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Original Article

Normal weight obesity and functional outcomes in older adults☆,☆☆

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ABSTRACT

Background: Obesity defined by body mass index (BMI) is associated with higher levels of functional impairment. However, BMI strata misrepresent true adiposity, particularly in those with a normal BMI but elevated body fat (BF%) (normal weight obesity [NWO]) whom are at higher metabolic and mortality risk. Whether this subset of patients is associated with worsening functional outcomes is unclear.
Methods: Subjects aged ≥60 years with a BMI ≥18.5 kg/m^2 from NHANES III (1988–1994) were included. We created sex-specific tertiles of BF%. Data on physical limitations (PL), instrumental (IADL) and basic activities of daily living (BADL) were obtained. The analysis focused on the association between NWO and these outcomes. Comparative rates among each tertile using logistic regression (referent = lowest tertile) were assessed, incrementally adding co-variates.
Results: Of the 4484 subjects aged ≥60 years, 1528 had a normal BMI, and the range of the mean age of tertiles was 69.9–71.2 years. Lean mass was lowest in the elevated BF% group than in the middle or low tertiles (42.6 vs 44.9 vs 45.8; $p < 0.001$). Those with NWO had higher PL risk than the referent in females only in our adjusted model (males OR 1.18 [0.63–2.21]; females OR 1.90 [1.04–3.48]) but not after incorporating lean mass (males OR 1.11[0.56–2.20]; females (1.73 [0.92–3.25]). Neither sex with high BF% had higher IADL risk than the corresponding tertiles (males OR 0.67 [0.35–1.33]; females OR 1.20 [0.74–1.93]). NWO was protective in males only (OR 0.28 [0.10–0.83]) but not in females (OR 0.64 [0.40–1.03]).
Conclusions: NWO is associated with increased physical impairment in older adults in females only, highlighting the importance of recognizing the association of obesity with disability in elders.

1. Introduction

Body mass index (BMI) is an easy to use measure of adiposity in routine clinical practice and according to national and international guidelines, the method to identify and diagnose obesity [1]. BMI has been linked in population-based epidemiological studies to cardiac risk factors, including hypertension, dyslipidemia, and diabetes [2], but also to mortality [3] and institutionalization [4]. However, BMI has failed to account for processes occurring throughout the aging process, including changes in stature from osteoporosis or kyphosis [5], and important age-related loss in muscle mass termed sarcopenia [6]. Diagnostic sensitivity of BMI in assessing obesity drops with age and misses up to ~50% of subjects otherwise classified as having obesity [7,8].

Gold standard assessment of body composition using computer tomography and magnetic resonance imaging has been proposed; yet, these costly measures are fraught with problems. Both dual energy X-ray absorptiometry and bioelectrical impedance (BIA) have been suggested as reasonable alternatives [6]. We previously identified a group of subjects misclassified as not having obesity based on BMI but having elevated body fat percentage (BF%) [9], even in older adults [10]. This subset of patients with normal weight obesity (NWO) was shown to be at higher risk of cardiometabolic dysregulation, endothelial dysfunction, insulin resistance, metabolic syndrome, and mortality [10].

While the proportion of older adults in the United States continues to rise [11], a concomitant alarming rise in obesity prevalence in all ages has also been demonstrated [12]. Older adults living longer are at higher risk of developing incident physical limitations and disability than in the past [13]. Previous studies have established the relationship

Abbreviations: ADL, activities of daily living; BF, body fat; BMI, body mass index; NHANES, National Health and Nutrition Examination Survey; NWO, normal weight obesity; WC, waist circumference.

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between obesity measured by BMI and disability [14]; however, to our knowledge, no data specifically examines this subset of normal BMI subjects with elevated BF%. Extending our previous work, we speculate that normal BMI subjects with elevated BF% would also be at higher risk of functional outcomes.

2. Methods

2.1. Study design + population

NHANES III is a population-based study of non-institutionalized adults of the United States conducted by the Centers for Disease Control between 1988 and 1994. The dataset is publically available with study design, sampling characteristics and survey components available online at http://www.cdc.gov/nchs/nhanes.htm. Briefly, the survey is a complex, stratified design that oversamples minorities and older adults. Data was downloaded in March 2013. This study was exempt from the local institutional review board review due to the de-identified data and analysis proposed.

We identified 6178 subjects ≥60 years old who were sampled, interviewed and examined by a physician at a mobile examination center. All races (non-Hispanic White, non-Hispanic Black, and Hispanic American) were included. A total of 1694 participants without complete anthropometric or bioelectrical impedance measures were excluded. We identified 4484 in our analytic cohort.

2.2. Demographic characteristics

Date of birth was verified against an age verification chart, with differences of self-reported age on the initial screening questionnaire reconciled per protocol. Age at screening was used for baseline measurements. Race was self-reported as was education level which was dichotomized by ≤12 years and >12 years. Trained staff performed interviews with data collection automated. All questions were directed to subjects or where appropriate to proxies. Co-morbidities were ascertained by self-report. Smokers answered, "Do you smoke cigarettes," while 'ever smokers' included subjects answering "Have you ever smoked at least 100 cigarettes in your lifetime."

A calibrated digital scale measured weight in kilograms. Height was ascertained in centimeters using a stadiometer with the subject breathing deeply after inhalation with their weight distributed evenly on both feet. Waist circumference (WC) was measured by palpating the right iliac crest, crossing the mid-axillary line, placing the measure around the trunk's body at minimal respiration in the standing position. Hip circumference was ascertained at the side seams of the pants above the hips, at maximum extension of the buttocks, with the tape measure held snuggly. Waist–hip ratio was obtained using the ratio of waist and hip circumference. BMI was calculated as weight (kg) divided by height (m) squared and grouped into standard categories (≤18.5 kg/m^2, 18.5–25 kg/m^2, 25–29.9 kg/m^2, ≥30 kg/m^2). All procedures were performed on the right side of the body except where physically incapable of doing so. For quality assurance purposes, replicates and data review were performed.

2.3. Body composition measures

Body composition was assessed using bioelectrical impedance analysis. NHANES III utilized a Valhalla 1990B Bio-resistance Body Composition Analyzer (Valhalla Scientific, San Diego, CA), and data was converted using sex-specific predictive equations from an independent and separate cohort to RJL-resistance values, to determine fat-free mass and total body water [15]. The difference between weight (kg) and fat-free mass was calculated total body fat. Total body fat divided by weight multiplied by 100 was considered BF%.

Subjects were classified according to standard BMI categories. We subdivided each BMI category according to sex-specific body fat tertiles (high, medium, low). In males, the boundaries were <22.9, 22.9–28.0, and >28.0%; in females they were <34.5, 34.5–40.3, >40.3%. Those in the highest tertile were considered to have the greatest degree of adiposity. The term normal weight obesity (NWO) identified the group of persons with a normal BMI (18.5–24.9 kg/m^2) in the upper tertile of BF%.

2.4. Functional outcomes

Subjects were asked a number of self-perception questions pertaining to physical limitations (PL), limitations in instrumental activities of daily living (IADL) and basic activities of daily living (BADL). All activities are self-reported and subjects noted on a scale of 1 to 4 the degree of difficulty (none to unable to do). We classified subjects as having 'any difficulty' if they indicated any response other than 'no difficulty,' in line with a previous study [14]. Physical limitations assessed the following movements: walking ¼ mile, walking 10 stairs without resting; stooping, crouching, or kneeling; lifting or carrying 10 pounds; walking between rooms on the same floor; standing up from a chair, and the use of an assist device. There are seven well accepted IADLs [16]; however, NHANES only consisted of information pertaining to managing money, house chores, preparing meals, or help handling routine needs. Lastly, we classified subjects as having any type of ADL disability if they had any type of difficulty getting in/out of bed, inability to dress or eat, as NHANES did not have information on bathing or toileting [17].

2.5. Statistical analysis

All data was merged according to NHANES procedures. Continuous variables are represented as means (standard deviations) and categorical variables as counts (percent). We calculated weighted means, standard errors for continuous variables, and weighted percentages for categorical variables using the SURVEYMEANS and SURVEYFREQ procedures (SAS Institute Inc, Cary, NC). An analysis of variance tested differences between tertiles by sex. Our primary outcome was to determine the impact of adiposity (sex-specific) within the normal BMI category on risk of functional outcomes as measured by Physical Limitations (PL), IADL, and BADL disability. The referent category was subjects in the lowest tertile of body fat percent. We created a number of stepwise multivariable models to observe the impact of covariates on our outcome of choice. Our base model included age and sex (Model 1). Model 2 adjusted for baseline demographic and socioeconomic characteristics including race, education, and smoking status. We adjusted for co-morbidities including cardiovascular disease (stroke, myocardial infarction), non-skin cancer, bronchitis and emphysema (Model 3). Model 4 adjusted Model 3 for fat-free mass to partially account for sarcopenia, which is prevalent in this population. We also adjusted for BMI (Model 5), and waist–hip ratio (Model 6) as a measure of visceral adiposity. Model 7 adjusted Model 3 with waist circumference only. We also assessed correlations between continuous anthropometric measures. All odds ratio estimates were weighted and calculated using SAS procedure SURVEYLOGISTIC that accounts for a complex survey design, using pseudo-strata, pseudo-primary sampling units, and sampling weights provided by the National Institute for Health Statistics. Taylor series linearization approach was used for variance estimation as it was recommended by NHANES. All estimates were weighted and calculated using SAS version 9.2 (SAS Institute Inc. Cary, NC). Statistical significance was defined as $p < 0.05$.

3. Results

The range of the mean age of the tertiles examined was 67.9 to 71.2 years. Demographic and functional characteristics of our included cohort are indicated in Table 1. In normal BMI participants, waist–hip ratio, waist circumference and BMI increased with higher tertile of body fat. Co-morbidities were no different across tertiles. Prevalence