Prevalence of Sarcopenia Obesity in Patients Treated at a Rural, Multidisciplinary Weight and Wellness Center

John A Batsis[1,2,3] ⓘD, Diane Gilbert-Diamond[4], Auden C McClure[5], Aaron Weintraub[5] ⓘD, Diane Sette[5], John N Mecchella[5], Sivan Rotenberg[5], Summer B Cook[5] and Richard I Rothstein[5]

[1]Geisel School of Medicine at Dartmouth, Hanover, NH, USA. [2]Department of Medicine, Dartmouth-Hitchcock Medical Center, Lebanon, NH, USA. [3]The Dartmouth Institute for Health Policy & Clinical Practice, Lebanon, NH, USA. [4]Department of Epidemiology, Geisel School of Medicine at Dartmouth, Hanover, NH, USA. [5]Department of Kinesiology, University of New Hampshire, Durham, NH, USA.

ABSTRACT: Sarcopenic obesity portends poor outcomes, yet it is under-recognized in practice. We collected baseline clinical data including data on body composition (total and segmental muscle mass and total body fat), grip strength, and 5-times sit-to-stand. We defined sarcopenia using cut-points for appendicular lean mass (ALM) and obesity using body-fat cut-points. A total of 599 clinic patients (78.5% female; mean age was 51.3 ± 14.2 years) had bioelectrical impedance analysis (BIA) data (83.8%). Mean body mass index (BMI) and waist circumference were 43.1 ± 8.9 kg/m^2 and 132.3 ± 70.7 cm, respectively. All patients had elevated body fat. There were 284 (47.4%) individuals fulfilling criteria for ALM-defined sarcopenia. Sarcopenic obese persons had a lower BMI (38.2 ± 6.4 vs 47.6 ± 8.6; $P < 0.001$), fat-free mass (113.0 kg ± 16.1 vs 152.1 kg ± 29.4; $P < 0.001$), fat mass ($48.4\% \pm 5.9$ vs $49.5\% \pm 6.2$; $P = 0.03$), and visceral adipose tissue (216.8 ± 106.3 vs 242.7 ± 133.6 cm^3; $P = 0.009$) than those without sarcopenic obesity. Grip strength was lower in those with sarcopenic obesity (25.1 ± 8.0 vs 30.5 ± 11.3 kg; $P < 0.001$) and sit-to-stand times were longer (12.4 ± 4.4 vs 10.8 second ± 4.6; $P = 0.03$). Sarcopenic obesity was highly prevalent in a rural, tertiary care weight and wellness center.

KEYWORDS: obesity, sarcopenic obesity, rural, patient-reported outcomes, muscle

Introduction

Current strategies for managing obesity in adults focus on lifestyle measures, including delivering intensive behavioral and nutritional therapy in clinical practices.[1,2] A multidisciplinary treatment team is recommended by the 2014 American Heart Association guidelines that encourages weight loss of 5% which can lead to marked improvements in comorbidity.[3] Most successful weight-loss programs struggle to meet such demands,[4] particularly in rural areas,[5] where staff availability and specialty are limited[6] and reimbursement is poor.[7]

Sarcopenic obesity is an emerging syndrome that is observed in adults with obesity.[8] Sarcopenia is broadly defined as the loss of muscle mass, strength, and/or function with aging.[9,10] Yet, fat can infiltrate into muscle fibers, promoting insulin resistance and contributing to weakness and physical disability.[8] Traditional lifestyle measures as outlined by current guidelines emphasize the importance of aerobic exercise but omit the contribution of obesity and weight loss to physiological muscle processes. A 1 kg weight loss not only leads to loss of fat but can lead to a loss of approximately .25 kg of muscle.[11] There is promising evidence that resistance exercises can potentially treat sarcopenic obesity[12,13] and is essential in the management of populations with obesity.

Anthropometric measures such as body mass index (BMI) or waist circumference (WC) are accepted as surrogate clinical measures for the assessment of both muscle and fat mass but are highly inaccurate and lack diagnostic accuracy.[14,15] When available, body composition measures such as dual-energy x-ray absorptiometry (DXA) or bioelectrical impedance analysis (BIA) have augmented accurate assessment of muscle and fat mass within both the research and clinical settings.[8,16-18] Using BIA in an office setting is a low-cost procedure, requires minimal training and oversight, can provide an accurate determination of the components of muscle and fat, and can overcome the inability to measure sarcopenic obesity in clinical practice.[19] The ability to identify obese individuals with low fat-free or muscle mass has important clinical implications, in which it can guide providers to augment multimodality treatments with resistance training. While, the definition of sarcopenic obesity varies in the literature,[20,21] the Foundation for the National Institutes of Health (FNIH) and other major societies do not specify diagnostic criteria for this entity. We defined

sarcopenic obesity using cut-points of both FNIH[10] and those from American Association of Clinical Endocrinologists[22] for sarcopenia and body fat, respectively. As such, we sought to evaluate the prevalence of sarcopenic obesity, as defined by the FNIH cut-points for appendicular lean mass (ALM)[10] and cut-points for body fat, in an academic, rural weight, and wellness center.

Methods

Study setting

The study setting was located at the Dartmouth-Hitchcock Weight and Wellness Center (WWC), an interdisciplinary clinic focusing on treatment of weight and weight-related comorbidities. Dartmouth-Hitchcock is a rural tertiary care medical center located in Lebanon, NH on the New Hampshire and Vermont border and is New Hampshire's only academic medical center with a catchment population area of approximately 1.5 million persons. The study was reviewed and approved by the Committee for the Protection of Human Subjects at Dartmouth College. The STROBE statement for nutritional epidemiology is attached in the Supplementary materials (Supplemental Material).

Clinical program

The WWC clinic opened in January 2016 and offers multidisciplinary, comprehensive medical management. Patients require a referral from their primary-care clinician, allowing for ongoing coordination of care between primary and specialty teams. A patient-centered treatment plan was formulated at the initial consultation with a provider specializing in weight management. As part of a patient's initial intake visit, a comprehensive survey instrument was completed in advance of their visit and a trained nurse completes objective anthropometric and functional measures (see below). All information was directly entered into the electronic medical record.

Study cohort

Between January 2016 and March 2018, 715 unique patients were evaluated by a clinician at the WWC, of whom 599 had a bioelectrical impedance analysis (BIA; Figure 1) at the intake visit. The remaining 116 patients did not have their measurements performed for the following reasons: a medical contraindication (n = 6, see below), lost to follow-up (n = 60), patient refusal (n = 5), machine malfunction (n = 12), or general staff unavailability (n = 38). As with any initiation of a clinical infrastructure, our measures changed slightly over time accounting for some of the missing functionality and questionnaire data in a subset of data. We excluded eight patients with missing comorbidities at the baseline visit for specific analyses using this covariate.
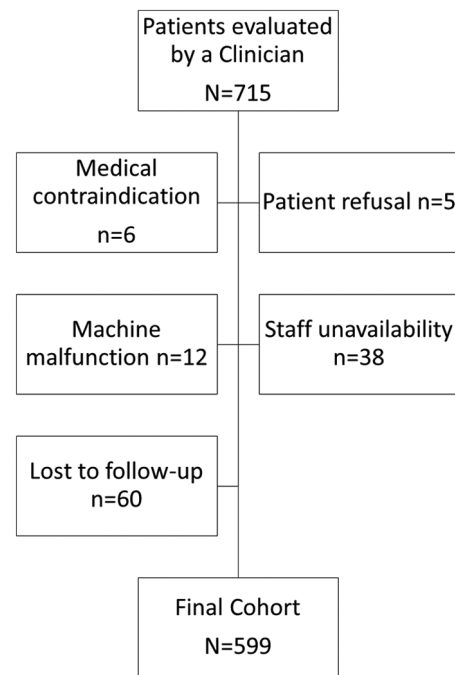
Figure 1. Participant flow and exclusion criteria of cohort.

Body composition

Body composition was assessed using the 8-point Seca m514 (Hamburg, Germany) bioelectrical impedance analyzer that has previously validated equations.[23,24] The apparatus has the capabilities of determining segmental fat-free or muscle mass (appendicular and total body), overall fat mass, and visceral fat mass through multi-frequency analysis. Its capacity weight is 300 kg. All participants stood on the apparatus, barefoot, holding each side at the requisite contact points. The total duration of analysis was approximately 20 seconds. Height, date of birth, and self-reported physical activity levels (ranging on a scale from 0 to 5 [*very inactive* to *very active*]) were directly entered into the console by the nurse, who received formal training to perform these assessments. Contraindications to using a BIA included an uncontrolled cardiac arrhythmia, pregnancy status, an implantable device (pacemaker, automatic implantable cardiac defibrillator, TENS unit, infusion pumps, artificial hearts, or other portable electronic medical devices). Ascertainment of BIA did not account for a patient's recent hydration status, alcohol or recent physical activity. Waist circumference was measured snuggly using a tape measure around the abdomen above the iliac crest, parallel to the floor at the end of exhalation.

Sarcopenic obesity definitions

Sarcopenia was defined using the definition of low ALM put forth by the 2014 Foundation of the National Institute of Health Sarcopenia Project.[10] ALM was calculated as the sum of the BIA-measured lean mass of all four limbs (right arm, left arm, right leg, and right arm). Sex-specific cut-points of ALM

of <19.75 kg in men and <15.02 kg in women defined sarcopenia. This group also stated the importance of a relationship between muscle mass and muscle strength, yet a causal, direct pathway does not exist. Elevated body fat was defined as values exceeding 25% and 35%, in men and women,[15] respectively, and >88 cm and >102 cm for WC.[25] Sarcopenic obesity was defined using the combination of ALM and body-fat percent cut-points.

Baseline characteristics

Data within the medical record was extracted for baseline demographic variables (age, sex, race/ethnicity, insurance, and smoking status), and comorbid conditions (anxiety, chronic obstructive pulmonary disease, depression, high cholesterol, osteoarthritis, sleep apnea, cerebrovascular disease, and non-alcoholic fatty liver disease) based on the International Classification of Disease 10 codes (http://www.who.int/classifications/icd/en/) from the problem list. Ethnicity was categorized as Hispanic versus non-Hispanic, and race was categorized as American Indian/Pacific Islander, Black or African-American, White, or other. Primary insurance status was classified as Medicare, Medicaid or charity care, commercial insurance, self-pay, or other. Smoking status is routinely assessed at all clinic visits and categorized as former smoker, current smoker, or non-smoker.

Functional measures

Grip Strength was assessed using a JAMAR dynamometer (Patterson Medical, Warrenville, IL). Patients are instructed to sit, flex their dominant arm at 90° on a level surface and squeeze the dynamometer which is adjusted to their hand size. Four measurements are obtained (two on each limb), and the mean (in kg) was entered into a designated field in the medical record. Low grip strength was classified as <26 kg in men and <16 kg in women.[10] The five times sit-to-stand test is a measure of lower extremity strength.[26] Patients sat in a chair with their arms crossed in a chair with back and were instructed to stand, unassisted with their arms crossed, extending their body fully upright and then sitting down completely, before rising again. This was done five times. Time (in seconds) was measured from the onset of the first rise to the onset of the fifth rise. The six-minute walk test was a measure of aerobic capacity performed in a 100-foot long corridor.[27] This assessment was performed according to the American Thoracic Society guidelines by a nurse. Measurements of blood pressure, heart rate, and oxygen saturation before and after the evaluation. Distance in feet was recorded in the medical record and was converted to meters.

Questionnaires

Participants completed several self-reported questionnaires using an electronic touchpad device or on their home computer in advance of the baseline clinic visit. The University of Rhode Island Change Assessment (URICA)[28] is a scale based on the transtheoretical model of behavioral change[29] consisting of 12 questions in four domains—pre-contemplation, contemplation, action, and maintenance. A final readiness score was calculated. A score <8 is suggestive of pre-contemplation, a score of 8-11.99 is considered a contemplation state, and a score >12 is classified as a preparation state for treatment. The Weight–Efficacy Lifestyle Short-Form (eight questions)[30] assessed patient self-efficacy and the Patient Reported Outcome Measures Information System Global (10 items)[31] measured physical function (six questions) and general health (physical and mental health).

Statistical analysis

Data from the BIA analyzer was aggregated with variables of interest from the electronic medical record extracted with the assistance of the Dartmouth-Hitchcock Analytics Institute into a composite data set. Descriptive statistics, means ± standard deviation, and counts (percentages) were calculated. Patients with obesity were categorized by lean mass (sarcopenia) status (low vs normal), and prevalence was further stratified by sex, race, and age category (18-40 years, 40-60 years, 60-70 years, and ≥70 years). Comparisons between low and normal lean mass groups were conducted using unpaired t-tests for continuous variables and chi-square tests for categorical variables (or their non-parametric equivalences). All analyses were performed using STATA, version 15 (College Station, TX). A P value of less than 0.05 was considered statistically significant.

Results

Of the 715 patients, we included 599 in our analytic data set (Table 1). All patients were classified as having body-fat defined obesity. The prevalence of sarcopenic obesity using ALM-defined sarcopenia was 47.6% using the FNIH cut-point for ALM at their intial visit. Individuals with sarcopenic obesity were older (greater than 60 years old), more likely to be female, and were less likely to have osteoarthritis and sleep apnea.

Table 2 highlights clinical and BIA-specific anthropometric and body composition measures. Individuals with ALM-defined sarcopenic obesity were lighter (100.1 kg ± 13.5 vs 137.8 kg ± 26.6; $P < 0.001$), had lower BMI (38.2 kg/m² ± vs 47.6 kg/m² ± 8.6; $P < 0.001$), and lower total body fat (48.7 kg ± 10.3 vs 68.6 ± 18.0 kg; $P < 0.001$) than individuals without sarcopenic obesity. Prevalence of sarcopenic obesity is depicted in Figure 2 (Appendix 1) in the overall sample of individuals BIA data, by sex, race, and age category.

In our subset of patients who had functional measures (Table 3), grip strength was significantly lower (25.1 ± 8.0 vs 30.5 ± 11.3; $P < 0.001$) and sit-to-stand time was slower (12.4 ± 4.4 vs 10.8 ± 4.65 seconds, $P < 0.001$) in those with

Table 1. Baseline characteristics of Weight and Wellness patients with obesity.

	OVERALL	LEAN MASS STATUS		P VALUE
		LOW	NORMAL	
	N=599	N=285	N=314	
Age, years	51.3 ± 14.1	54.5 ± 13.3	48.5 ± 14.2	<.001
Age category				
18-40 years	143 (23.9)	45 (15.8)	98 (31.2)	<.001
40-60 years	268 (44.7)	129 (45.3)	139 (44.3)	
60-70 years	131 (21.9)	78 (27.4)	53 (16.9)	
>70 years	57 (9.5)	33 (11.6)	24 (7.6)	
Female sex	470 (78.5)	251 (88.1)	219 (69.8)	<.001
Hispanic race	4 (0.7)	1 (0.4)	3 (1.0)	.30
Ethnicity				.12
American Indian	2 (0.3)	1 (0.4)	1 (0.3)	
Black	12 (2.0)	2 (0.7)	10 (3.2)	
White	581 (97.0)	279 (97.9)	302 (96.2)	
Other	4 (0.7)	3 (1.1)	1 (0.3)	
Insurance				.74
Medicare	133 (22.2)	67 (23.2)	66 (21.0)	
Medicaid/State assistance	51 (8.5)	23 (8.1)	28 (8.9)	
Commercial/other	415 (69.3)	195 (68.7)	220 (70.1)	
Smoking status				.48
Current	38 (6.3)	15 (5.3)	23 (7.3)	
Former	179 (29.9)	81 (28.4)	98 (31.2)	
Never	374 (62.4)	184 (64.6)	190 (60.5)	
Unknown	8 (1.3)	5 (1.8)	3 (1.0)	
Comorbidities[a]				
Anxiety	158 (26.4)	73 (25.6)	85 (27.1)	.62
COPD	7 (1.2)	7 (2.5)	0	.005
CAD	40 (6.7)	14 (4.9)	26 (8.3)	.09
Depression	179 (29.9)	84 (29.5)	95 (30.3)	.76
Diabetes	102 (17.0)	50 (17.5)	52 (16.6)	.80
High cholesterol	178 (29.7)	89 (31.2)	89 (28.3)	.50
Osteoarthritis	115 (19.2)	43 (15.1)	72 (22.9)	.01
Sleep apnea	210 (35.1)	85 (29.8)	125 (39.8)	.007
Cerebrovascular disease	10 (1.7)	7 (2.5)	3 (1.0)	.16
NAFLD	33 (5.6)	17 (6.0)	16 (5.2)	.67

Values represented are means ± standard deviation, counts (column percents). All participants were classified as having body-fat defined obesity. Sarcopenia was defined using the FNIH-definition of ALM (<26 kg in men; <16 kg in women).
Abbreviations: ALM, appendicular lean mass; CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; NAFLD, non-alcoholic fatty liver disease.
[a]Eight participants did not have any medical problems documented in the problem list.

Table 2. Body composition and anthropometric measures in patients with obesity.

	OVERALL (N = 599)	SARCOPENIA STATUS		*P* VALUE
		PRESENT (N = 285)	ABSENT (N = 314)	
Height, m	1.66 ± 0.09	1.62 ± 0.08	1.70 ± 0.09	<.001
Weight, kg	119.9 ± 28.5	100.1 ± 13.5	137.8 ± 26.6	<.001
Body mass index, kg/m^2	43.1 ± 8.9	38.2 ± 6.4	47.6 ± 8.6	<.001
Waist Circumference, cm	132.3 ± 70.7	127.9 ± 100.5	136.3 ± 18.7	.15
High WC (yes/no)	594 (99.2)	281 (98.6)	313 (99.7)	.15
Body fat, kg	59.2 ± 39.2	48.7 ± 10.3	68.6 ± 18.0	<.001
Body fat, %	49.0 ± 6.1	48.4 ± 5.9	49.5 ± 6.2	.03
High body fat, %	599 (100)	284 (100)	314 (100)	1.00
Visceral adipose tissue, cm^3	6.54 ± 4.47	4.50 ± 2.37	8.38 ± 5.08	<.001
Skeletal muscle mass, kg	29.6 ± 8.0	24.4 ± 4.2	34.4 ± 7.6	<.001
ALM, kg	16.7 ± 4.7	13.4 ± 2.2	19.8 ± 4.3	<.001
Right leg, kg	15.0 ± 4.3	12.0 ± 1.85	17.8 ± 4.1	<.001
Left leg, kg	14.9 ± 4.2	11.9 ± 1.82	17.6 ± 3.85	<.001
Left arm, kg	3.4 ± 1.1	2.76 ± 0.68	3.97 ± 1.11	<.001
Right arm, kg	3.54 ± 1.2	2.87 ± 0.71	4.15 ± 1.18	<.001
ALM	0.39 ± 0.08	0.358 ± 0.068	0.421 ± 0.083	<.001

All values presented are mean ± standard deviation, or counts (percent).
Abbreviations: ALM, appendicular lean mass; BMI, body mass index; WC, waist circumference.
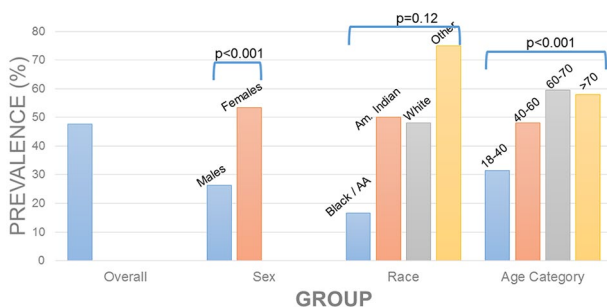
Figure 2. Prevalence of low lean mass in adults with obesity.

sarcopenic obesity. We did not observe differences in the 6 minute walk, readiness to change or self-efficacy scores. PROMIS physical function scoring and self-reported health was higher in those with sarcopenic obesity than those without. No differences in baseline characteristics were observed between those individuals with full functional measures and individuals with at least one missing measure (Appendix 2).

Discussion
Prevalence of sarcopenic obesity defined using ALM and body-fat percent cut-points, approached 50% among adults at their intake visit upon referral for obesity management in a rural, academic weight treatment center. Our results suggest the importance of recognizing sarcopenic obesity, defined using low lean mass (LLM) and elevated body-fat mass, in adults, irrespective of age, as it may be associated with impaired objective physical function and likely is underdiagnosed in clinical practice.

Surprisingly, prevalence of sarcopenic obesity were higher than those reported in other literature estimates of cross-sectional data, including reports of participants younger than the age of 60 years as is the case in our center.[20,32] In other studies, rates of sarcopenic obesity markedly increase with age,[10,33-35] which was not consistently observed in our sample. There are several potential explanations for these findings. First, cross-sectional, population-based studies are often representative of community-dwelling adults and may not be representative of individuals seeking obesity management within a health-care setting. Second, sarcopenic obesity is strongly associated with functional impairments and disability, rising with age.[36,37] Presumably, individuals with a significant disability may be less likely to seek care for obesity leading to the lower rates in those aged >70 years. Third, younger individuals at risk or with

Table 3. Functional and patient-reported outcome measures in patients with obesity.

		OVERALL	LOW LEAN MASS STATUS		P VALUE
			LOW	NORMAL	
Strength measures	n				
Grip strength (kg)	488	27.9 ± 10.3	25.1 ± 8.0	30.5 ± 11.3	<.001
Sit-to-stand (seconds)	491	11.6 ± 4.6	12.4 ± 4.4	10.8 ± 4.65	<.001
6-minute walk test, (m)	495	426.8 ± 219.0	435.1 ± 106.7	418.5 ± 290.6	.41
Subjective measures					
URICA					
Readiness	359	10.1 ± 2.0	10.3 ± 2.1	9.9 ± 1.9	.11
WEL-SF	373	48.8 ± 17.3	50.5 ± 17.5	47.4 ± 17.0	.08
PROMIS					
Physical function	359	43.4 ± 8.11	44.8 ± 8.0	42.2 ± 8.0	.003
Mental health	373	44.1 ± 8.9	45.9 ± 8.7	42.5 ± 8.8	<.001
Physical health	367	42.7 ± 7.7	44.0 ± 7.8	41.6 ± 7.4	.003

All values presented are mean ± standard deviation, or counts (percent). A *P* value represents the differences between obese individuals with and without ALM-defined sarcopenia (<19.75 kg in men; <15.02 kg in women).
Abbreviations: ALM, appendicular lean mass; PROMIS, Patient Reported Outcome Measurement Information Systems (higher score, 0-100 is suggestive of better health); URICA, University of Rhode Island Change Assessment (precontemplative <8; contemplation state 8-11.99; preparation state for treatment >12); WEL-SF, Weight Efficacy Short-Form (assessed weight self-efficacy).

physical impairments may seek care due to the reduced co-morbidity burden as compared to older adults. The baseline comorbid characteristics are reflective of such. Last, there continues to be a bias against managing obesity in an older adult population[38] despite emerging evidence suggesting its importance.[39]

Our objective, patient-reported outcome measures provide exploratory, pragmatic information regarding the baseline characteristics of patients with sarcopenic obesity presenting in a real-world setting. The relationship between fat-free (muscle mass) and muscle strength is not causal nor linear,[10,33,34] yet our results demonstrate parallel relationships between muscle and strength. Our results demonstrate significant differences in grip strength and in sit-to-stand strength. Such robust measures and trends of upper and lower extremity strength parallel findings observed in epidemiological studies.[10,33-35] The lack of differences in 6-minute walk test suggests that sarcopenic obesity may have a lesser impact on cardiopulmonary and aerobic fitness as opposed to its biologic effect of muscle although larger sample sizes could be helpful in clarifying this association. An alternative explanation was this population had higher baseline performance as compared to other interventional studies.[40] Readiness-to-change, and indicator of willingness to engage in therapy, was no different in these populations suggesting a potential referral bias in those with sarcopenic obesity. In addition, the significantly higher baseline scores on the PROMIS scales in those with sarcopenic obesity is intriguing.

While purely speculative, we hypothesize that the individuals with sarcopenic obesity seeking weight loss perceive themselves as healthier and likely believe they may be able to improve their health. These findings may be indicators of health-status and could be considered, irrespective of sarcopenia status, of engagement in such a program. Sarcopenic obesity is generally associated with reduced quality of life[41] and thus future work is needed to clarify and ascertain with the differences in PROMIS are in fact due to sarcopenia or other factors.

Our study has many strengths. These findings are the first to our knowledge evaluating sarcopenic obesity in the context of a natural experiment of obesity using clinic-based data from an electronic medical record. Given that data were collected as part of routine care, complete case ascertainment was excellent (>85%). Our overall functional and patient-reported outcome measure completion rate was lower (55.5%); however, our sensitivity analysis comparing the baseline characteristics of individuals with and without such measures found no significant differences. This approach suggests that our analytical sample is likely representative of the true population referred for treatment.

There are some limitations to our analysis in addition to the missing information. We are reliant on administrative data in the electronic medical record for our analyses, whose use has been challenged by others.[42,43] We also may not have sufficiently captured medical problems. Nursing staff conducts much of the objective information, and while trained, we have no method in a natural environment to validate their technique and hence

they may be subject to measurement bias. Our clinic may not be representative of the entire population and is subject to referral bias seen in academic centers. While our population may have external validity among rural, caucasian referral populations that can provide initial formative estimates on its prevalence within rural settings, we caution generalization to other populations. While BIA has been proven to be helpful in the ascertainment of body composition, it has considerable limitations itself and reduced diagnostic accuracy as compared to DXA[17,18] and indeed may have lower accuracy in adults with obesity.[44,45] While BIA may over- or under-estimate fat or lean mass, it may be well within acceptable ranges considering the poor sensitive of BMI. Furthermore, there are no practical or pragmatic means of performing DXA in all patients outside of a research setting due to regulatory and reimbursement issues ultimately prompting the application of DXA-derived cutoffs to BIA. Such an approach has been previously suggested in guidelines. FNIH also uses ALM_{BMI} as a cut-point for sarcopenia that normalizes muscle mass for BMI. However, our previous work suggests that ALM may, in fact, be a better predictor of adverse metabolic and inflammatory outcomes.[46] Integrating an ALM_{BMI} cut-point for sarcopenia while using percent body fat for obesity may lead to potential confounding and collinearity.

These preliminary findings have considerable implications. Adults of all ages are at risk for sarcopenic obesity and clinicians failing to recognize and identify sarcopenia in individuals with obesity could potentially be detrimental to this referral population. Unopposed weight loss in obese individuals with sarcopenia can further propagate its development, promoting not only fat loss but furthering muscle and bone loss.[12,40] This loss of muscle loss places individuals at additional risk of adverse outcomes, including cardiovascular disease,[47] disability[48] and early mortality.[49] Weight-loss programs should include resistance-based exercise programs,[40,50] vitamin D supplementation,[51] and potential augmentation of protein intake in efforts to mitigate sarcopenia.[52]

Conclusions
Sarcopenic obesity is common in a tertiary care, academic rural obesity clinic, suggesting its importance in its recognition. Our results highlight the importance of identifying sarcopenia using the definition of LLM in adults with obesity, irrespective of age as their objective physical function may be impaired.

Authors' Note
Work to be presented at The Obesity Society 2018 Annual Meeting, Nashville, TN. Committee for the Protection of Human Subjects #:30801

Acknowledgements
The authors thank the staff of the Dartmouth Weight and Wellness Center including Tara Efstathiou, Laurie Gelb, Eugene Soboleski, and Jennifer Snide from the Dartmouth-Hitchcock Analytics Institute.

Author Contributions
JAB Designed and implemented the research, to the analysis of the results, critically revised the manuscript, an approved the final version,DGD Designed and implemented the research, contributed to the analysis of the results, critically revised the manuscript, and approved the final version, ACM Designed and implemented the research, contributed to the analysis of the results, critically revised the manuscript, and approved the final version, AW Implemented the research, contributed to the analysis of the results, critically revised the manuscript, and approved the final version, DS Contributed to the analysis of the results, critically revised the manuscript, and approved the final version, JNM Implemented the research, contributed to the analysis of the results, critically revised the manuscript, and approvedthe final version, SR Implemented the research, contributed to the analysis of the results, critically revised the manuscript, and approvedthe final version, SBC Implemented the research, contributed to the analysis of the results, critically revised the manuscript, and approvedthe final version, RIR Implemented the research, contributed to the analysis of the results, critically revised the manuscript, and approvedthe final version.

ORCID iDs
John A. Batsis https://orcid.org/0000-0002-0845-4416
Aaron Weintraub https://orcid.org/0000-0002-0139-5898

Supplemental material
Supplemental material for this article is available online.

REFERENCES
1. McTigue KM, Harris R, Hemphill B, et al. Screening and interventions for obesity in adults: summary of the evidence for the U.S. Preventive Services Task Force. *Ann Intern Med*. 2003;139:933–949. doi:10.7326/0003-4819-139-11 -200312020-00013.
2. Moyer VA, U.S. Preventive Services Task Force. Screening for and management of obesity in adults: U.S. Preventive Services Task Force recommendation statement. *Ann Intern Med*. 2012;157:373–378. doi:10.7326/0003-4819-157-5 -201209040-00475.
3. Jensen MD, Ryan DH, Apovian CM, et al. 2013 AHA/ACC/TOS guideline for the management of overweight and obesity in adults. *Circulation*. 2014;129:S102– S138. doi:10.1161/01.cir.0000437739.71477.ee.
4. DesRoches CM, Buerhaus P, Dittus RS, Donelan K. Primary care workforce shortages and career recommendations from practicing clinicians. *Acad Med*. 2015;90:671–677. doi:10.1097/ACM.0000000000000591.
5. MacDowell M, Glasser M, Fitts M, Nielsen K, Hunsaker M. A national view of rural health workforce issues in the USA. *Rural Remote Health*. 2010;10: 1531.
6. Mitchell NS, Prochazka AV, Glasgow RE. Time to RE-AIM: why community weight loss programs should be included in academic obesity research. *Prev Chronic Dis*. 2016;13:E37. doi:10.5888/pcd13.150436.
7. Batsis JA, Huyck KL, Bartels SJ. Challenges with the Medicare obesity benefit: practical concerns & proposed solutions. *J Gen Intern Med*. 2015;30:118–122. doi:10.1007/s11606–014–3031–6.
8. Batsis JA, Villareal DT. Sarcopenic obesity in older adults: definition, etiology, epidemiology, treatment and future directions. *Nat Rev Endocrinol*. 2018 September;14(9):513–537. doi: 10.1038/s41574-018-0062-9. Review
9. Cruz-Jentoft AJ, Bahat G, Bauer J, et al. Sarcopenia: revised European consensus on definition and diagnosis. *Age Ageing*. 2018;48:16–31. doi:10.1093/ageing/ afy169.
10. Studenski SA, Peters KW, Alley DE, et al. The FNIH sarcopenia project: rationale, study description, conference recommendations, and final estimates. *J Gerontol A Biol Sci Med Sci*. 2014;69:547–558. doi:10.1093/gerona/glu010.

11. Heymsfield SB, Gonzalez MC, Shen W, Redman L, Thomas D. Weight loss composition is one-fourth fat-free mass: a critical review and critique of this widely cited rule. *Obes Rev*. 2014;15:310–321. doi:10.1111/obr.12143.

12. Villareal DT, Chode S, Parimi N, et al. Weight loss, exercise, or both and physical function in obese older adults. *N Engl J Med*. 2011;364:1218–1229. doi:10.1056/NEJMoa1008234.

13. Weiss EP, Jordan RC, Frese EM, Albert SG, Villareal DT. Effects of weight loss on lean mass, strength, bone, and aerobic capacity. *Med Sci Sports Exerc*. 2017;49:206–217. doi:10.1249/MSS.0000000000001074.

14. Batsis JA, Mackenzie TA, Bartels SJ, Sahakyan KR, Somers VK, Lopez-Jimenez F. Diagnostic accuracy of body mass index to identify obesity in older adults: NHANES 1999–2004. *Int J Obes*. 2016;40:761–767. doi:10.1038/ijo.2015.243.

15. Romero-Corral A, Somers VK, Sierra-Johnson J, et al. Accuracy of body mass index in diagnosing obesity in the adult general population. *Int J Obes*. 2008;32:959–966. doi:10.1038/ijo.2008.11.

16. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, et al. Sarcopenia: European consensus on definition and diagnosis: report of the European Working Group on Sarcopenia in Older People. *Age Ageing*. 2010;39:412–423. doi:10.1093/ageing/afq034.

17. Kyle UG, Bosaeus I, De Lorenzo AD, et al. Bioelectrical impedance analysis-part I: review of principles and methods. *Clin Nutr*. 2004;23:1226–1243. doi:10.1016/j.clnu.2004.06.004.

18. Kyle UG, Bosaeus I, De Lorenzo AD, et al. Bioelectrical impedance analysis-part II: utilization in clinical practice. *Clin Nutr*. 2004;23:1430–1453. doi:10.1016/j.clnu.2004.09.012.

19. Santilli V, Bernetti A, Mangone M, Paoloni M. Clinical definition of sarcopenia. *Clin Cases Miner Bone Metab*. 2014;11:177–180.

20. Batsis JA, Barre LK, Mackenzie TA, Pratt SI, Lopez-Jimenez F, Bartels SJ. Variation in the prevalence of sarcopenia and sarcopenic obesity in older adults associated with different research definitions: dual-energy X-ray absorptiometry data from the National Health and Nutrition Examination Survey 1999-2004. *J Am Geriatr Soc*. 2013;61:974–980. doi:10.1111/jgs.12260.

21. Batsis JA, Villareal DT. Sarcopenic obesity in older adults: aetiology, epidemiology and treatment strategies. *Nat Rev Endocrinol*. 2018;14:513–537. doi:10.1038/s41574-018-0062-9.

22. Garvey WT, Mechanick JI, Brett EM, et al. American association of clinical endocrinologists and American college of endocrinology comprehensive clinical practice guidelines for medical care of patients with obesity. *Endocr Pract*. 2016;22:1–203. doi:10.4158/EP161365.GL.

23. Bosy-Westphal A, Jensen B, Braun W, Pourhassan M, Gallagher D, Muller MJ. Quantification of whole-body and segmental skeletal muscle mass using phase-sensitive 8-electrode medical bioelectrical impedance devices. *Eur J Clin Nutr*. 2017;71:1061–1067. doi:10.1038/ejcn.2017.27.

24. Bosy-Westphal A, Schautz B, Later W, Kehayias JJ, Gallagher D, Muller MJ. What makes a BIA equation unique? Validity of eight-electrode multifrequency BIA to estimate body composition in a healthy adult population. *Eur J Clin Nutr*. 2013;67:S14–S21. doi:10.1038/ejcn.2012.160.

25. Batsis JA, Nieto-Martinez RE, Lopez-Jimenez F. Metabolic syndrome: from global epidemiology to individualized medicine. *Clin Pharmacol Ther*. 2007;82:509–524. doi:10.1038/sj.clpt.6100355.

26. Buatois S, Miljkovic D, Manckoundia P, et al. Five times sit to stand test is a predictor of recurrent falls in healthy community-living subjects aged 65 and older. *J Am Geriatr Soc*. 2008;56:1575–1577. doi:10.1111/j.1532-5415.2008.01777.x.

27. ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories. ATS statement: guidelines for the six-minute walk test. *Am J Respir Crit Care Med*. 2002;166:111–117. doi:10.1164/ajrccm.166.1.at1102.

28. DiClemente CC, Schlundt D, Gemmell L. Readiness and stages of change in addiction treatment. *Am J Addict*. 2004;13:103–119. doi:10.1080/10550490490435777.

29. Romain AJ, Bernard P, Hokayem M, Gernigon C, Avignon A. Measuring the processes of change from the transtheoretical model for physical activity and exercise in overweight and obese adults. *Am J Health Promot*. 2016;30:272–278. doi:10.1177/0890117116633829.

30. Ames GE, Heckman MG, Grothe KB, Clark MM. Eating self-efficacy: development of a short-form WEL. *Eat Behav*. 2012;13:375–378. doi:10.1016/j.eatbeh.2012.03.013.

31. Cella D, Riley W, Stone A, et al. The Patient-Reported Outcomes Measurement Information System (PROMIS) developed and tested its first wave of adult self-reported health outcome item banks: 2005-2008. *J Clin Epidemiol*. 2010;63:1179–1194. doi:10.1016/j.jclinepi.2010.04.011.

32. Batsis JA, Mackenzie TA, Emeny RT, Lopez-Jimenez F, Bartels SJ. Low lean mass with and without obesity, and mortality: results from the 1999-2004 national health and nutrition examination survey. *J Gerontol A Biol Sci Med Sci*. 2017;72:1445–1451. doi:10.1093/gerona/glx002.

33. Alley DE, Shardell MD, Peters KW, et al. Grip strength cutpoints for the identification of clinically relevant weakness. *J Gerontol A Biol Sci Med Sci*. 2014;69:559–566. doi:10.1093/gerona/glu011.

34. Cawthon PM, Peters KW, Shardell MD, et al. Cutpoints for low appendicular lean mass that identify older adults with clinically significant weakness. *J Gerontol A Biol Sci Med Sci*. 2014;69:567–575. doi:10.1093/gerona/glu023.

35. Dam TT, Peters KW, Fragala M, et al. An evidence-based comparison of operational criteria for the presence of sarcopenia. *J Gerontol A Biol Sci Med Sci*. 2014;69:584–590. doi:10.1093/gerona/glu013.

36. Batsis JA, Mackenzie TA, Lopez-Jimenez F, Bartels SJ. Sarcopenia, sarcopenic obesity, and functional impairments in older adults: National Health and Nutrition Examination Surveys 1999-2004. *Nutr Res*. 2015;35:1031–1039. doi:10.1016/j.nutres.2015.09.003.

37. Baumgartner RN, Wayne SJ, Waters DL, Janssen I, Gallagher D, Morley JE. Sarcopenic obesity predicts instrumental activities of daily living disability in the elderly. *Obes Res*. 2004;12:1995–2004. doi:10.1038/oby.2004.250.

38. Batsis JA, Zagaria AB. Addressing obesity in aging patients. *Med Clin North Am*. 2018;102:65–85. doi:10.1016/j.mcna.2017.08.007.

39. Batsis JA, Gill LE, Masutani RK, et al. Weight loss interventions in older adults with obesity: a systematic review of randomized controlled trials since 2005. *J Am Geriatr Soc*. 2017;65:257–268. doi:10.1111/jgs.14514.

40. Villareal DT, Aguirre L, Gurney AB, et al. Aerobic or resistance exercise, or both in dieting obese older adults. *N Engl J Med*. 2017;376:1943–1955. doi:10.1056/NEJMoa1616338.

41. Rizzoli R, Reginster JY, Arnal JF, et al. Quality of life in sarcopenia and frailty. *Calcif Tissue Int*. 2013;93:101–120. doi:10.1007/s00223-013-9758-y.

42. Iezzoni LI, Foley SM, Daley J, Hughes J, Fisher ES, Heeren T. Comorbidities, complications, and coding bias: does the number of diagnosis codes matter in predicting in-hospital mortality? *JAMA*. 1992;267:2197–2203.

43. Mears SC, Bawa M, Pietryak P, et al. Coding of diagnoses, comorbidities, and complications of total hip arthroplasty. *Clin Orthop Relat Res*. 2002;402:164–170. doi:10.1097/00003086-200209000-00014.

44. Bosaeus M, Karlsson T, Holmang A, Ellegard L. Accuracy of quantitative magnetic resonance and eight-electrode bioelectrical impedance analysis in normal weight and obese women. *Clin Nutr*. 2014;33:471–477. doi:10.1016/j.clnu.2013.06.017.

45. Wang ZH, Yang ZP, Wang XJ, Dong YH, Ma J. Comparative analysis of the multi-frequency bio-impedance and dual-energy X-ray absorptiometry on body composition in obese subjects. *Biomed Environ Sci*. 2018;31:72–75. doi:10.3967/bes2018.008.

46. Batsis JA, Mackenzie TA, Barre LK, Lopez-Jimenez F, Bartels SJ. Sarcopenia, sarcopenic obesity and mortality in older adults: results from the National Health and Nutrition Examination Survey III. *Eur J Clin Nutr*. 2014;68:1001–1007. doi:10.1038/ejcn.2014.117.

47. Hamer M, O'Donovan G. Sarcopenic obesity, weight loss, and mortality: the English Longitudinal Study of Ageing. *Am J Clin Nutr*. 2017;106:125–129. doi:10.3945/ajcn.117.152488.

48. Hirani V, Blyth F, Naganathan V, et al. Sarcopenia is associated with incident disability, institutionalization, and mortality in community-dwelling older men: the concord health and ageing in men project. *J Am Med Dir Assoc*. 2015;16:607–613. doi:10.1016/j.jamda.2015.02.006.

49. Tian S, Xu Y. Association of sarcopenic obesity with the risk of all-cause mortality: a meta-analysis of prospective cohort studies. *Geriatr Gerontol Int*. 2016;16:155–166. doi:10.1111/ggi.12579.

50. Garber CE, Blissmer B, Deschenes MR, et al. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. *Med Sci Sports Exerc*. 2011;43:1334–1359. doi:10.1249/MSS.0b013e318213fefb.

51. Villareal DT, Apovian CM, Kushner RF, et al. Obesity in older adults: technical review and position statement of the American Society for Nutrition and NAASO, The Obesity Society. *Am J Clin Nutr*. 2005;82:923–934.

52. Porter Starr KN, Pieper CF, Orenduff MC, et al. Improved function with enhanced protein intake per meal: a pilot study of weight reduction in frail, obese older adults. *J Gerontol A Biol Sci Med Sci*. 2016;71:1369–1375. doi:10.1093/gerona/glv210.

Appendix 1. Prevalence of sarcopenic obesity in a weight center.

	SARCOPENIA		*P* VALUE
	PRESENT	ABSENT	
Overall	285 (47.6)	314 (52.4)	
Sex			
Male	34 (26.4)	95 (73.6)	<.001
Female	251 (53.4)	219 (46.7)	
Race			
American Indian/Alaskan	1 (50)	1 (50)	.12
Black	2 (16.7)	10 (83.3)	
White	279 (48.0)	302 (52.0)	
Other	3 (75.0)	1 (25.0)	
Age category			<.001
18-40 years	45 (31.5)	98 (68.5)	
40-60 years	129 (48.1)	139 (51.9)	
60-70 years	78 (59.5)	53 (40.5)	
>70 years	33 (58.0)	24 (42.1)	

All values presented are counts (percent).

Appendix 2. Comparison of individuals without versus with patient-reported measures.

CHARACTERISTICS	WITHOUT MEASURES	WITH MEASURES	*P* VALUE
	N = 267	N = 332	
Age, year	51.4 ± 13.6	51.3 ± 14.5	.92
Female (%)	208 (77.9)	262 (78.9)	.76
Race (%)			
Black	6 (2.3)	6 (1.8)	
White	257 (96.3)	324 (97.6)	.08
Other	4 (1.5)	4 (0.6)	
Ethnicity (%)			
Hispanic/Latino	3 (1.1)	1 (0.3)	.37
Insurance (%)			
Medicare	47 (17.6)	86 (25.9)	
Medicaid/assistance	21 (7.9)	30 (9.0)	.03
Commercial	199 (74.5)	216 (65.1)	
Smoking (%)			
Current	16 (6.0)	22 (6.6)	
Former	79 (29.6)	100 (30.1)	.69
Never	170 (63.7)	204 (61.5)	
Comorbidities			
Anxiety	70 (26.8)	70 (21.2)	.11

(Continued)

Appendix 2. (Continued)

CHARACTERISTICS	WITHOUT MEASURES	WITH MEASURES	*P* VALUE
	N = 267	N = 332	
Chronic obstructive pulmonary disease	2 (0.8)	5 (1.5)	.40
Coronary artery disease	16 (6.1)	24 (7.3)	.58
Diabetes	44 (16.9)	58 (17.6)	.82
Depression	71 (27.2)	108 (32.7)	.15
High cholesterol	80 (30.7)	98 (29.7)	.79
Osteoarthritis	52 (19.9)	63 (19.1)	.81
Sleep apnea	91 (34.9)	119 (36.1)	.76
Cardiovascular disease	5 (1.9)	5 (1.5)	.71
Non-alcoholic fatty liver disease	10 (3.8)	23 (7.0)	.99
Body composition measures			
Weight	118.5 ± 26.1	120.9 ± 30.4	.31
Waist circumference	135.1 ± 91.1	130.1 ± 48.4	.39
High waist circumference	265 (99.3)	329 (99.1)	.84
Sarcopenia status (%)	127 (47.6)	158 (47.6)	.99
Body mass index, kg/m^2	42.7 ± 8.2	43.4 ± 9.5	.35
Appendicular lean mass, kg	16.6 ± 4.5	16.8 ± 4.8	.63
Fat mass, kg	58.1 ± 16.3	60.0 ± 19.0	.21
Body fat, %	48.7 ± 6.2	49.1 ± 5.9	.45
Visceral adipose tissue, cm	6.26 ± 3.97	6.76 ± 4.82	.78
Skeletal muscle mass	29.6 ± 7.8	29.7 ± 8.2	.80

Excluded individuals consisted of study subjects with at least one functional measure (grip strength, sit-to-stand, 6 minute walk, URICA, WEL-SF, PROMIS) missing in their data. All values presented are mean ± standard deviation, or counts (percent). A *P* value represents the differences between individuals with and without ALM-defined sarcopenia (<19.75 kg in men; <15.02 kg in women).

Abbreviations: ALM, appendicular lean mass; PROMIS, Patient Reported Outcome Measurement Information Systems; URICA, University of Rhode Island Change Assessment; WEL-SF, Weight Efficacy Short-Form.