01.

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Table 4

Body Fat Percentages and Hazard Ratios of Cancer Mortality

		Q1	Q2	Q3	Q4
Total FM%	Weighted sample [1]	25.2%	25.2%	24.8%	24.8%
	FM% range, men	≤23.4	23.5-27.3	27.4-31.0	≥31.1
	FM% range, women	≤34.5	34.5-39.6	39.6-43.8	≥43.9
	Weighted total mortality [2]	0.9%	0.8%	1.4%	2.0%
	Model 1 [3]	1.90(0.88,4.07)	Ref	1.37(0.74,2.55)	1.76(1.01,3.08) [6]
	Model 2 [4]	1.54(0.73,3.27)	Ref	1.38(0.76,2.50)	1.76(0.99,3.13)
Trunk FM%	Weighted sample [1]	25.1%	25.2%	24.9%	24.9%
	FM% range, men	≤23.4	23.5-28.7	28.8-33.2	≥33.3
	FM% range, women	≤30.8	30.9-37.9	38.0-43.4	≥43.5
	Weighted total mortality [2]	0.9%	0.9%	1.4%	1.8%
	Model 1 [3]	1.53(0.67,3.47)	Ref	1.19(0.60,2.36)	1.38(0.75,2.54)
	Model 2 [4]	1.32(0.60,2.91)	Ref	1.29(0.64,2.59)	1.41(0.75,2.65)
	Model 3 [5]	1.06(0.49,2.29)	Ref	1.27(0.61,2.65)	1.21(0.55,2.65)
Leg FM%	Weighted sample [1]	25.0%	25.2%	25.1%	24.7%
	FM% range, men	≤23.05	23.10-26.80	26.85-30.65	≥30.70
	FM% range, women	≤39.05	39.10-43.35	43.40-47.50	≥47.55
	Weighted total mortality [2]	1.2%	1.1%	1.1%	1.7%
	Model 1 [5]	1.55(0.73,3.27)	Ref	0.93(0.51,1.68)	1.22(0.72,2.06)
	Model 2 [4]	1.39(0.67,2.88)	Ref	1.00(0.55,1.83)	1.29(0.72,2.30)
	Model 3 [5]	1.54(0.74,3.22)	Ref	0.91(0.49,1.70)	0.96(0.52,1.75)

FM%=fat mass percentage;

[1] Data are weighted percentages of total study population;

[2] Data are weighted mortality in each group;

[3] Hazard ratios were calculated in survey-based Cox proportional hazards model in each imputed DXA data set first, and then pooled to get single estimates. Model 1, adjusted for age (in 5-year age group);

[4] Model 2, further adjusted for ethnicity (non-Hispanic White, non-Hispanic Black, Mexican American, other Hispanic, or other ethnic groups), education (high school or below, any college, or college graduate or above), marital status (single, married or living with partner, or divorced or widowed or separated), family income to poverty ratio (<1, 1-3, or >3), family history of chronic diseases (diabetes, hypertension, stroke, or angina), regular moderate-to-vigorous physical activity (yes, or no), smoking status (nonsmoker, past smoker, current smoker with ≤10 cigarettes per day, current smoker with 11 to 20 cigarettes per day, or current smoker with >20 cigarettes per day), and alcohol consumption (nondrinker, 1-3 drinks/day, or >4 drinks/day) based on model 1;

[5] Model 3, further adjusted for body mass index (<18.5, 18.5-22.9, 23-24.9, 25-27.4, 27.5-29.9, 30.0-32.4, 32.5-34.9, and ≥35 kg/m^2) based on model 2;

[6] P<0.05.