Frailty, Body Mass Index, and Abdominal Obesity in Older People

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Background. Frailty has been conceptualized as a wasting disorder with weight loss as a key component. However, obesity is associated with disability and with physiological markers also recently linked with frailty, for example, increased inflammation and low antioxidant capacity. We aimed to explore the relationship between frailty and body mass index (BMI) in older people.

Methods. Data were from 3,055 community-dwelling adults aged 65 years and older who participated in the English Longitudinal Study of Ageing. Frailty was defined both by an index of accumulated deficits and by the Fried phenotype. BMI was divided into five categories, and waist circumference 88 cm or more (for women) and 102 cm or more (for men) was defined as high. Analyses were adjusted for sex, age, wealth, level of education, and smoking status.

Results. The association between BMI and frailty showed a U-shaped curve. This relationship was consistent across different frailty measures. The lowest frailty index (FI) scores and lowest prevalence of Fried frailty were in those with BMI 25–29.9. At each BMI category, and using either measure of frailty, those with a high waist circumference were significantly more frail.

Conclusions. Both the phenotypic definition of frailty and the FI show increased levels of frailty among those with low and very high BMIs. In view of the rise in obesity in older populations, the benefits and feasibility of diet and exercise for obese older adults should be a focus of urgent inquiries. The association of frailty with a high waist circumference, even among underweight older people, suggests that truncal obesity may be an additional target for intervention.

Key Words: Frail older people—Body mass index—Obesity.

UNDERSTANDING frailty has become the focus of extensive research, but there is, as yet, no universally accepted definition of frailty so that it can be operationalized in different ways. In recent years, two main approaches for the measurement of frailty have emerged (1): One involves counting the accumulation of "deficits" across many systems, and the other identifies frailty as a clinical syndrome or phenotype characterized by a specific set of signs and symptoms. The most well-known and widely used phenotype was defined by Fried and colleagues (2) and identifies someone as frail when they meet three or more of five criteria (weight loss of 10 lb or more in past year, self-reported exhaustion, weak grip strength, slow walking speed, and low physical activity). Unintentional weight loss is also a core component of many other syndromic–phenotypic definitions of frailty (3).

The inclusion of weight loss in frailty criteria is congruent with the conceptualization of frailty as a wasting disorder, with sarcopenia as a major pathophysiological feature (4,5). However, there are also theoretical reasons to link frailty to obesity. Obesity in older people is associated with greater risk of impaired physical function (6), which is closely intertwined with frailty (7), however it is defined (3,8). Second, obesity induces a proinflammatory state (9), which has also been associated with frailty, across different definitions of the term (10).

Studies investigating the relationship between obesity and frailty have been comparatively small and have used only Fried's phenotypic definition of frailty. An association between obesity and frailty was recently reported in 599 older women (11), and participants of the Cardiovascular Health Study (CHS) who developed frailty had higher weight and were more likely to have central obesity (12). Here, we aimed to investigate the relationship between body mass index (BMI) and frailty in older people and to determine whether any association was dependent on the definition of frailty used.

METHODS

Study Design and Participants

The data come from Wave 2 of the English Longitudinal Study of Ageing (ELSA), a nationally representative panel

study of community-dwelling adults aged 50 years and older in England. ELSA participants were recruited from households involved in the Health Survey for England (HSE), an annual government-sponsored cross-sectional survey, in 1998, 1999, and 2001. Households were included in ELSA if one or more individuals living there was aged 50 years or older. There were 19,924 individuals in households that responded to HSE who would have been aged 50 years by the time the ELSA sample was taken in 2002, although not all these individuals participated in HSE. Excluding the 2,596 individuals who had died or were ineligible for follow-up, 11,392 (65.7%) became ELSA participants. Analyses of sociodemographic characteristics against census results indicated that the ELSA sample remained population representative (13).

At Wave 2 in 2004, anthropometric data were collected and physical performance testing was conducted on 4,056 participants aged 65 years or older (*M* 71.9 years). Of these, complete height and weight data were gathered on 3,855 participants (95.0%), and the mean BMI for this group was 27.7 (95% confidence interval [CI] 27.5–27.8). Complete data on frailty measures, BMI, waist circumference, and all covariates were available for 3,055 participants (75.3%): For this group, mean BMI was 27.5 (95% CI 27.4–27.7) and mean age was 71.4 years.

Measures

Frailty was defined both by an index of accumulated deficits and by the Fried phenotype. A frailty index (FI) was constructed from variables or deficits representing conditions that accumulate with age and are associated with adverse outcomes (14). Deficits included sensory and functional impairments, self-reported comorbidities, poor or fair self-rated health, low mood or depression measured by the eight-item Center for Epidemiological Studies-Depression (CES-D8) scale (15), and a score in the lowest 10% of a composite measure of global cognitive function (16). Each individual's deficit points were summed and divided by the total number of deficits considered (in this case 58) to yield a FI with theoretical range 0–1. For example, someone with six deficits would have an FI value of 0.1 (6/58). Higher values indicated a greater number of problems and hence greater frailty.

Variables used to operationalize the phenotypic definition of frailty were similar to those used in the original frailty phenotypic studies (3). Strength was measured in kilograms using a grip gauge, and physical activity was estimated using self-report of duration and intensity of usual activities (17). The gait speed test involved an 8-feet walk at usual pace, with the mean of duplicate measures recorded (17). As in Fried's study, cutoffs for positive frailty indicators for strength, physical activity, and gait speed were set at the lowest 20% of the group. Exhaustion was based on self-report of "could not get going" on the CES-D8 questionnaire

(15). Weight loss was defined as loss of 5% or more of body weight since enrollment in the Health Survey for England (in 1998, 1999, or 2001).

A nurse measured height and weight according to a strict protocol (18). BMI was calculated as weight in kilograms divided by the square of height in meters and was categorized into five groups (<20, 20–24.9, 25–29.9, 30–34.9, and ≥35). Waist circumference 88 cm or more (for women) and 102 cm or more (for men) was defined as high because these are the cutoffs for significant abdominal obesity in the diagnosis of metabolic syndrome (19).

Statistical Analysis

Analyses were adjusted for potential confounders associated with frailty in later life:

- Sex (3,8).
- Age (3,8).
- Level of education (20) based on age full-time school education completed: age 14 or younger, age 15, age 16, age 17, or age 18 or older.
- Wealth (21), including financial, housing, and pension assets, divided by quintiles.
- Smoking status (22) based on self-report and categorized as never having smoked cigarettes, having quit smoking, or being a current smoker.

All analyses were weighted for complex survey design and nonresponse and conducted using Stata SE Version 10.1 (StataCorp PL, College Station, TX). Linear regression analysis was used to estimate the effects of exposures and potential confounders on FI, and logistic regression was used for phenotypic frailty. Adjusted predictions were calculated using Stata's postestimation commands.

RESULTS

Most participants were women (Table 1) in whom having a BMI 30 or more was more common (29.1%) than in men (23.4%). Similarly, more women than men had a high waist circumference (56.4% compared with 46.1%). Frailty was more prevalent in women both in terms of mean FI (0.15 in women and 0.11 in men) and in terms of phenotypic frailty (mean prevalence 0.09 in women and 0.07 in men). Increasing age was associated with greater frailty: Cross-sectionally, the mean rate of deficit accumulation was 0.032 per year on a log scale. The FI and the sum of phenotypic measures correlated moderately with each other ($R = .45$).

Following adjustment for potential confounders, the association between BMI and the FI showed a U-shaped curve. FI scores were lowest in those with BMI 20–24.9 (0.12, 95% CI 0.12–0.13) and 25–29.9 (0.13, 95% CI 0.13–0.13). Compared with these categories, FI was higher in those with BMI less than 20 (0.15, 95% CI 0.14–0.16) and in those with BMI 30–34.9 (0.15, 95% CI 0.15–0.16) and 35 or more (0.21, 95% CI 0.20–0.21). Using the phenotypic

Table 1. Baseline Characteristics of English Longitudinal Study of Ageing 2004 Participants Aged 65 Years and Older

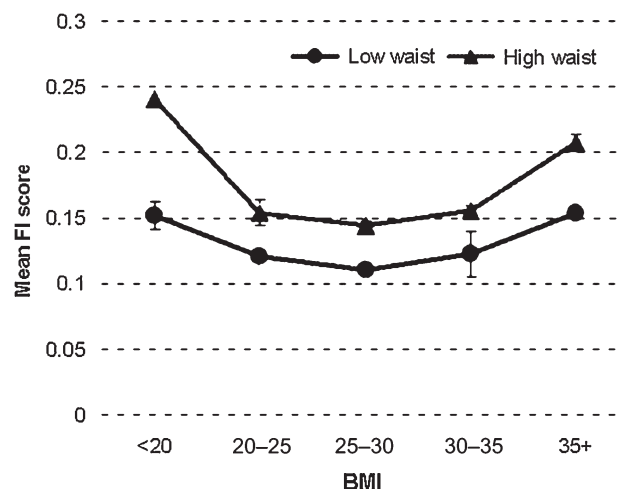| Characteristics	Men (*N* = 1,359)	Women (*N* = 1,696)
Age in y (%)		
65–69	439 (32.3)	526 (31.0)
70–74	400 (29.4)	456 (26.9)
75–79	286 (21.0)	361 (21.3)
80+	234 (17.2)	353 (20.8)
Frailty index, *M* (*SD*)	0.11 (0.10)	0.15 (0.12)
Proportion with three or more Fried criteria (*SD*)	0.07 (0.25)	0.09 (0.29)
Body mass index (%)		
<20	30 (2.2)	61 (3.6)
20–24.9	314 (23.1)	487 (28.7)
25–29.9	698 (51.4)	665 (38.6)
30–34.9	266 (19.6)	361 (21.3)
≥35.0	51 (3.8)	133 (7.8)
% With high waist circumference (*SD*)	46.1 (49.9)	56.4 (49.6)
Age left full-time education, *n* (%)		
≤14	500 (36.8)	584 (34.4)
15–18	708 (52.1)	954 (56.3)
≥19	151 (11.1)	158 (9.3)
Smoking, *n* (%)		
Never smoked	371 (27.3)	824 (48.6)
Ex smoker	845 (62.2)	687 (40.5)
Current smoker	143 (10.5)	185 (10.9)

Figure 1. Mean frailty index (FI) score in English Longitudinal Study of Ageing Wave two participants aged 65 years and older by body mass index (BMI) categories and waist circumference. *Notes:* "High waist" is waist circumference 88 cm or more (women) and 102 cm or more (men). Scores were adjusted for sex, age, level of education, and smoking status, and 95% confidence intervals are shown.

definition, frailty was most prevalent among those with BMI less than 20 (18.0%, 95% CI 15.4–20.6) and was least prevalent in those with BMI 25–29.9 (7.2%, 95% CI 6.8–7.7) or 30–34.9 (7.6%, 95% CI 4.9–9.9). The relationship between BMI and phenotypic frailty also exhibited a U shape: 13.0% (95% CI 11.3–14.7) of older people with BMI of 35 or more had three or more frailty criteria. This U-shaped relationship between BMI and frailty was also present, for both FI and phenotypic frailty, when frailty was calculated separately by gender.

Mean levels of frailty according to the FI and phenotypic frailty definitions were calculated in relation to BMI categories separately for those who did and who did not have a high waist circumference (Figures 1 and 2). In each BMI category, and using either measure of frailty, people with a high waist circumference were frailer than those of comparable BMI who had a normal waist circumference. For example, among those with BMI 25–29.9, those with normal waist circumference had a mean FI value of 0.11 (95% CI 0.11–0.11), whereas those with high waist circumference had a mean FI value of 0.14 (95% CI 0.14–0.15). In the same BMI category, prevalence of phenotypic frailty was 5.8% (95% CI 5.4–6.3) in those with normal waist circumference compared with 8.4% (95% CI 7.7–9.1) in those with high waist circumference.

DISCUSSION

Both the phenotypic definition of frailty and the FI show increased levels of frailty among those with low and very high BMIs. Abdominal adiposity seems to confer additional

risk, with greater levels of frailty among those with high waist circumferences.

The association between BMI and frailty, consistent across different definitions of the term, has parallels, which may be informative. Aging, the increased risk of mortality over time, can be conceptualized as a decline in stress resistance that results from changes in thousands of variables (23). In such a model, mortality risks associated with covariates are U or J shaped (23), as here. For physiological
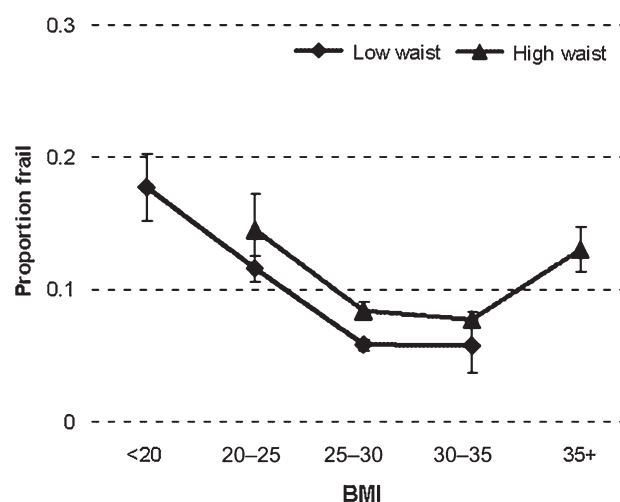

Figure 2. Proportion Fried frail in English Longitudinal Study of Ageing Wave 2 participants aged 65 years and older by body mass index (BMI) category and waist circumference. *Notes:* "High waist" is waist circumference 88 cm or more (women) and 102 cm or more (men). Scores were adjusted for sex, age, level of education, and smoking status, and 95% confidence intervals are shown.

systems, the risks of adverse outcomes associated with covariates are also usually U shaped (24). Even at a cellular level, common processes involved inactivation of adaptive responses required to protect cells from stressful environments exhibit U- or inverted U-shaped responses (25). Although these observations provide no confirmation of scale invariance, perhaps it is not surprising that the "risk state" of frailty is associated with both extremes of BMI.

Our findings must be interpreted with caution. We were not able to operationalize the phenotypic criteria exactly as Fried and colleagues proposed (2), although similar modifications have been made by others who have replicated the work (26,27). Here, weight loss was estimated as loss of 5% or more from 3 to 6 years earlier, whereas the phenotypic definition was based on weight loss over the preceding year. About 24.4% of participants met our weight loss criterion compared with 17.5% in the Canadian Study of Health and Ageing, 12.7% of people in the Women's Health and Ageing Study (WHAS), and 7.3% in the CHS (27,28). Overall, the prevalence of frailty in our sample (9.7%) is close to that reported previously in other populations (11.3% in WHAS and 11.6% in the CHS) (27,28). With respect to the FI, it has less strict criteria for which items are included in the definition (14). The construction of FIs from different numbers and types of variables allows comparisons between data sets. For example, we found that the mean FI value for ELSA participants increased with age at approximately 3% per year on a log scale: This corresponds exactly to the relationship of FI with age in studies from Australia, Canada, Sweden, and the United States (29).

Another caution is in relation to the cross-sectional design. It affords no insights into the temporal relationships between loss or gain in weight and frailty onset and denies the opportunity to explore outcomes, such as institutionalization and death.

The accumulation of abdominal fat, measured indirectly through waist circumference, is a major determinant of disability in the periretirement age period (30). Abdominal adiposity may also be particularly important in frailty pathogenesis. Abdominal adiposity is associated with low-grade systemic inflammation, mediating its link with metabolic syndromes (31,32). Furthermore, those with increased waist circumference have higher markers of oxidative stress, independent of BMI (33). Excessive and unopposed oxidative stress may be the core mechanism leading to age-associated frailty (34), with evidence supporting a direct causal role for reactive oxygen species in skeletal muscle damage and low grip strength (35). This is, to our knowledge, the first study in older people to link increased waist circumference both to an FI and to a phenotypic frailty.

Our results regarding the additional impact of truncal obesity on frailty in older people reinforce the importance of diet and exercise for older adults. Even among underweight older people, those with a higher waist circumfer-

ence were more likely to be frail. Abdominal obesity among older people with low BMIs may therefore be an additional target for intervention. Physical activity decreases abdominal fat (36), and endurance exercise training stimulates mitochondrial biosynthesis (37). Reduced abdominal adiposity and increased oxidative activity may underlie physical activity's benefit to function independent of its effects on weight reduction (17). We also found that older people with very high BMIs were more likely to be frail, a consistent result across different definitions of the term. Most clinical trials of intended weight loss by dietary programs or pharmacotherapy have excluded older people (38). In view of the impending epidemic of obesity in older populations (39), the benefits and feasibility of intervention for obese older adults should be a focus of urgent inquiries.

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