HHS Public Access
Author manuscript
J Nutr Health Aging. Author manuscript; available in PMC 2020 January 01.

Published in final edited form as:
J Nutr Health Aging. 2019 ; 23(2): 138–144. doi:10.1007/s12603-018-1138-x.

Association of Obesity and Frailty in Older Adults: NHANES 1999-2004

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Abstract

Objective: Body composition changes with aging can increase rates of obesity, frailty and impact function. Measuring adiposity using body fat (%BF) or central adiposity using waist circumference (WC) have greater diagnostic accuracy than traditional measures such as body mass index (BMI).

Design: This is an observational study

Setting: This study focused on older community-dwelling participants

Participants: We identified individuals age ≥ 60 years old using the 1999–2004 cross-sectional National Health and Nutrition Survey (NHANES).

Intervention: The primary analysis evaluated the association between frailty and %BF or WC. Frailty was the primary predictor (robust=referent) and %BF and WC were considered continuous outcomes. Multiple imputation analyses accounted for missing characteristics.

Measurement: Dual energy x-ray absorptiometry was used to assess %BF and WC was objectively measured. Frailty was defined using an adapted version of Fried's criteria that was

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There are no conflicts of interest pertaining to this manuscript

self-reported: (low BMI<18.5kg/m^2; slow walking speed [<0.8m/s]; weakness [unable to lift 10lbs]; exhaustion [difficulty walking between rooms on same floor] and low physical activity [compared to others]). Robust, pre-frail and frail persons met zero, 1 or 2, and ≥3 criteria, respectively.

Results: Of the 4,984 participants, the mean age was 71.1±0.2 (SE) years and 56.5% were females. We classified 2,246 (50.4%), 2,195 (40.3%), and 541 (9.2%) individuals as robust, pre-frail and frail, respectively. Percent BF was 35.9±0.13, 38.3±0.20 and 40.0±0.46 in the robust, pre-frail and frail individuals, respectively. WC was 99.5±0.32 in the robust, 100.1±0.43 in pre-frail, 104.7±1.17 in frail individuals. Compared to robust individuals, only frail individuals had greater %BF on average (β=0.97±0.43,p=0.03); however, pre-frail and frail individuals had 2.18 and 4.80 greater WC, respectively (β=2.18±0.64,p=0.002, and β=4.80±1.1,p<0.001).

Conclusion: Our results demonstrate that in older adults, frailty and pre-frailty are associated with a greater likelihood of high WC (as dichotomized) and a greater average WC (continuous).

Keywords

frailty; obesity; pre-frailty; waist circumference; body fat

Introduction

Obesity is associated with increased rates of coronary artery disease, stroke, accelerated death rates and has become of greater concern recently in older adults (1, 2). Excessive adipose tissue leads to reduced physical capabilities, increased metabolic instability, increased inflammation and low antioxidant capacity (3–5). Rates continue to rise in older adults with a notable 56% increase in those 60 to 69 and 36% increase in those over age 70 in 2000 compared to 1991(6, 7). Currently 37% of adults over 65 are obese and this number is suspected to increase as Baby Boomers move into their geriatric years (8). Fat mass tends to peak at the ages of 60–70 years followed by subsequent decline in both skeletal muscle and fat mass leading to a different body distribution in this age group (9, 10).

Frailty and obesity, defined by body mass index (BMI), are both associated with disability, increased healthcare utilization, institutionalization and earlier mortality (11–18); however, their direct association is less defined in older patients. Frailty by Fried’s criteria is defined as greater than or equal to three of the following criteria: unintentional weight loss of 10 lbs. or greater, self-reported exhaustion, muscle weakness defined by grip strength, slow walking speed [<0.8m/s], and low physical activity (19). More evidence is showing the risk of frailty actually increases with obesity which is contrary to previous thoughts of frailty as a “wasting disorder” (4). The Cardiovascular Health Study which initially defined frailty demonstrated higher BMI in frail patients versus those pre-frail or robust (20). A 22 year follow up study in Finland showed that BMI-defined obesity was associated with higher rates of pre-frailty and frailty compared to robust individuals, suggesting obesity could be a contributing factor to progression along the frailty spectrum (21, 22).

Epidemiologically, body mass index (BMI) has traditionally been used to ascertain adiposity status but may not be the ideal tool due its poor sensitivity and its lack of distinction between fat and muscle. The Scottish Health Survey showed that while BMI rates continue to rise between those 60 and 70 years old, waist circumference (WC) increased at a faster rate of 5–10 cm in those between 50 and 70 years old. This disproportionate increase in WC may indicate a worse obesity epidemic than can be inferred by BMI alone (23). To our knowledge, there few studies evaluating percent body fat (%BF) or WC's relationship with frailty as continuous or dichotomized variables. Our aim was to further evaluate the relationship of frailty and obesity using potentailly more accurate definitions for defining geriatric obesity.

Methods

Study Design and Participants

Participants included in the analysis were identified from the 1999–2004 cross-sectional study National Health and Nutrition Survey (NHANES) managed by the Center for Disease control. Full details are available at http://www.cdc.gov/nchs/nhanes.html (accessed January 2018). The survey was conducted on non-institutionalized persons and oversampled Non-Hispanic blacks, Mexican Americans and persons greater than 60 years of age.

NHANES consisted of 38,077 participants, of which 31,125 were interviewed, and 29,402 were examined in a mobile examination center. For this secondary analysis of data, we included participants aged 60 years older with body composition measures and frailty variables for a final analytical cohort of 4,984 participants. The local Institutional Review Board at Geisel School of Medicine at Dartmouth exempted this study from review due to the de-identified nature of the data.

Study Variables

We defined frailty in our study sample according to the phenotypic frailty model (19), using participant self-reported and objective (measured) data. This phenotypic definition consists of five criteria derived from the Cardiovascular Health Study (19, 24) as follows: unintentional weight loss of 10 lbs. or more in a year; self-reported exhaustion; weakness defined by grip strength; slow walking speed; and low physical activity. We adapted the criteria to define each variable respectively using data available in NHANES: low body mass index (BMI)<18.5kg/m^2; difficulty walking between rooms; difficulty lifting or carrying 10 lbs.; gait speed <0.8 m/s; and self-reported reduced physical activity compared to others your age (25). As NHANES 2003–2004 did not collect gait speed data, we imputed gait speed for this wave of data (see below). Frailty was defined as meeting three or more of the following criteria and pre-frailty was defined as meeting 1 or 2 criteria. Individuals not meeting any criteria were classified as robust.

Anthropometric and Body composition Measures:

Obesity was defined in two ways to approximate overall and central adiposity using %BF and WC, respectively. Dual energy x-ray absorptiometry was used to assess %BF (26). Body fat cutoffs for defining obesity were ≥25% in males and ≥35% or greater in females. WC was determined by palpation of the right iliac crest, crossing the mid-axillary line then placing measurement tool around the trunk at minimal respiration in the standing position.

Cut points for high WC, were defined as ≥102 cm in men, and ≥88 cm in women. Weight was measured on an electronic digital scale, calibrated in kilograms. Height was measured standing on a vertical backboard of a stadiometer, with their weight evenly distributed on both feet after deep inhalation. BMI (kg/m^2) was calculated using measured weight in kilograms divided by height in meters squared.

Co-variates

Demographic variables included self-reported age, sex, race, marital status, education, smoking status, and ethnicity. We categorized respondents as non-Hispanic white, non-Hispanic black and Hispanic American. Those reporting another race/ethnicity were categorized as other. We ascertained self-reported comorbidities such as diabetes, arthritis, coronary artery disease, congestive heart failure and non-skin cancer. Participants were classified as "smokers" if they had smoked at least 100 cigarettes in their lifetime and further classified as former or current smokers. Education was classified as greater or less than high school education. Dysfunction in Basic Activities of Daily Living (BADL) and Independent Activities of Daily Living (IADL) was defined as difficulty in completing at least one basic activity or independent activities of daily living, respectively as previously described (26).

Statistical Analysis

Analyses incorporated primary sampling units, weighting and strata as per guidelines to account for the complex sampling design of NHANES. Continuous variables are represented as mean ± standard error, and categorical variables are represented as counts (weighted percentages). An analysis of variance and chi-square assessed differences in baseline characteristics by group (robust, pre-frail and frail). Gait speed was not assessed in NHANES 2003–2004 therefore multiple imputation analyses was used to account for missing values using R (v 3.3.2) and the package *mice* for 3,645 participants. The package creates plausible data values from a distribution specifically designed for each data point; five imputed data sets are generated using predictive mean matching. The correction variables used were age, sex, education, race, diabetes, arthritis, congestive heart failure, cancer, and lean mass percent. The five data sets were averaged, resulting in a final imputed data set used for analysis. Analyses were run on the full imputed data set as well as a subset excluding the imputed variables to test the quality. The data presented in our results is based on full imputed data alone, data excluding imputed variables is not shown.

The primary analytic aim was to determine the relationship between frailty status (referent=robust) and obesity status. Separate models were constructed to account for different definitions of obesity (body fat and waist circumference). First, linear regression modeling was used to evaluate %BF and WC as continuous outcome variables on frailty status and values are presented as beta ± standard error using linear regression modeling. Second, we constructed logistic regression models with body-fat defined obesity (yes/no) or elevated waist circumference (yes/no) as the outcome with frailty status as the primary predictor. Three separate models evaluated the association between obesity and frailty. Model 1 was unadjusted; Model 2 included age, gender, race, education (greater or less than high school education), smoking (current, former, never); and Model 3 included the covariates in Model 2 and additionally adjusted for the self-reported comorbidities such as diabetes, heart failure, cancer, coronary artery disease and arthritis. Results are presented as odds ratios with 95% confidence intervals when classified categorically. Data analysis was conducted using STATA version 14 (College Station, TX). A p-value of <0.05 was considered statistically significant.

RESULTS

Our final data set included 4,984 participants (56.6% females) aged over 60 years. Mean age was 71.1± 0.19 years with a mean BMI of 28.2± 0.10 kg/m^2. The majority of the participants were non-Hispanic whites (Table 1). We classified 2,246 (50.4%), 2,195 (40.3%) and 541 (9.2%) individuals as robust, pre-frail and frail respectively. Mean %BF and WC was 35.9±0.13 and 99.5±0.32 in those robust, 38.3±0.20 and 100.1±0.43 in those pre-frail, and 40.0±0.46 and 104.7±1.17 in those who were frail. Frail and pre-frail participants were more likely to be females, have higher BMI and be of older age. Frail and pre-frail patients were more likely to have concurrent comorbidities such as diabetes, coronary artery disease, arthritis, stroke, chronic kidney disease and COPD. Dysfunction in at least one IADL or BADL was highly significant in pre-frailty and frailty. There were no observed differences in baseline characteristics of gender, race and most comorbidities with the exception of stroke in those with completed frailty variable data versus those without complete frailty data. There was a significant difference was seen in regards to age, BMI and IADL limitations (Appendix Table 1).

Table 2 denotes frailty measurement prevalence among WC and %BF. In the high WC group, higher prevalence of pre-frailty (42.5%) and frailty (7.9%) were observed compared to the normal WC groups for pre-frailty (37.3%) and frailty (4.6%) ($p \leq 0.001$). Also, individuals with high WC were more likely to have a greater number of frailty components ($p \leq 0.001$). Prevalence of frailty and pre-frailty ($p=0.51$) was not statistically significantly different across %BF cut off points; however the prevalence of frailty and pre-frailty was significantly greater in high WC versus low WC individuals.

Multivariable analysis of the relationship between frailty and obesity is represented in Table 3. After adjustment, %BF as a continuous variable was significantly associated with frailty ($\beta=0.97\pm0.43, p=0.03$), while pre-frailty was not significant ($\beta=0.37\pm0.27, p=0.18$). In contrast WC as a continuous variable was associated with higher rates of pre-frailty ($\beta=2.18\pm0.64, p=0.002$) and frailty ($\beta=4.80\pm1.1, p<0.001$) in our fully adjusted model. When evaluating data in Model 2, there appears to be a more significant relationship between frailty progression and both WC and %BF. Model 2 data even demonstrates a significant relationship between pre-frailty and frailty when defining WC by dichotomized cut-points. Also, Model 2 demonstrates a significant relationship between pre-frailty and %BF that is lost with further adjustment in Model 3. In logistic regression models evaluating the odds of obesity according to %BF and WC cutoff points, neither pre-frail nor frail individuals were more likely than robust individuals to be obese in our fully adjusted model.

DISCUSSION

Our results demonstrate that in older adults, frailty and pre-frailty are associated with an increased likelihood of high WC (as dichotomized) and a greater average WC (continuous). No relationship of frailty with %BF or WC was observed when using standard cut points for these measures in our study population.

Previous studies looking at the relationship between BMI-defined obesity and frailty status have had conflicting results. One study showed those who were obese frail had significantly higher rates of death compared to those with obesity alone (27) while another longitudinal study demonstrated that frail older women with obesity actually had reduced likelihood of adverse events such as death (28). One potential explanation for these differences is that the primary measure of obesity used in these studies, BMI, is a poor marker of adiposity, with poor sensitivity in older adults (29). Most studies to date looking at the obesity and frailty relationship use BMI primarily (30, 31). One study using BMI and WC by traditionally accepted cut points to define obesity found that those with higher WC were frailer than those with comparable BMI and normal WC (4) demonstrating WC may confer additional frailty risk that cannot be assessed with BMI. No studies to the author's knowledge compare the association of frailty with both %BF and WC by multiple metrics (continuous and dichotomized) to define these variables in geriatric participants.

Also, based on our results, we demonstrate that central adiposity, reflected by waist circumference, may demonstrate a stronger relationship with frailty over %BF. With aging, there is an increased accumulation of intra-abdominal fat compared to total fat with the progressive loss of lean body mass (9). The buildup of visceral fat contributing to central obesity is strongly associated with increased inflammation, insulin resistance and metabolic dysregulation (32, 33) An English study showed a strong upward linear trend in central obesity rates even in those aged 70–89 years, suggesting this to be a significant factor in this population (34). One study of participants with obesity showed a linear increase in intra-abdominal fat by computerized tomography with aging even if there was no change in whole body fat mass (35). It has been shown that %BF can differentiate visceral from subcutaneous fat, however, it does not reflect the alteration in increasing central fat distribution that is observed in older adults (35, 36). A study examining post-menopausal women showed that acute-phase proteins and pro-inflammatory markers were associated with hip fat mass and android fat (central obesity) and not associated with whole body fat (%BF)(37). A meta-analysis looking at inflammation and frailty demonstrated that frailty and pre-frailty both had higher CRP and IL-6 levels (38) therefore it is possible that increasing inflammation maybe the reason we see the stronger association of the frailty spectrum with WC rather than %BF.

Lastly, our study used traditionally accepted %BF and WC thresholds to further examine %BF and WC relationship with frailty (39). However, cut points are based on a large population cohort not specific populations. The current waist circumference cut-off points are based on adults age 20–74 years(40) and a meta-analysis showed no relevant increase in overall mortality when using these in older adults further bringing these cut points into question as far as clinical relevance for this population(39). It is thought they may be too narrow in the aged population and wider ranges may more clearly identify those at risk for the adverse outcomes of obesity(41). Investigators in a Netherland's study aimed to find the optimal cutoff for older adults and suggested 109 cm in men and 98 cm in women (42). Interesting, our Model 2 data demonstrated a significant relationship between pre-frailty and frailty when defining WC by dichotomized cut-points possibly demonstrating that there is a relationship there but we are simply losing power as we adjust more for participants who may have more missing data on those additional variables corrected for in Model 3.

This analysis has a number of strengths and limitations. We used a large, population-based cohort of older adults relying on the use of previously validated metrics to define frailty (25). Our limitations included modification of the original definition of Fried's frailty in order to operationalize it based on the variables present in NHANES (25). Due to the limitation in our data set we were not able to evaluate weight loss but only define this variable by low BMI which may limit our ability to capture those with elevated BMI and recent weight loss. Despite this our study does show comparable percentage rates along the frailty spectrum to other studies defining frailty by Fried's model (4, 19, 43, 44). Also, walking speed was missing for 3,645 participants therefore we performed multiple imputations to maximize our ability to perform our data analysis by including variables that could accurately predict this variable. As with any cross-sectional population-based analysis, causality cannot be inferred and future longitudinal, interventional studies are needed.

The relationship between frailty and obesity as well as the validity of the definitions used to define these variables is important to clarify. Interventions such as weight loss and exercise can ameliorate frailty and directly affect the downstream negative outcomes of central obesity observed in older adults (45, 46). Pre-frailty, frailty and obesity have all been associated with disability, increased healthcare utilization, institutionalization and earlier overall mortality as individual entities (11–18). Here, we show WC may demonstrate the strongest relationship with frailty and serve as a potentially better predictor of frailty risk in this older obese population. This easy to measure anthropometric measure could be integrated in clinical practices with minimal cost and importantly could provide some prognostication in older adults. Additional studies should investigate the direct relationship of frailty and obesity, however our study has been able to demonstrate WC as potentially the most accurate way of defining obesity in this geriatric population moving forward.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

FINANCIAL DISCLOSURE

Dr. Crow's research reported in this publication was supported by The Dartmouth Center for Health and Aging and the Department of Medicine.

Dr. Bartels receives funding from the National Institute of Mental Health: K12 HS0217695 (AHRQ); R01 MH078052; R01 MH089811; R01 MH102325; R24 MH102794; the Centers for Disease Control and Prevention: U48 DP005018; and the Health Resources and Services Administration: U1 QHP28718; T32 HP30036.

Dr. Bruce receives funding support from the National Institutes of Health: R25 MH068502, R01 MH096441 and UL1 TR001086.

Dr. Lohman receives funding from the National Institute of Mental Health: T32 MH073553.

Dr. Batsis' research reported in this publication was supported in part by the National Institute on Aging of the National Institutes of Health under Award Number K23AG051681.

Alexander Titus' research reported in this publication was supported in part by the National Institutes of Health under Award Number T32LM012204. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

Research reported in this publication was supported by The Dartmouth Clinical and Translational Science Institute, under award number UL1TR001086 from the National Center for Advancing Translational Sciences (NCATS) of the National Institutes of Health (NIH). The content is solely the responsibility of the author(s) and does not necessarily represent the official views of the NIH.

This work was also supported by the Dartmouth Health Promotion and Disease Prevention Research Center (Cooperative Agreement Number U48DP005018) from the Centers for Disease Control and Prevention. The findings and conclusions in this journal article are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

Abbreviations

%BF	Percent Body Fat
BMI	Body Mass Index
WC	Waist Circumference

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Table 1:

Baseline Characteristics of Study Participants

Characteristics	Total	Robust	Pre-Frail	Frail	P value
N	4,984	2,246	2,195	541	
Age, mean (+/- SE), y*	71.1 ±0.19	68.7±0.22	73.3±0.23	74.9±0.45	<0.001
Females, no. (%)	2,531 (56.6)	949 (47.2)	1,244 (65.6)	336 (68.1)	<0.001
Men, no. (%)	2,453 (43.5)	1,297 (52.8)	951 (34.4)	205 (31.9)	<0.001
Race and Ethnicity, no. (%)					<0.001
Non-Hispanic White	2,846 (81.2)	1,387 (86.1)	1,203 (77.4)	256 (70.5)	
Non-Hispanic Black	811 (8.3)	281 (5.5)	403 (10.3)	127 (15.8)	
Hispanic American	1,202 (7.2)	533 (5.9)	522 (8.1)	146 (10.8)	
Other	125 (3.2)	45 (2.4)	67 (4.2)	12 (3.0)	
College ed. or higher, no. (%)	1,676 (40.6)	986 (50.4)	585 (32.3)	105 (23.4)	<0.001
Smoker no. (%)					0.02
Never	2,327 (46.7)	1,004 (44.2)	1,052 (49.1)	271 (50.3)	
Former	2,035 (41.4)	948 (43.9)	889 (39.6)	198 (35.5)	
Current	611 (11.9)	288 (11.9)	254 (11.4)	69 (14.3)	
BMI (kg/m2) mean, (+/- SE)*#	28.2± 0.10	27.8± 0.12	28.3± 0.18	30.7± 0.49	<0.001
BADL Limitation*	2,423 (47.3)	576 (25.3)	1,320 (63.5)	527 (96.8)	<0.001
IADL Limitation*	1,751 (32.6)	248 (10.2)	988 (46.4)	515 (94.5)	<0.001
Comorbidities, no. (%)**					
Diabetes	1,060 (18.3)	356 (13.2)	499 (21.0)	205 (34.5)	<0.001
Heart Failure	373 (7.1)	47 (1.9)	211 (10.1)	115 (22.9)	0.34
Non Skin Cancer	916 (21.7)	418 (22.1)	395 (20.8)	103 (22.9)	0.49
Coronary Artery Disease	870 (18.3)	297 (14.2)	421 (20.1)	152 (30.9)	<0.001
Arthritis	2,379 (50.2)	786 (38.3)	1,228 (59.8)	363 (73.6)	<0.001
HTN	2,326 (87.7)	892 (87.0)	1,123 (87.7)	311 (90.1)	0.34
Stroke	405 (7.6)	101 (4.5)	192 (8.3)	112 (21.1)	<0.001
COPD	496 (11.8)	130 (6.8)	269 (15.9)	97 (21.4)	<0.001
Chronic Kidney Disease	81(4.2)	22 (2.5)	39 (4.8)	20 (11.5)	0.03
Waist circumference (WC)*	100.1±0.22	99.5±0.32	100.1±0.43	104.7±1.17	<0.001
Percent Body Fat (%BF)*	37.2±0.11	35.9±0.13	38.3±0.20	40.0±0.46	<0.001

* values are represents as means ± standard error or counts (weighted percentages)

\# The body mass index is the weight in kilograms divided by the square of the height in meters.

** Comorbidities were self-reported by participants at initiation of screening.

*** BADL and IADL indicates that they have dysfunction in at least one basic activity or daily living or independent activities of daily living, respectively.

Abbreviations

COPD: Chronic Obstructive Pulmonary Disease; HTN: Hypertension; IADL: Independent Activities of Daily Living; BAL: Basic Activities of Daily Living; BMI: Body Mass Index, WC: Waist Circumference, %BF: Percent Body Fat

Table 2:

Frailty Component Prevalence Among Obese Using Dichotomized Measures

	Overall	Low Body Fat	High Body Fat‡		Normal WC	High WC†	
Frailty Components	N= 4984	N= 597	N= 4194	**p-value**	N= 1705	N=2905	**p-value**
0 component	2,246 (50.4)	265 (48.2)	1943 (51.7)	0.04	889 (58.1)	2181 (52.6)	<0.001
1 component	1,486 (27.7)	192 (31.6)	1258 (27.4)		511 (28.3)	1413 (28.3)	
2 component	709 (12.6)	82 (12.4)	608 (12.7)		195 (9.1)	648 (12.4)	
3 component	371 (6.4)	46 (6.5)	265 (5.6)		80 (3.2)	268 (12.4)	
4 component	167 (2.8)	10 (1.0)	119 (2.5)		29 (1.4)	99 (1.8)	
5 component	3 (<0.01)	2 (0.3)	1 (<0.01)		1 (0.04)	1 (0.01)	
Frailty Prevalence				**p-value**			**p-value**
Robust	2,246 (50.4)	265 (44.4)	1,943 (46.3)		889 (58.1)	1292 (49.6)	
Pre-Frail	2,195 (40.3)	274 (45.9)	1,866 (44.5)	0.51	706 (37.3)	1355 (42.5)	<0.001
Frail	541 (9.2)	58 (9.7)	385 (9.2)		110 (4.6)	258 (7.9)	

† An elevated waist circumference is defined as ≥88cm in females and ≥102cm in males

‡ An elevated % body fat is defined as ≥35% in females and ≥25% in males

Table 3:

Multivariable Analysis of Obese Patients along the Frailty Spectrum

Outcomes		Robust*	Pre-frail	p-value	Frail	p-value
Waist Circumference† (Continuous) (β (+/- SE)	**Model 1**		0.6 ±0.66	0.29	5.2 ±1.2	<0.001
	Model 2		3.9 ±0.57	<0.001	9.2 ±1.0	<0.001
	Model 3		2.18±0.64	0.002	4.80±1.1	<0.001
Body fat ‡ (Continuous) (β (+/- SE)	**Model 1**		2.4±0.25	<0.001	4.1±0.49	0.18
	Model 2		0.91±0.25	<0.001	2.3 ±0.45	<0.001
	Model 3		0.37±0.27	0.18	0.97±0.43	0.03
Waist Circumference† (Dichotomized) OR [95%CI]	**Model 1**	reference	1.33 [1.1–1.6]	<0.001	2.0 [1.6–2.5]	<0.001
	Model 2	reference	1.37 [1.1–1.7]	<0.001	2.1 [1.6–2.8]	<0.001
	Model 3	reference	1.1 [0.89–1.4]	0.33	1.3 [0.9–1.85]	0.15
Body fat‡ (Dichotomized) OR [95%CI]	**Model 1**	reference	0.85 [0.65–1.11]	0.24	0.97 [0.67–1.4]	0.89
	Model 2	reference	0.98 [0.73–1.3]	0.89	1.22 [0.83–1.8	0.30
	Model 3	reference	0.77 [0.55–1.1]	0.13	0.74 [.48–1.2]	0.19

* *Models using waist circumference and body fat as continuous variables consist of the % body fat for robust and the* β coefficients and associated standard errors for pre-frail and frail categories, which represent the differences in respective obesity-status as compared to robust.

† An elevated waist circumference is defined as ≥88cm in females and ≥102cm in males

‡ An elevated % body fat is defined as ≥35% in females and ≥25% in males

Model 1: Unadjusted; Model 2: Adjusted for age, gender, race, education, smoking; Model 3: Model 2 co-variates and diabetes, heart failure, cancer, coronary artery disease, arthritis