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Association between body composition and hip fractures in older women with physical frailty

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Abstract

Aims—We sought to determine the extent to which higher lean and fat mass as measured by dual-x-ray absorptiometry (DXA) in older adults with frailty are related to total hip bone mass density index (BMD) and rate of hip fractures.

Methods—The data are from the Women's Health Initiative Observational Study. We identified 872 participants aged 65+ with body-composition measures and positive frailty. Frailty was determined using modified Fried's criteria. Linear and Cox regressions were used to model study outcomes.

Results—During the follow-up period, 5.6% (n = 49) had sustained a hip fracture. Body composition indexes were associated with total hip BMD (p<0.001 for all). In models adjusted for age, ethnicity, smoking, history of fractures, recurrent falls, number of frailty criteria and corresponding lean mass, the hazard ratio (HR) for hip fracture per 1 kg/m^2 increase in fat mass was 0.73 (95% confidence interval [CI] 0.60–0.88) for appendicular compartment, 0.76 (0.65–0.89) for trunk, and 0.84 (0.77–0.93) for whole-body fat mass. HR for hip fracture per 1 kg/m^2 increase in appendicular lean mass was 0.63 (95% CI 0.46–0.88). However, after final adjustment

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DISCLOSURE STATEMENT
The authors declare no conflict of interest

Supporting documents :
Supplementary Figure 1: Participants flow chart.
Supplemental Table1A. Correlation between cross-sectional (Year 3) and longitudinal (Year 3 to Year 6 change) indexes of lean and fat body-composition
Supplemental Table1B. Correlation between cross-sectional (Year 3) and longitudinal (Year 3 to Year 6 change) indexes of lean and fat boday-composition and total-hip bone mass density (BMD) index

for total hip BMD, the only index that remained statistically significant was whole-body fat mass (p for trend=0.04).

Conclusion—We demonstrated that in frail older women higher fat and lean mass was associated with reduced hip-fracture rates. Higher whole-body adiposity, however, was also associated with lower hip-fracture rate independent of total hip BMD. Our results confirm the importance of weight maintenance in frail populations.

Keywords

bone; hip fracture; fat mass; frailty; lean mass; longitudinal

INTRODUCTION

With the aging of the global population, physical frailty, now recognized as a distinct geriatric syndrome, has become an important concern in public health worldwide.[1] The most widely used operational definition of frailty includes the presence of three of the following indicators: muscle strength loss, slowness, fatigue, low physical activity and a decline in body weight.[2] Frail older adults are at an increased risk for falls, hip fracture, disability, and mortality.[2–4]

Mounting evidence suggests that body weight is positively associated with bone health in older adults.[5] However, evidence also indicates that lean and fat masses, which together account for 95% of body weight, might have a distinct relationship with bone mass measures.[6–8] Because frail participants have lower muscle mass and higher fat mass than non-frail persons[9], and because osteoporosis is highly prevalent in the elderly population[10], it is important to understand the potential consequences of body-composition change in older persons with frailty first in the context of bone health and then with regard to risks of osteoporotic fractures. Derangements in inflammatory, endocrine, coagulation, and metabolic systems, which were repeatedly demonstrated in frail older adults[11,12], might preclude generalizability of the findings from the non-frail population to those with frailty. For instance, our previous research showed that adiposity in frailty has a different impact on survival[14] than the one observed in non-frail population.[25]

To address the gap, we evaluated longitudinal data from a prospective cohort with previously validated frailty ascertainment to test the hypothesis that higher lean or fat mass is associated with better bone health and a lower risk of hip fractures in older women with physical frailty. Of secondary interest, we also sought to examine whether changes over time in body-composition measures are associated with bone-related outcomes.

METHODS

Study population

The Women's Health Initiative Observational Study (WHI OS) comprised 93,676 women aged 50 to 79 years at baseline (1993–1998) from 40 U.S. clinical centers. Details of the WHI study design and baseline characteristics have been reported elsewhere.[13] The WHI

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study was approved by the institutional review boards at all 40 clinic sites, and all participants provided written informed consent at baseline.

At baseline and the 3- and 6-year follow-up clinical visits, OS participants recruited in Pittsburgh, PA, Birmingham, AL, and Tucson and Phoenix, AZ, WHI clinical centers completed questionnaires on demographic, medical and psychosocial characteristics; clinically provided weight and height measures; and received a whole-body dual-energy X-ray absorptiometry (DXA) exam.

For this analysis, we identified 872 WHI OS women at least 65 years of age with complete data at the Year 3 clinical visit to characterize frailty using modified Fried's criteria and available anthropometric and DXA data. Congruent with Fried's definition[2], frailty was operationalized as the presence of three or more of the following criteria: muscle weakness, slow walking speed, fatigue, low physical activity, and unintentional weight loss. This operationalization for frailty was adapted and validated in the WHI and has been extensively used in the WHI OS cohort[4,14,15]. The analytical sample was limited to only those meeting the definition of frail (see Supplementary Figure 1).

DXA measures

With use of the same standard protocol at three clinical sites, whole-body scans were obtained from Hologic QDR scanners (QDR 2000, 2000+, or 4500W; Hologic, Waltham, MA) at randomization and during the follow up visits at years 3 and 6. Scanner performance was monitored longitudinally by using spine and whole-body phantom scans. Quality control procedures included periodic review of random scans, monitoring of phantom scans, in-vivo and in-vitro cross calibrations and were overviewed by the University of California, San Francisco, DXA Coordinating Center.[26,27] In vivo cross-calibration was performed at 2 sites to convert QDR4500 to QDR2000-equivalent values when 2 QDR2000 scanners were retired. These correction factors and adjustment for longitudinal changes in scanner performance were applied to participant scan results. Quality assurance procedures included detecting and reporting on scans if the coefficient of variation exceeded 0.5% threshold.

The imaging results provided values for masses of lean and fat tissues for the whole body and specific regions, and bone mass density (BMD) estimates for the total hip. Body-compartment-specific scores were calculated as follows: (1) appendicular compartment indicated the sum of lean or fat tissues in both arms and legs. (2) lean and fat soft tissue of the trunk indicated central fat or lean mass, and (3) total body lean or fat mass indicated the whole-body-composition scores. Lean and fat mass *index* at Year 3 (static index) was calculated as body-compartment-specific scores in kg divided by height in meters squared. A percentage change over time (dynamic index) was calculated as the difference between Year 6 and Year 3 measures.

Hip fractures

The primary outcome for this study was incidence of hip fracture. Hip fractures were ascertained from annual self-report and then centrally adjudicated by WHI physician adjudicators using medical records. Because our goal was to examine incidence of hip fracture subsequent to ascertainment of frailty, we excluded fractures that were reported before the third and the sixth annual follow-up visit for analyses that used static and dynamic indexes respectively

Covariates

Baseline data on demographic variables (baseline age, race/ethnicity, family income), smoking status (*Never smoker; Past Smoker; Current smoker*), and history of fractures for the first time at age 55 or older and history of recurrent (2+) falls in the previous year were obtained by self-report. During Year 3 clinical visits, trained and certified staff collected anthropometric measurements. Weight to the nearest 0.1 kg and height to the nearest 0.1 cm were used to compute body mass index (BMI).

Statistical analyses

First, two sample *t* tests and chi-square tests were used to evaluate mean and proportion by incident hip fracture. Second, we computed Pearson correlation coefficients of lean and fat body-composition indexes and BMD scores. Third, multiple linear regressions were fitted to examine the association between body-composition indexes and total hip BMD with initial adjustment for age and then additionally for ethnicity, smoking, history of previous fractures, recurrent falls, and a number of frailty criteria. Fourth, to examine the multivariate relationship between appendicular, trunk, and whole-body mass indexes measured at Year 3 and incident hip fracture, hazard ratios (HRs) and 95% confidence intervals (CIs) were estimated using separate Cox proportional hazards models. Survival models were first adjusted for age and then for ethnicity, smoking, history of previous fractures, recurrent falls and a number of frailty criteria. Furthermore, to understand whether risks of hip fracture associated with fat mass were independent of lean mass, we included additional adjustment for a continuous measure of corresponding lean mass. The final set of models included further adjustment for total hip BMD scores. The proportional hazards assumption was examined with Schoenfeld residuals. All statistical analysis was completed using STATA, version 11.2 (StataCorp, College Station, TX).

RESULTS

Among the 872 WHI OS frail older women, 5.6% ($n = 49$) had sustained a hip fracture over a mean follow-up of 11.5 years (range 3.2–18.7). The mean (SD) age at incident hip fracture was 85.4 (6.31) years. At Year 3 clinical visit, women with a fracture were older, were more likely to be White, had lower BMI and total hip BMD, (Table 1).

Furthermore, frail participants with a hip fracture had lower appendicular, trunk and total body fat mass indexes ($P < 0.001$, for all). Differences in lean mass were only observed for appendicular body compartment ($P = 0.04$). There were no significant differences observed in percentage change over time in body-composition indexes by incident hip fracture.

Pearson correlation coefficients showed that static lean and fat mass indexes were moderately correlated with each other (correlation coefficients ranging from 0.47 to 0.57, $P < 0.001$ for all); whereas dynamic indexes showed merely weak reciprocal correlation with a maximum estimate of −0.25 ($p<0.001$) for TLM and TFM indexes (Supplementary Table 1A). Likewise, static Year 3 body-composition indexes were moderately correlated with

Year 3 total hip BMD (correlation coefficients ranging from 0.28 to 0.42, $P < 0.001$ for all). In contrast, percentage change from Year 3 to Year 6 in body-composition indexes was not correlated with Year 6 total hip BMD ($P > 0.05$ for all [Supplementary Table 1B]).

In either minimally or fully adjusted models, greater fat and lean mass indexes were associated with greater total hip BMD (Table 2). Modest differences were observed in R^2 estimates so that age-adjusted models with lean mass indexes explained merely 14 to 17% of the variance in total hip BMD versus fat mass indexes that explained 20 to 22% of that variance.

In age-adjusted models the HR for hip fracture per 1 kg/m^2 increase in fat mass index was 0.76 (95% CI 0.66 –0.88) for appendicular compartment, 0.78 (0.69–0.89) for trunk and 0.87 (0.81–0.93) for whole-body fat mass (Table 3). The associations remained virtually unchanged after additional adjustment for ethnicity, income, smoking, history of fractures, recurrent falls, a number of frailty criteria and corresponding lean mass. However, after final adjustment for total hip BMD, the only index that remained statistically significant was whole-body fat mass (p for trend =0.043). A comparable set of analyses using lean mass indexes yielded significant estimates only for appendicular lean mass (HR 0.63; 95% CI 0.46–0.88) while adjusting for age, ethnicity, smoking, history of fractures, recurrent falls and number of frailty criteria. Further adjustment for total hip BMD attenuated the strength of the association, rendering non-significant HRs.

DISCUSSION

In this study we demonstrated that among frail women, appendicular, trunk and total body fat and lean mass indexes were significant determinants of total hip BMD. In the context of hip fractures, higher lean and fat mass indexes were associated with lower risks of hip fractures, but whole-body fat was the only index to retain that indirect association independently of total-hip BMD. Change over time in body-composition indexes was not a significant determinant of bone health in older women with frailty.

Although, to our knowledge, this is the first study to evaluate the association of dynamics in body composition with risks of hip fracture in a sample of exclusively frail, older participants, our results are in accordance with previous studies in non-frail or mixed populations of older women that demonstrated the association between whole-body and abdominal fat mass measures and lower risks of hip fracture.[16,17] More importantly, in these studies both whole-body and abdominal fat mass measures were associated with fracture risks, and the later association was independent of BMD, indicating that central adiposity might be informative in predicting fractures over and beyond BMD. In our analyses trunk fat mass was also at the margins of significance; yet, it is important to highlight that potential benefits of central adiposity in the context of bone health should be carefully weighted against risks of cardiovascular morbidity.

Higher lean mass was not a significant correlate of hip fractures in models adjusted for total hip BMD. These findings were surprising given a confluence of low BMD and low lean mass on fracture risks.[28] However our results are in accordance with a previous report by

Lang et al.[18] that showed that a decrease in thigh muscle mass, as measured by computed tomography, was a significant correlate of incident hip fractures in non disabled older (73+) persons, but further adjustment for BMD by DXA eliminated the association and resulted in non-significant estimates. Thus, pending further research, one cautious interpretation is that positive impact of lean mass on hip fracture risk might be channelled through adaptive bone related anabolic processes.

Because scarce literature exists on the association between changes over time in body composition and incident hip fractures in older women, we compared our results with studies that examined dynamics in weight. In a large study that used pooled data across the WHI studies, postmenopausal women who lost more than 5% of their baseline weight within next 3 years of follow up had 65% higher rate of hip fractures as compared with women with stable weight (<5% change).[29] In another study in four communities within the United States among older women, those who experienced at least 5% weight loss in later years had increased rates of hip bone loss and a twofold greater risk of subsequent hip fracture.[19] Similarly, in women aged 67 years and older, extreme weight loss of 10% or more beginning at a younger age was associated with increased risks of hip fracture.[20] Our results, on the other hand, showed that although body-composition scores seem to be consistently lower among women with hip fractures, the change over time was not a significant correlate of total hip BMD. Possible explanations for our null findings are a relatively low sample size in frail women with two DXA measures, proximity of two measures that precluded pronounced variability over time, and probable selection bias—women had to survive long enough to have the second body-composition measure.

A number of mechanisms for the fat–bone relationship in older adults have been proposed and include the effect of soft tissue mass on skeletal loading, the association of fat mass with the secretion of bone active hormones from the pancreatic beta cell, and the secretion of bone active hormones from the adipocyte.[5] Moreover, some also suggested that individuals with higher fat mass might be protected during falls by fat cushioning.[16] Given consistency of our findings with those observed in non-frail populations, it would be reasonable to assume that the above-mentioned physiological mechanisms might also be pertinent in physically vulnerable or frail older adults.

Before considering causality, there are several important confounders to be considered. We have adjusted for variables previously demonstrated to be associated with hip fracture in women[21] such as ethnicity and history of fractures, but the possibility of residual and hidden confounding still exists. Women with hip fracture, in our study, had a higher rate of recurrent falls in the past 12 months. Frail women are at an increased risk of recurrent falls compared with non-frail women[3], and most hip fractures are the result of falls[22]. Falls may act as a mediating factor between body composition and fractures since a lower muscle mass may lead to falls[23], but may also act as a confounding factor of poor health.[24] In our study, adjustment for recurrent falls did not attenuate the observed associations, indicating that falls were neither a significant confounding nor a mediating factor in the association between body composition and hip fracture.

The strengths of this study include the large sample size of frail older women, the use of well-validated frailty criteria, and direct measure of body composition at different body compartments. We also acknowledge several limitations. The number of women with a hip fracture in our sample was relatively small, thus limiting the statistical power of some of the stratum. Given the preponderance of White participants, our results may not be widely generalizable. In fact, most epidemiological studies in this topic are based on White women because this population have by far the highest fracture rate, however the external validity for other ethnic populations is needed. Finally, although DXA is acceptable tool for the assessment of body composition changes, some limitations in precision were noted in obese individuals and in characterisation of lean mass tissue.[30] Thus, our dynamic index results should be interpreted cautiously given relatively small mean changes and potential for increased measurement error.

In conclusion, our findings indicate that in frail older women, higher fat and lean mass was associated with reduced hip-fracture risks, with an important caveat that whole-body adiposity was the only measure to be associated with lower risks of hip fractures independent of total hip BMD. Our results confirm the importance of weight maintenance in frail older adults.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Baseline, Year 3 and Year 6 characteristics of the 872 WHI OS frail older women by hip-fracture incidence

Characteristics	**Fracture (*n* = 49)**	**Non-fracture (*n* = 823)**	***P* value**
Age[a], yr (SD)	73.84 (4.55)	72.21 (4.52)	0.015
White[b], *n* (%)	47 (95.9)	642 (78.10)	0.003
Income[b], *n* (%)			0.467
≤$20000	14 (28.57)	295 (36.42)	
$20000–$50000	21 (42.86)	331 (40.86)	
>$50000	14 (28.57)	184 (22.72)	
BMI[a], kg[a]/m^2 (SD)	26.28 (4.84)	29.44 (6.34)	0.006
Height[a], cm (SD)	160.18 (5.98)	159.99 (6.24)	0.84
Weight[a], kg (SD)	67.33 (12.53)	75.43 (17.02)	0.001
Smoker[a], *n* (%)	4 (8.16)	52 (6.42)	0.63
Previous fracture[b], *n* (%)	19 (44.19)	111 (13.79)	0.001
Recurrent Falls in 12 month[b], *n* (%)	16 (33.33)	0.51 (0.84)	<0.001
Total hip BMD[a], g/cm (SD)	0.72 (0.09)	0.83 (0.14)	<0.001
Number of Frailty criteria, *n* (%)			0.407
3 criteria	24 (48.98)	458 (55.65)	
4 criteria	21 (42.86)	328 (39.85)	
5 criteria	4 (8.16)	37 (4.50)	
Body-composition measures			
Static indexes			
ALM/height^2, kg/m^2 (SD)	5.38 (0.99)	5.72 (1.12)	0.04
AFM/height^2, kg/m^2 (SD)	5.61 (1.95)	6.76 (2.34)	<0.001
TLM/height^2, kg/m^2 (SD)	7.56 (1.01)	7.65 (1.00)	0.49
TFM/height^2, kg/m^2 (SD)	5.02 (2.06)	6.36 (2.46)	<0.001
WBLM/height^2, kg/m^2 (SD)	13.94 (1.88)	14.43 (2.00)	0.09
WBFM, /height^2, kg/m^2 (SD)	11.13 (3.71)	13.63 (4.59)	<0.001
Dynamic indexes	**Fracture (*n* = 32)[c]**	**Non-fracture (547)[c]**	
% change in weight, % (SD)	−0.95 (7.72)	0.62 (11.93)	0.46
% change in height, % (SD)	−0.52 (1.50)	−0.65 (1.61)	0.65
% change in ALM, % (SD)	−0.43 (9.65)	1.86 (9.98)	0.21
% change in AFM, % (SD)	−1.59 (13.02)	−1.24 (12.89)	0.88
% change in TLM, % (SD)	−0.15 (7.98)	1.25 (6.72)	0.25
% change in TFM, % (SD)	−4.68 (21.16)	−2.71 (18.43)	0.56
% change in WBLM, % (SD)	−1.13 (6.44)	0.31 (5.38)	0.28
% change in WBFM, % (SD)	−2.00 (15.97)	−1.09 (13.37)	0.71

ALM = appendicular lean mass; AFM = appendicular fat mass; TLM = trunk lean mass; TFM = trunk fat mass; SD = standard deviation; WBLM = whole-body lean mass; WBFM = whole body fat mass

[a]Year 3 measure;

[b]Baseline measure;

[c]Incident hip fractures after Year 6 measure

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Table 2

Linear regressions of Year 3 body-composition measures on total-hip bone mass density (BMD)

	Total-hip BMD (g/cm^2)							
	Model 1[a]				Model 2[b]			
	beta	*SE*	*P* value	R^2	beta	*SE*	*P* value	R^2
ALM, kg/m^2	0.032	0.004	<0.001	0.14	0.031	0.005	<0.001	0.17
AFM, kg/m^2	0.022	0.001	<0.001	0.20	0.023	0.002	<0.001	0.24
TLM, kg/m^2	0.043	0.004	<0.001	0.17	0.044	0.004	<0.001	0.19
TFM, kg/m^2	0.021	0.002	<0.001	0.20	0.022	0.002	<0.001	0.23
WBLM, kg/m^2	0.021	0.002	<0.001	0.16	0.021	0.002	<0.001	0.18
WBFM, kg/m^2	0.012	0.0009	<0.001	0.22	0.013	0.001	<0.001	0.26

AFM = appendicular fat mass; ALM = appendicular lean mass; TFM = trunk fat mass; TLM = trunk lean mass; SE = standard error; WBFM = whole-body fat mass; WBLM = whole-body lean mass;

[a] adjusted for age

[b] adjusted for age, ethnicity, smoking, previous fractures, recurrent falls and number of frailty criteria

[c] *P* for trend

Table 3

Hazard ratios for hip fractures per increase in body-composition measures

	Events/Person-years	Model 1[a]		Model 2[b]		Model 3[c]	
		HR (95% CI)	*P* value	HR (95% CI)	*P* value	HR (95% CI)	*P* value
ALM, kg/m^2		0.67 (0.49–0.91)	0.01	0.63 (0.46–0.88)	0.007	0.82 (0.58–1.18)	0.290
ALM categories			0.009[d]		0.021[d]		0.153[d]
QRT1	16/2,405	Ref		Ref		Ref	
QRT2	15/2,539	0.77 (0.38–1.56)		0.84 (0.41–1.75)		1.10 (0.52–2.34)	
QRT3	11/2,515	0.55 (0.25–1.19)		0.62 (0.27–1.45)		0.67 (0.28–1.62)	
QRT4	7/2,613	0.32 (0.13–0.79)		0.28 (0.09–0.86)		0.49 (0.15–1.57)	
AFM, kg/m^2		0.76 (0.66–0.88)	<0.001	0.73 (0.60–0.88)	0.001	0.86 (0.70–1.05)	0.141
AFM categories			0.0015[d]		0.015[d]		0.176[d]
QRT1	22/2,481	Ref		Ref		Ref	
QRT2	11/2,409	0.47 (0.22–0.98)		0.39 (0.18–0.85)		0.55 (0.25–1.26)	
QRT3	12/2,571	0.55 (0.27–1.11)		0.51 (0.23–1.11)		0.76 (0.33–1.73)	
QRT4	4/2,609	0.16 (0.06–0.47)		0.13 (0.03–0.59)		0.29 (0.06–1.44)	
TLM, kg/m^2		0.89 (0.65–1.22)	0.46	0.82 (0.58–1.15)	0.250	1.09 (0.76–1.56)	0.651
TLM categories			0.39[d]		0.279[d]		0.665[d]
QRT1	18/2,494	Ref		Ref		Ref	
QRT2	9/2,416	0.54 (1.06–1.22)		0.70 (0.31–1.60)		0.82 (0.35–1.95)	
QRT3	7/2,580	0.36 (0.15–0.86)		0.48 (0.19–1.18)		0.79 (0.31–2.04)	
QRT4	15/2,581	0.81 (0.41–1.62)		0.70 (0.31–1.57)		1.24 (0.53–2.90)	
TFM, kg/m^2		0.78 (0.69–0.89)	<0.001	0.76 (0.65–0.89)	0.001	0.85 (0.72–1.01)	0.059
TFM categories			0.003[d]		0.013[d]		0.183[d]
QRT1	19/2,514	Ref		Ref		Ref	
QRT2	16/2,469	0.89 (0.46–1.73)		0.89 (0.45–1.78)		1.29 (0.63–2.66)	
QRT3	9/2,473	0.51 (0.23–1.12)		0.50 (0.19–1.32)		0.87 (0.31–2.44)	
QRT4	5/2,615	0.25 (0.09–0.68)		0.25 (0.08–0.81)		0.47 (0.14–1.60)	

	Events/Person-years	Model 1[a]		Model 2[b]		Model 3[c]	
		HR (95% CI)	*P* value	HR (95% CI)	*P* value	HR (95% CI)	*P* value
WBLM, kg/m^2		0.84 (0.71–0.99)	0.04	0.86 (0.72–1.03)	0.096	0.97 (0.80–1.17)	0.728
WBLM categories			0.03[d]		0.069[d]		0.526[d]
QRT1	19/2,435	Ref		Ref		Ref	
QRT2	10/2,533	0.45 (0.21–0.98)		0.61 (0.27–1.35)		0.62 (0.26–1.44)	
QRT3	11/2,450	0.56 (0.26–1.18)		0.67 (0.29–1.54)		0.88 (0.37–2.07)	
QRT4	9/2,653	0.36 (0.16–0.82)		0.37 (0.14–1.00)		0.63 (0.28–1.74)	
WBFM, kg/m^2		0.87 (0.81–0.93)	<0.001	0.84 (0.77–0.93)	<0.001	0.91 (0.82–1.00)	0.06
WBFM categories			<0.001[d]		0.004[d]		0.043[d]
QRT1	22/2,529	Ref		Ref		Ref	
QRT2	15/2,500	0.68 (0.35–1.32)		0.53 (0.26–1.09)		0.84 (0.39–1.83)	
QRT3	8/ 2,542	0.36 (0.16–0.80)		0.41 (0.17–0.99)		0.63 (0.25–1.59)	
QRT4	4/2,569	0.17 (0.06–0.51)		0.09 (0.02–0.48)		0.19 (0.04–0.99)	

AFM = appendicular fat mass; ALM = appendicular lean mass; CI = confidence interval; HR = hazard ratio; QRT = quartile; TFM = trunk fat mass; TLM = trunk lean mass; WBFM = whole-body fat mass; WBLM = whole-body lean mass.

[a] adjusted for age

[b] adjusted for age, ethnicity, smoking, previous fractures, recurrent falls, number of frailty criteria (and corresponding lean mass measure for models with fat mass scores)

[c] adjusted for age, ethnicity, smoking, previous fractures, recurrent falls, number of frailty criteria, corresponding lean mass in models with fat measure and total hip bone mass density

[d] *P* for trend