HHS Public Access

Author manuscript

Calcif Tissue Int. Author manuscript; available in PMC 2024 June 23.

Published in final edited form as:

Calcif Tissue Int. 2024 January ; 114(1): 60–73. doi:10.1007/s00223-023-01138-4.

Impact of EASO/ESPEN-defined Sarcopenic Obesity following a Technology-Based Weight Loss Intervention

Brian S. Wood[a], **Dakota J. Batchek**[b], **David H. Lynch**[a], **Hillary B. Spangler**[a], **Danae C. Gross**[b], **Curtis L. Petersen**[a], **John A. Batsis**[a,b]

[a]Division of Geriatric Medicine, UNC School of Medicine, Chapel Hill, North Carolina, USA

[b]Department of Nutrition, Gillings School of Global Public Health, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina, USA

Abstract

Background: Sarcopenic Obesity is the co-existence of increased adipose tissue (obesity) and decreased muscle mass or strength (sarcopenia) and is associated with worse outcomes than obesity alone. The new EASO/ESPEN consensus provides a framework to standardize its definition. This study sought to evaluate whether there are preliminary differences observed in weight loss or physical function in older adults with and without sarcopenic obesity taking part in a multicomponent weight loss intervention using these new definitions.

Corresponding Author: John A. Batsis, MD, AGSF, john.batsis@gmail.com, Mailing address: 5017 Old Clinic Building, Chapel Hill, NC 27599, Fax: 919-962-9795.

AUTHORSHIP

Wood: Substantial contribution to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; Drafting the work or revising it critically for important intellectual content; Final approval of the version to be published; Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Batchek: Substantial contribution to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; Drafting the work or revising it critically for important intellectual content; Final approval of the version to be published; Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Lynch: Substantial contribution to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; Drafting the work or revising it critically for important intellectual content; Final approval of the version to be published; Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Spangler: Substantial contribution to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; Drafting the work or revising it critically for important intellectual content; Final approval of the version to be published; Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Gross: Substantial contribution to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; Drafting the work or revising it critically for important intellectual content; Final approval of the version to be published; Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Petersen: Substantial contribution to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; Drafting the work or revising it critically for important intellectual content; Final approval of the version to be published; Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Batsis: Substantial contribution to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; Drafting the work or revising it critically for important intellectual content; Final approval of the version to be published; Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Conflicts of Interests: There are no potential conflicts of interest to disclose.

Methods: A 6-month, non-randomized, non-blinded, single-arm pilot study was conducted from 2018–2020 in adults ≥65 years with a body mass index (BMI) ≥30 kg/m^2. Weekly dietitian visits and twice-weekly physical therapist-led exercise classes were delivered using telemedicine. We conducted a secondary retrospective analysis of the parent study (n=53 enrolled, n=44 completers) that investigated the feasibility of a technology-based weight management intervention in rural older adults with obesity. Herein, we applied five definitions of sarcopenic obesity (outlined in the consensus) to ascertain whether the response to the intervention differed among those with and without sarcopenic obesity. Primary outcomes evaluated included weight loss and physical function (30-second sit-to-stand).

Results: In the parent study, mean weight loss was −4.6 kg (95% CI: −3.6, −5.6; p< 0.001). Physical function measures of 30-s sit-to-stand showed a mean increase of 3.1 in sit-to-stand repetitions (+1.9, +4.3; p< 0.001). In this current analysis, there was a significant decrease in weight and an increase in repetitions between baseline and follow-up within each group of individuals with and without sarcopenia for each of the proposed definitions. However, we did not observe any significant differences in the changes between groups from baseline to follow-up.

Conclusions: The potential lack of significant differences in weight loss or physical function between older adults with and without sarcopenic obesity participating in a weight loss intervention may suggest that well-designed, multicomponent interventions can lead to similar outcomes irrespective of sarcopenia status in persons with obesity. Fully powered randomized clinical trials are critically needed to confirm these preliminary results.

Introduction

Ageing is associated with a variety of underlying changes at the biological level that drive the development of chronic diseases [1]. Adults over their lifespan typically gain adipose tissue due to the combined effects of underlying cellular changes, such as reduced mitochondrial volume and oxidative capacity, hormonal changes, and decreased energy expenditure [2]. This increased adiposity, compounded by genetic and environmental influences, can lead to the development of obesity as adults age [3]. Obesity rates in older adults aged ≥65 years exceed 40%, and are strongly associated with functional decline, mobility disability, nursing home placement, and death [4–7]. However, efforts that seek to address obesity purely by lowering body weight in this population are problematic. This is a result of sarcopenia, which is the physiologic, age-associated loss of muscle mass and strength and function, that is often accelerated by the development of chronic diseases. Thus, conventional weight loss interventions that purely focus on reducing caloric input may risk worsening sarcopenia, which itself is strongly associated with functional decline [8].

In recent years, the syndrome of sarcopenic obesity has been formally characterized as the co-existence of increased adipose tissue (obesity) and decreased muscle mass or strength (sarcopenia) [9]. Sarcopenic obesity has been postulated to synergistically lead to a wide variety of adverse outcomes, more so than obesity or sarcopenia alone [10]. People with sarcopenic obesity have an increased risk of cardiometabolic disorders, mobility disability, functional impairment, and mortality [11, 12]. However, efforts to study sarcopenic obesity and its treatment outcomes have historically been limited given the discrepancies in definitions used by both clinicians and researchers. Previous definitions

of sarcopenic obesity have included a range of characteristics using various measures of body imaging, muscle indexes, and body fat percentage. Additionally, definitions are heavily reliant on their different reference populations [13–15]. As such, the prevalence rate ranges considerably - one study noted up to an 18-fold difference depending on the definition used [16].

The absence of a consensus definition for sarcopenic obesity led to recent guidelines put forth by the European Association for the Study of Obesity (EASO) and the European Society for Clinical Nutrition and Metabolism (ESPEN) [17]. This consensus holds promise for characterizing the definitions of sarcopenic obesity by standardizing its nomenclature. As a result of the challenges in the definition, there has been a paucity of studies exploring the differences in treatment outcomes in this population. As was highlighted in the EASO/ESPEN guidelines, there is concern that the treatment of sarcopenic obesity may require nuanced and personalized approaches that differ from those with obesity alone without sarcopenia. Weight loss may risk the loss of muscle mass which can then lead to worsening of physical functioning in adults with sarcopenic obesity. As the interplay between fat and muscle impact both chronic inflammation and myokine signaling, identifying the response to conventional interventions can help us advance precision nutrition and exercise interventions to maximize their impact and improve physical function. Therefore, our goal in this study was to apply these new definitions in a retrospective analysis of older adults with obesity who participated in a multicomponent, technology-based, weight loss intervention [18]. To our knowledge, there are no studies that have assessed whether older adults with obesity and sarcopenia respond differently to diet and exercise interventions compared to those persons without sarcopenic obesity using this updated definition. Thus, as a secondary analysis of existing data, we aim to provide formative data as to whether the presence of sarcopenia in the context of obesity leads to differences in weight loss, physical function changes, or body composition changes.

Methods

Study Description

The full protocol for this technology-based, weight loss intervention has been previously described [18]. In brief, this was a six-month single-arm study conducted in rural New Hampshire and Vermont, United States, that delivered a nutritional and exercise intervention using video-conferencing to older adults with obesity. The study was conducted between October 2018 and May 2020. The study was approved by both the Dartmouth-Hitchcock and the University of North Carolina at Chapel Hill Institutional Review Boards. All participants provided informed consent. The study was registered on clinicaltrials.gov NCT#03104205.

Participants

Participants were all community-dwelling older adults (65 years of age or older) who spoke English and were selected via a physician referral from a primary care practice. Inclusion criteria consisted of a body mass index (BMI) greater than 30 kg/m^2, availability of high-speed internet at home, a Callahan cognitive screen [19] score of ≥3 and an Older Americans Resources and Services questionnaire [20] score of ≥6. Exclusion criteria were

previously described [18], but included end stage, congestive heart failure, dementia, renal insufficiency, and nursing home or hospital admission in the past six months prior to screening. There were 142 total screened participants, 27 of which were ineligible. Of the remaining n=115, there were 53 participants who consented and enrolled in the original trial (see Supplementary Figure 1).

Intervention Description

Participants engaged in a weekly virtual 1:1 session with a registered dietitian, as well as a monthly, in-person, group nutritional session as previously described [18]. Participants also participated in twice weekly virtual 75-minute sessions led by a physical therapist, as well as monthly in-person exercise sessions. The exercise sessions incorporated balance, flexibility, and resistance training. Participants were also encouraged to perform a single 75-minute exercise session on their own and an additional 150 minutes of moderate intensity aerobic walking per week. During the twice weekly virtual group visits, the physical therapist adjusted and personalized a participant's exercise program, and the registered dietitian personalize the nutrition program on an individual basis. All participants were provided a Fitbit Alta HR for remote monitoring of their aerobic step activity.

Measurements

The primary preliminary efficacy measures for this study were weight loss and changes in 30 second sit to stand (STS) repetitions. Weight loss was assessed with a A+D™ digital scale and was measured in kilograms in participants without shoes, jackets, or heavy clothing. The 30 second STS repetitions were measured by instructing participants to sit in a chair with a backrest with their arms folded. The number of times that participants were able to stand up and sit down in 30 seconds was recorded. Subjective measures determined the impact of the intervention on diet quality and physical function. Diet quality was measured using the total Rapid Eating and Activity Assessment for Patients short version (REAP-S), which has been validated previously with higher scores indicating improved diet quality [21]. A trained research assistant conducted two National Cancer Institute Automated Self-Administered-24 (ASA-24) dietary assessment tool evaluations (30-min each) at baseline and follow-up. The ASA-24 is an automatically coded, self-administered 24-hour dietary recall that assesses overall caloric intake. In this study, we averaged these two assessments to provide a measure of total caloric intake at each time point [22]. Measures of physical function were assessed using the 32-item function component of the Late-Life Function and Disability Instrument (LLFDI) [23].

Several additional measures of objective physical function were also assessed. As this intervention was conducted in part during the first part of the COVID-19 pandemic, of the participants that completed the intervention (n=44), we were unable to obtain full follow-up objective data in 11 participants. A 6-minute walk test (6MWT) was conducted by measuring the total distance walked in meters by participants over 6 minutes while in a 70-meter corridor using guidelines as outlined by the American Thoracic Society [24]. Gait speed (in meters/second) was measured over a 4-meter course in a hallway, with ramp-up and ramp-down phases. Three trials were performed and the maximum was used in the analysis. Grip strength was measured (in kilograms) in both hands using a Jamar handheld

dynamometer, three times each, alternating every 30 seconds, with the arm extended at 90° and laid on a flat surface. The maximum value attained for each measurement session was used.

Changes in body composition were assessed using the Seca 514 mBCA bioelectrical impedance analyzer (Hamburg, Germany). Studies have validated the SECA mBCA 514 as a tool to estimate body composition via fat free mass (in kilogram)[25], with additional studies demonstrating similarly accurate findings in normal weight and higher BMI individuals[26]. Furthermore, studies have validated equations that account for height, age, and sex that are used specifically to estimate skeletal muscle mass using bioelectrical impedance analysis (BIA)[27]. Body composition was assessed after a 12-hour overnight fast. Participants were asked to only take a sip of water to take their morning medications, but not consume any coffee, tea, or alcohol during this period of time. Patients were instructed to remove their outer jackets, shoes, and socks and step onto the analyzer which uses a flow of low alternating current using eight electrodes (four per hand). After placing their feet on the analyzer, the participants were instructed to grip the electrodes on each side of the analyzer as measurements were taken. Participants' self-reported physical activity level and waist circumference were inputted into the system as variables. Total skeletal muscle mass and total fat mass (both in kilograms) were assessed along with visceral adipose tissue (VAT) in liters.

Definition of Sarcopenic Obesity

The recent EASO/ESPEN joint consensus statement presented a proposed definition and diagnostic criteria for sarcopenic obesity that can be used in clinical practice and research. Sarcopenic obesity was defined as "the co-existence of obesity and sarcopenia" [9]. A diagnostic procedure was proposed that began with screening that was deemed indicative of possible sarcopenic obesity if an individual had a high BMI (in kg/m^2) or waist circumference (in centimeters) and surrogate parameters for sarcopenia such as clinical symptoms or a positive result on screening questionnaires. A diagnosis of sarcopenic obesity was confirmed if individuals met specific cutoffs for skeletal muscle function and body composition that included both increased fat and decreased muscle measurements. Both the initial paper [9] and follow-up manuscript [[29] provided tables to reflect different cut points and were consistent in their recommendations. Altered body composition was defined as increased fat mass percentage by Gallagher et al [30] Reduced muscle mass was defined using Batsis' definition of appendicular lean mass-adjusted by body weight measured using dual x-ray absorptiometry (DEXA) or using Janssen's definition which used total skeletal muscle mass adjusted by weight using bioelectrical impedance analysis (BIA). As BIA was used in our pilot study and not DEXA, Janssen's definition was used. [27] The guidelines also recommended the inclusion of skeletal muscle functional parameters of either chair stand, knee extensor, or handgrip strength. Yet, no specific recommendations were provided as to which to use. In this study, we conducted both the handgrip strength and 30-second chair stand test. Multiple cut points for handgrip were used. Those by Dodds et al. were recommended (Definition 2 in the present study)[31]. However, as the cut points from the Sarcopenia Definition Outcomes Consortium (Definition 1) [32] were also included in the consensus EASO/ESPEN guidelines, we included these as well. The remaining handgrip

strength cut points were based on older guidelines or for those in non-white populations, for which they would not be applicable to this cohort. The thresholds for 30-second chair stand proposed by Rikli were the only ones outlined and were utilized herein (Definition 3) [33]

Hence, using the available variables from this cohort, we considered five possible definitions of sarcopenic obesity using combinations of several different parameter cutoffs proposed in the EASO/ESPEN definitions (Table 1). Each of these definitions included physical function assessments based on grip strength or 30 second STS and body composition components consisting of percent body fat and sarcopenia scores as highlighted above. Two composite definitions of sarcopenic obesity status were also defined, both of which relied on body composition criteria highlighted above: Definition 4 also used one of the thresholds for sarcopenia from either the Sarcopenia Definition Outcomes Consortium handgrip criteria or Rikli's 30-second chair stand criteria; and Definition 5 used one of the thresholds for sarcopenia defined by using either Dodds' handgrip criteria or the Rikli's 30-second chair stand criteria.

Statistical Analysis

Baseline demographics were collected for all participants, including comorbidities and social characteristics. Continuous variables were expressed in mean ± standard deviation (SD) with changes represented using 95% confidence intervals. Categorical values were expressed as counts and percentages. Participants were categorized using each of the five sarcopenic obesity definitions as outlined above (Table 1). For this analysis, the primary study outcomes were to ascertain the observed changes in weight and physical function measured using 30-second STS. Secondary outcomes included changes in 6MWT, gait speed, LLFDI scores, REAP-S scores, energy intake using ASA-24, body fat, visceral adipose tissue, and skeletal muscle mass/weight. For each definition of sarcopenic obesity, outcomes were analyzed using a paired t-test within each category, and an unpaired t-test to test the differences of each outcome between baseline and follow-up between groups (sarcopenia vs. no sarcopenia). As a further exploratory analysis, subgroup analyses within each definition compared outcomes based on response status (loss >5% of body weight). We used a p-value of <0.05 as an indicator of statistical significance. STATA v.15 (College Station, TX) was used to analyze the data.

Results

The overall group consisted of 53 adults with a mean age of 72.9±3.9 (Table 2) years of which 69.8% were female (100% White). We compared baseline characteristics of the participants completing the intervention (n=44) to those who did not (n=9) in Table 2. Completers were more likely to have Medicare insurance (p=0.03) and a diagnosis of diabetes (p=0.05) than the non-completers. For our primary outcomes of the entire intervention cohort in our parent study, we saw a significant decrease in weight (Δ=−4.6 kg [95%CI: −3.6, −5.6]; p<0.001) and a significant improvement in 30-second STS repetitions (Δ=+3.1 repetitions [1.9, 4.3]; p<0.001). This was also observed in this current secondary analysis in individuals with and without sarcopenic obesity between baseline and follow-up.

However, we found no significant differences between groups in the change in variables between baseline and follow-up (Table 3 and Supplemental Table 1).

For our secondary outcomes, there was no difference in the pre/post measurements of gait speed for any group except using Definition 5 nor were there differences by sarcopenia status for any of the definitions. There were differences observed by sarcopenia status in the 6MWT that varied by definition. A significant post-intervention increase was observed in LLFDI score and REAP-S diet quality score for each definition irrespective of sarcopenia status. There were no significant differences in the change in LLFDI in the sarcopenic vs. non-sarcopenic group. There was however a significant difference in the change in REAP-S for those with sarcopenic obesity and those with non-sarcopenic obesity for some but not all definitions. There was no significant change in measured caloric intake using ASA-24 in either those with sarcopenic obesity or those with sarcopenic obesity.

While all participants had BIA performed at baseline for body composition, the unfolding of the COVID-19 pandemic during the study period precluded the collection of BIA for all participants at follow-up. In the subset of participants with pre- and post-intervention body composition measures (n=30), we observed significant decreases in fat mass % across all definitions with and without sarcopenia (Supplemental Table 1). There was a significant difference in pre/post values for skeletal muscle mass/weight for all definitions but not in the differences across groups by skeletal muscle mass/weight (Supplemental Table 1). There was a significant difference in VAT for some but not all sarcopenic obesity definitions and sarcopenic or non-sarcopenic obesity groups, but there was no difference in the differences across groups. Additional exploratory analyses compared the effect of the intervention by weight loss response status. Overall, we observed few differences in the changes by response status (loss of >5% of body weight) (Tables 4).

Discussion

Our secondary analysis of this pilot study may suggest that a technology-based weight loss intervention utilizing exercise and nutritional interventions for adults with obesity may provide similar benefits across weight loss, physical function, and functional status domains for both participants classified with and without sarcopenic obesity. Our preliminary results are based on the recent EASO/ESPEN consensus definitions for sarcopenic obesity. An additional major finding is that even in persons classified as having sarcopenic obesity, there were no adverse changes in skeletal muscle mass/weight. This has major implications on the content and design of future interventions.

The weight loss observed in our overall study cohort approaches the threshold for clinically significant weight loss of 5% for both those with and without sarcopenic obesity [34]. The corresponding improvement in 30 second STS is also clinically relevant across sarcopenic obesity status groups and has been previously associated with improved quality of life and physical function [35]. Together, these suggest that weight loss was achieved while simultaneously improving physical function.

Yet, traditional weight loss interventions focusing on caloric restriction have a strong potential of reducing muscle mass. Minimizing dietary intake can lead to a decrease in muscle protein synthesis and an increase in muscle proteolysis [36, 37]. Previous research in this population group has shown dietary restriction without concomitant resistance exercise can lead to loss of muscle mass and decreased handgrip strength [38]. Beyond muscle loss, caloric restriction has been linked to alterations in bone metabolism and possible decreases in bone mineral density, potentially putting patients at higher risk of fractures [39]. Interventions that combine exercise with caloric restriction may mitigate this risk [40, 41]. The benefits of resistance training for treating sarcopenic obesity have been well established, with several studies suggesting improved muscle mass and function in older adults [42–44]. Additionally, nutrition interventions that increase protein intake are associated with increased muscle mass and decreased total body fat in individuals with sarcopenic obesity [45, 46]. Our pilot findings of preserved skeletal muscle mass suggest our multi-component telemedicine intervention may have avoided the pitfall of worsening muscle loss and functional decline while losing weight risked by caloric restriction alone. These foundational results suggest that even when losing weight with this delivery modality, muscle preservation may be possible.

One important aspect to highlight is that participants with sarcopenic obesity were heavier than those without sarcopenia. While participants with sarcopenic obesity were heavier at baseline, they had no significant differences in skeletal muscle mass/weight. Using cutpoints that are not normalized for height can lead to challenges when using straight cutpoints to ascertain sarcopenia.

Notably, previous studies have used varied definitions of sarcopenic obesity, which makes intra-study comparison difficult. Our study serves as one of the first to utilize the recent EASO/ESPEN consensus definitions for sarcopenic obesity. Use of this definition holds promise for improving standardization of the term “sarcopenic obesity”. We used multiple definitions for sarcopenic obesity based on the consensus definition with most of our findings demonstrating similar results irrespective of the definition used. While we acknowledge this may increase the risk of type II error, gaining an understanding and trends on the variability of the impact on the definitions can be helpful to the consortium’s goal of streamlining definitions. Future studies may benefit from consolidating to a single one of these definitions to further limit additional variability between studies. Lastly, our sub-group analyses compared outcomes for responders and non-responders to losing weight.

We acknowledge that our study had a number of limitations that limit the ability to generalize and make solid causal inferences. First, the cohort lacked racial diversity with a strong female predominance preventing us from identifying racial- or sex-differences. Second, the small number of participants as part of this feasibility study suggested that our analyses may have lacked sufficient power to detect significant differences, particularly in the responder vs non-responder subgroups. Future, adequately powered trials are critically needed. Third, this feasibility study’s design lacked randomization, blinding, and did not have a control group. These can introduce bias into the interpretation of our results. Fourth, the long-term implications of the study are also limited given the fixed six-month duration of the study. It is unclear whether these persistent changes in weight loss or

function will be maintained. Fifth, our limited sample size prevents us from controlling for potential confounders. Sixth, we acknowledge that we were unable to determine all possible combinations proposed by EASO/ESPEN as a result of only having BIA data. However, this consortium is proposing additional, streamlined definitions in the coming years that may overcome this limitation. While we acknowledge these limitations, our analysis utilizes contemporary definitions and permits us to gain an early understanding of precision medicine – tailoring the right intervention to the right person. We recognize that certain individuals did not lose weight or improve function. Future work should focus on the heterogeneity of response in this patient population.

Conclusion:

We provide foundational evidence that this multicomponent weight loss intervention for older adults with obesity demonstrated similar weight loss and improvements in physical functioning with maintained muscle mass in individuals with and without sarcopenic obesity using the new EASO/ESPEN consensus definitions. Our findings suggest that multicomponent weight loss interventions may potentially confer benefit for older adults with obesity irrespective of sarcopenic obesity status.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Disclosures:

Dr. Batsis' research reported in this publication was supported in part by the National Institute on Aging under Award Number K23AG051681. Support was also provided by the Dartmouth Health Promotion and Disease Prevention Research Center supported by Cooperative Agreement Number U48DP005018 from the Centers for Disease Control and Prevention, the Dartmouth Clinical and Translational Science Institute, under award number UL1TR001086, and the NC Translational and Clinical Sciences (NC TraCS) Institute, which is supported by the National Center for Advancing Translational Sciences (NCATS), National Institutes of Health, through Grant Award Number UL1TR002489. Dr. Batsis also owns equity in SynchroHealth LLC.

Abbreviations

6MWT	6-minute walk test
BIA	Bioelectrical Impedance Analysis
BMI	Body mass index
DEXA	Dual x-ray absorptiometry (DEXA)
EASO	European Association for the Study of Obesity
ESPEN	European Society for Clinical Nutrition and Metabolism
LLFDI	Late-Life Function and Disability Instrument
REAP-S	Rapid Eating and Activity Assessment for Patients Short Version
SD	Standard deviation

STS	sit to stand
VAT	Visceral adipose tissue

References:

1. Guo J, Huang X, Dou L, et al. (2022) Aging and aging-related diseases: from molecular mechanisms to interventions and treatments. Signal Transduct Target Ther 7:391. 10.1038/s41392-022-01251-0 [PubMed: 36522308]
2. Batsis JA, Villareal DT (2018) Sarcopenic obesity in older adults: aetiology, epidemiology and treatment strategies. Nat Rev Endocrinol 14:513–537. 10.1038/s41574-018-0062-9 [PubMed: 30065268]
3. Zamboni M, Mazzali G (2012) Obesity in the elderly: an emerging health issue. Int J Obes 36:1151–1152. 10.1038/ijo.2012.120
4. Hales CM, Fryar CD, Carroll MD, et al. (2018) Trends in Obesity and Severe Obesity Prevalence in US Youth and Adults by Sex and Age, 2007–2008 to 2015–2016. JAMA 319:1723. 10.1001/jama.2018.3060 [PubMed: 29570750]
5. Jensen GL, Friedmann JM (2002) Obesity Is Associated with Functional Decline in Community-Dwelling Rural Older Persons. J Am Geriatr Soc 50:918–923. 10.1046/j.1532-5415.2002.50220.x [PubMed: 12028181]
6. Zizza CA, Herring A, Stevens J, Popkin BM (2002) Obesity Affects Nursing-Care Facility Admission among Whites but Not Blacks. Obes Res 10:816–823. 10.1038/oby.2002.110 [PubMed: 12181391]
7. Flegal KM, Kit BK, Orpana H, Graubard BI (2013) Association of All-Cause Mortality With Overweight and Obesity Using Standard Body Mass Index Categories: A Systematic Review and Meta-analysis. JAMA 309:71. 10.1001/jama.2012.113905 [PubMed: 23280227]
8. Visser M (2011) Obesity, sarcopenia and their functional consequences in old age. Proc Nutr Soc 70:114–118. 10.1017/S0029665110003939 [PubMed: 21092365]
9. Donini LM, Busetto L, Bischoff SC, et al. (2022) Definition and diagnostic criteria for sarcopenic obesity: ESPEN and EASO consensus statement. Clin Nutr 41:990–1000. 10.1016/j.clnu.2021.11.014 [PubMed: 35227529]
10. Wannamethee SG, Atkins JL (2015) Muscle loss and obesity: the health implications of sarcopenia and sarcopenic obesity. Proc Nutr Soc 74:405–412. 10.1017/S002966511500169X [PubMed: 25913270]
11. Batsis JA, Mackenzie TA, Lopez-Jimenez F, Bartels SJ (2015) Sarcopenia, sarcopenic obesity, and functional impairments in older adults: National Health and Nutrition Examination Surveys 1999–2004. Nutr Res 35:1031–1039. 10.1016/j.nutres.2015.09.003 [PubMed: 26472145]
12. Batsis JA, Mackenzie TA, Barre LK, et al. (2014) Sarcopenia, sarcopenic obesity and mortality in older adults: results from the National Health and Nutrition Examination Survey III. Eur J Clin Nutr 68:1001–1007. 10.1038/ejcn.2014.117 [PubMed: 24961545]
13. Khor EQ, Lim JP, Tay L, et al. (2019) OBESITY DEFINITIONS IN SARCOPENIC OBESITY: DIFFERENCES IN PREVALENCE, AGREEMENT AND ASSOCIATION WITH MUSCLE FUNCTION. J Frailty Aging 1–7. 10.14283/jfa.2019.28
14. Seo HS, Lee H, Kim S, et al. (2021) Paravertebral Muscles as Indexes of Sarcopenia and Sarcopenic Obesity: Comparison With Imaging and Muscle Function Indexes and Impact on Cardiovascular and Metabolic Disorders. Am J Roentgenol 216:1596–1606. 10.2214/AJR.20.22934 [PubMed: 33852329]
15. Bahat G, Kilic C, Topcu Y, et al. (2020) Fat percentage cutoff values to define obesity and prevalence of sarcopenic obesity in community-dwelling older adults in Turkey. Aging Male 23:477–482. 10.1080/13685538.2018.1530208 [PubMed: 30422757]
16. Batsis JA, Barre LK, Mackenzie TA, et al. (2013) 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 N ational H ealth and N utrition E xamination S urvey 1999–2004. J Am Geriatr Soc 61:974–980. 10.1111/jgs.12260 [PubMed: 23647372]

17. Donini LM, Busetto L, Bischoff SC, et al. (2022) Definition and Diagnostic Criteria for Sarcopenic Obesity: ESPEN and EASO Consensus Statement. Obes Facts 15:321–335. 10.1159/000521241 [PubMed: 35196654]
18. Batsis JA, Petersen CL, Clark MM, et al. (2021) Feasibility and acceptability of a technology-based, rural weight management intervention in older adults with obesity. BMC Geriatr 21:44. 10.1186/s12877-020-01978-x [PubMed: 33435877]
19. Callahan CM, Unverzagt FW, Hui SL, et al. (2002) Six-Item Screener to Identify Cognitive Impairment Among Potential Subjects for Clinical Research: Med Care 40:771–781. 10.1097/00005650-200209000-00007 [PubMed: 12218768]
20. Doble SE, Fisher AG (1998) The dimensionality and validity of the Older Americans Resources and Services (OARS) Activities of Daily Living (ADL) Scale. J Outcome Meas 2:4–24 [PubMed: 9661728]
21. Segal-Isaacson CJ, Wylie-Rosett J, Gans KM (2004) Validation of a Short Dietary Assessment Questionnaire: The Rapid Eating and Activity Assessment for Participants Short Version (REAP-S). Diabetes Educ 30:774–781. 10.1177/014572170403000512 [PubMed: 15510530]
22. Subar AF, Kirkpatrick SI, Mittl B, et al. (2012) The Automated Self-Administered 24-Hour Dietary Recall (ASA24): A Resource for Researchers, Clinicians, and Educators from the National Cancer Institute. J Acad Nutr Diet 112:1134–1137. 10.1016/j.jand.2012.04.016 [PubMed: 22704899]
23. Sayers SP, Jette AM, Haley SM, et al. (2004) Validation of the Late-Life Function and Disability Instrument: Validation of LLFDI. J Am Geriatr Soc 52:1554–1559. 10.1111/j.1532-5415.2004.52422.x [PubMed: 15341561]
24. (2002) ATS Statement: Guidelines for the Six-Minute Walk Test. Am J Respir Crit Care Med 166:111–117. 10.1164/ajrccm.166.1.at1102 [PubMed: 12091180]
25. Bosy-Westphal A, Schautz B, Later W, et al. (2013) 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 67:S14–S21. 10.1038/ejcn.2012.160 [PubMed: 23299866]
26. Lahav Y, Goldstein N, Gepner Y (2021) Comparison of body composition assessment across body mass index categories by two multifrequency bioelectrical impedance analysis devices and dual-energy X-ray absorptiometry in clinical settings. Eur J Clin Nutr 75:1275–1282. 10.1038/s41430-020-00839-5 [PubMed: 33483630]
27. Janssen I, Heymsfield SB, Baumgartner RN, Ross R (2000) Estimation of skeletal muscle mass by bioelectrical impedance analysis. J Appl Physiol Bethesda Md 1985 89:465–471. 10.1152/jappl.2000.89.2.465
28. Bhasin S, Travison TG, Manini TM, et al. (2020) Sarcopenia Definition: The Position Statements of the Sarcopenia Definition and Outcomes Consortium. J Am Geriatr Soc 68:1410–1418. 10.1111/jgs.16372 [PubMed: 32150289]
29. Gortan Cappellari G, Guillet C, Poggiogalle E, et al. (2023) Sarcopenic obesity research perspectives outlined by the sarcopenic obesity global leadership initiative (SOGLI) - Proceedings from the SOGLI consortium meeting in rome November 2022. Clin Nutr Edinb Scotl 42:687–699. 10.1016/j.clnu.2023.02.018
30. Gallagher D, Heymsfield SB, Heo M, et al. (2000) Healthy percentage body fat ranges: an approach for developing guidelines based on body mass index. Am J Clin Nutr 72:694–701. 10.1093/ajcn/72.3.694 [PubMed: 10966886]
31. Dodds RM, Syddall HE, Cooper R, et al. (2014) Grip strength across the life course: normative data from twelve British studies. PloS One 9:e113637. 10.1371/journal.pone.0113637 [PubMed: 25474696]
32. Patel SM, Duchowny KA, Kiel DP, et al. (2020) Sarcopenia Definition & Outcomes Consortium Defined Low Grip Strength in Two Cross-Sectional, Population-Based Cohorts. J Am Geriatr Soc 68:1438–1444. 10.1111/jgs.16419 [PubMed: 32633830]
33. Rikli RE, Jones CJ (2013) Development and validation of criterion-referenced clinically relevant fitness standards for maintaining physical independence in later years. The Gerontologist 53:255–267. 10.1093/geront/gns071 [PubMed: 22613940]
34. Jensen MD, Ryan DH, Apovian CM, et al. (2014) 2013 AHA/ACC/TOS Guideline for the Management of Overweight and Obesity in Adults: A Report of the American College of

Cardiology/American Heart Association Task Force on Practice Guidelines and The Obesity Society. Circulation 129:. 10.1161/01.cir.0000437739.71477.ee

35. Wright AA, Cook CE, Baxter GD, et al. (2011) A Comparison of 3 Methodological Approaches to Defining Major Clinically Important Improvement of 4 Performance Measures in Patients With Hip Osteoarthritis. J Orthop Sports Phys Ther 41:319–327. 10.2519/jospt.2011.3515 [PubMed: 21335930]
36. Areta JL, Burke LM, Camera DM, et al. (2014) Reduced resting skeletal muscle protein synthesis is rescued by resistance exercise and protein ingestion following short-term energy deficit. Am J Physiol Endocrinol Metab 306:E989–997. 10.1152/ajpendo.00590.2013 [PubMed: 24595305]
37. Pasiakos SM, Cao JJ, Margolis LM, et al. (2013) Effects of high-protein diets on fat-free mass and muscle protein synthesis following weight loss: a randomized controlled trial. FASEB J Off Publ Fed Am Soc Exp Biol 27:3837–3847. 10.1096/fj.13-230227
38. Zibellini J, Seimon RV, Lee CMY, et al. (2016) Effect of diet-induced weight loss on muscle strength in adults with overweight or obesity - a systematic review and meta-analysis of clinical trials. Obes Rev Off J Int Assoc Study Obes 17:647–663. 10.1111/obr.12422
39. Soltani S, Hunter GR, Kazemi A, Shab-Bidar S (2016) The effects of weight loss approaches on bone mineral density in adults: a systematic review and meta-analysis of randomized controlled trials. Osteoporos Int J Establ Result Coop Eur Found Osteoporos Natl Osteoporos Found USA 27:2655–2671. 10.1007/s00198-016-3617-4
40. Weinheimer EM, Sands LP, Campbell WW (2010) A systematic review of the separate and combined effects of energy restriction and exercise on fat-free mass in middle-aged and older adults: implications for sarcopenic obesity: Nutrition Reviews©, Vol. 68, No. 7. Nutr Rev 68:375–388. 10.1111/j.1753-4887.2010.00298.x [PubMed: 20591106]
41. Shah K, Armamento-Villareal R, Parimi N, et al. (2011) Exercise training in obese older adults prevents increase in bone turnover and attenuates decrease in hip bone mineral density induced by weight loss despite decline in bone-active hormones. J Bone Miner Res Off J Am Soc Bone Miner Res 26:2851–2859. 10.1002/jbmr.475
42. Gadelha AB, Paiva FML, Gauche R, et al. (2016) Effects of resistance training on sarcopenic obesity index in older women: A randomized controlled trial. Arch Gerontol Geriatr 65:168–173. 10.1016/j.archger.2016.03.017 [PubMed: 27057600]
43. Liao C-D, Tsauo J-Y, Huang S-W, et al. (2018) Effects of elastic band exercise on lean mass and physical capacity in older women with sarcopenic obesity: A randomized controlled trial. Sci Rep 8:2317. 10.1038/s41598-018-20677-7 [PubMed: 29396436]
44. Chen H-T, Chung Y-C, Chen Y-J, et al. (2017) Effects of Different Types of Exercise on Body Composition, Muscle Strength, and IGF-1 in the Elderly with Sarcopenic Obesity. J Am Geriatr Soc 65:827–832. 10.1111/jgs.14722 [PubMed: 28205203]
45. Nabuco HCG, Tomeleri CM, Fernandes RR, et al. (2019) Effect of whey protein supplementation combined with resistance training on body composition, muscular strength, functional capacity, and plasma-metabolism biomarkers in older women with sarcopenic obesity: A randomized, double-blind, placebo-controlled trial. Clin Nutr ESPEN 32:88–95. 10.1016/j.clnesp.2019.04.007 [PubMed: 31221297]
46. Kemmler W, Grimm A, Bebenek M, et al. (2018) Effects of Combined Whole-Body Electromyostimulation and Protein Supplementation on Local and Overall Muscle/Fat Distribution in Older Men with Sarcopenic Obesity: The Randomized Controlled Franconia Sarcopenic Obesity (FranSO) Study. Calcif Tissue Int 103:266–277. 10.1007/s00223-018-0424-2 [PubMed: 29675640]

Table 1:

EASO/ESPEN Diagnostic Criteria for Sarcopenic Obesity[9]

	Males			Females		
Definition #	**Body Fat [29]**	**Sarcopenia [26]**	**Function**	**Body Fat [29]**	**Sarcopenia [26]**	**Function**
1	Body fat ≥ 31%	Skeletal muscle mass (skeletal muscle mass ÷ weight) % ≤ 37%	Grip Strength ≤35.5kg [31]	Body fat ≥ 43%	Skeletal muscle mass % ≤ 27.6%	Grip Strength ≤ 20kg [31]
2			Grip strength ≤ 27 kg [30]			Grip strength ≤ 16 kg [30]
3			Sit-to-Stand - 65–69 y: ≤ 16; 70–74 y: ≤ 15; 75–79 y ≤ 14; 80–84 y: ≤ 13; 85–89 y: ≤ 11 [32]			Sit-to-Stand - 65–69 y: ≤ 15; 70–74 y: ≤ 14; 75–79 y ≤ 13; 80–84 y: ≤ 12; 85–89 y: ≤ 11 [32]
4			Grip Strength ≤ 35.5kg [31] OR Sit-to-Stand - 65–69 y: ≤ 16; 70–74 y: ≤ 15; 75–79 y ≤ 14; 80–84 y: ≤ 13; 85–89 y: ≤ 11 [32]			Grip Strength ≤ 20 kg [31] OR Sit-to-Stand - 65–69 y: ≤ 15; 70–74 y: ≤ 14; 75–79 y ≤ 13; 80–84 y: ≤ 12; 85–89 y: ≤ 11 [32]
5			Grip Strength ≤ 27 kg [30] OR Sit-to-Stand - 65–69 y: ≤ 16; 70–74 y: ≤ 15; 75–79 y ≤ 14; 80–84 y: ≤ 13; 85–89 y: ≤ 11 [32]			Grip Strength ≤ 16 kg [30] OR Sit-to-Stand - 65–69 y: ≤ 15; 70–74 y: ≤ 14; 75–79 y ≤ 13; 80–84 y: ≤ 12; 85–89 y: ≤ 11 [32]

TABLE 2:

Baseline Characteristics[18]

	Overall	Completers	Non-Completers	P-value
	N=53	N=44	N=9	
Age, years	72.9 ± 3.9	73.2 ± 3.9	71.4 ± 3.8	0.20
Female Sex	37 (69.8)	32 (72.7)	5 (55.6)	0.30
Education				0.17
High school	7 (13.2)	7 (15.9)	0	
Some College	15 (28.3)	14 (31.8)	1 (11.1)	
College Degree	15 (28.3)	12 (27.3)	3 (33.3)	
Post-College Degree	16 (30.2)	11 (25.0)	5 (55.6)	
Income				0.45
Less than $25,000	10 (18.9)	9 (20.5)	1 (11.1)	
$25,000 to $49,999	10 (18.9)	7 (15.9)	3 (33.3)	
$50,000 to $74,999	11 (20.8)	11 (25.0)	0	
$75,000 to $99,999	13 (24.5)	10 (22.7)	3 (33.3)	
$100,000 or more	9 (17.0)	7 (15.9)	2 (22.2)	
Insurance				
Medicaid	1 (1.9)	0	1 (11.1)	0.15
Medicare	48 (90.6)	41 (93.2)	7 (77.8)	0.03
Private	32 (60.4)	25 (56.8)	7 (77.8)	0.24
Smoking Status				
Current	1 (1.92)	1 (2.3)	0	0.78
Former	21 (40.4)	17 (38.6)	4 (50.0)	
Never	30 (57.7)	26 (59.1)	4 (50.0)	
Marital Status				
Married	35 (66.0)	28 (63.6)	7 (77.8)	0.53
Widow	5 (9.4)	5 (11.4)	0	
Single	13 (24.5)	11 (25.0)	2 (22.2)	
Co-Morbidities				
Anxiety	5 (9.4)	4 (9.0)	1 (11.1)	0.85
COPD	4 (7.5)	3 (6.8)	1 (11.1)	0.66
Depression	12 (22.6)	12 (27.3)	0	0.08
Diabetes	14 (26.4)	14 (31.8)	0	0.05
Fibromyalgia	2 (3.8)	2 (4.6)	0	0.51
High Cholesterol	19 (39.9)	15 (34.1)	4 (44.4)	0.56
Hypertension	38 (71.7)	31 (70.5)	7 (77.8)	0.66
Osteoarthritis	19 (35.9)	16 (36.4)	3 (33.3)	0.86
Sleep Apnea	21 (39.6)	18 (40.9)	3 (33.3)	0.67
Stroke	2 (3.8)	1 (2.3)	1 (11.1)	0.21

All values represent as mean ± standard deviation or counts (%). Completers are defined as participants who completed the six-month intervention. P-values compare baseline characteristics between those completing the intervention vs. non-completers.

COPD: Chronic Obstructive Pulmonary Disease. Adapted from: Batsis JA, Petersen CL, Clark MM, et al. Feasibility and acceptability of a technology-based, rural weight management intervention in older adults with obesity. *BMC Geriatr*. 2021;21(1):44. doi:10.1186/s12877–020-01978-x

Table 3:

Pre/Post Differences in Outcomes by Sarcopenia Status*

	Definition 1			Definition 2			Definition 3		
	Sarcopenia	**Non-Sarcopenia**	**Difference**	**Sarcopenia**	**Non-Sarcopenia**	**Difference**	**Sarcopenia**	**Non-Sarcopenia**	**Difference**
	n=18	**n=26**		**n=6**	**n=38**		**n=20**	**n=24**	
Weight kg	−4.39 [−7.04, −2.53]; p<0.001	−4.54 [−5.58,−3.50]; p<0.001	−0.24 [−2.41, 1.92]; p=0.82	−5.73 [−8.30,−3.16]; p=0.002	−4.47 [−5.65, −3.29];p<0.001	−1.26 [−4.43, 1.82]; =0.41	−4.39 [−2.63,−6.15]; p<0.001	−4.93 [−3.80,−6.08], p<0.001	+0.54 [−1.59, 2.68]; =0.61
30s STS, reps	+2.67 [0.61, 4.73]; p=0.01	+3.48 [1.70–5.26]; p<0.001	−0.81 [−3.46,1.83] p=0.54	+3.50 [−0.28, 7.28]; p=0.13	+3.08 [1.69, 4.48; p<0.001	+0.42 [−3.36,4.20]; p=0.82	+3.60 [2.05, 5.17]; p<0.001	+2.60 [0.34, 4.86], p=0.03	+1.01 [−1.60, 3.62]; =0.44
Gait Speed m/s	+0.009 [−0.044,−0.062]; p=0.73	−0.07 [−0.15, 0.01]; p=0.09	−0.076 [−0.174, +0.021]; p=0.12	+−0.06 [−0.04, 0.16]; [=0.16	+0.05 [−0.10, 0.01]; p=0.16	−0.10 [−0.25,0.04]; p=0.16	−0.011 [−0.09, +0.06];p=0.75	−0.06 [−0.13, +0.011]; p=0.09	−0.049 [−0.15, 0.05]; p=0.32
6MWT, m	+36.5 [−6.5, +79.5];p=0.09	+46.1 [−3.2, +89.1; p=0.04	−9.63 [−68.9, 49.6]; p=0.74	+50.0 [−83.6, +183.6]; p=0.32	+40.7 [+9.27, +72.2]; p=0.01	+9.26 [−77.2, 95.7]; p=0.83	+46.1 [−2.6, 94.8]; 0.07	+37.9 [+0.30, +75.4]; p=0.049	+8.29 [−50.4, 67.0]; p=0.78
LLFDI	+6.8 [1.3, 12.4]; p=0.02]	+6.3 [2.3, 10.2]; p=0.003	+0.62 [−5.78, 7.02]; p=0.85	+9.7 [3.7, 15.6]; p=0.01	+6.0 [2.5, 9.6]; p=0.001	+3.64 [−5.47, +12.6]; p=0.43	+8.2 [3.1, 13.2]; p=0.003	+4.6 [1.0, 8.1]; p=0.02	+3.62 [−2.6, 9.8]; p=0.25
REAP-S	+6.3 [4.3, 8.3]; p<0.001	+3.4 [1.8, 5.0]; p<0.001	+2.9 [0.5,5.3]; p=0.02	+7.3 [2.7, 12.0]; p= 0.01	+4.2 [2.9, 5.5]; p<0.001	3.1 [−0.45,6.7]; p=0.08	+5.5 [3.7, 7.2]; p<0.001]	+3.6 [1.7, 5.5]; p=0.001	+1.9 [−0.64, +4.36]; p=0.14
ASA-24	−257.7 [−588.9, +73.5]; p=0.12	−37.8 [−251.9, +176.3]; p=0.72	−219.9 [−584.7, 144.8]; p=0.23	−189.6 [−570.4, 191.3]; p=0.26	120.2 [−326.7, 86.4]; p=0.25	−0.69.4 [−597.6, +458.7]; p=0.26	−184.8 [−474.8, +103.2];p=0.20	−66.7 [−296.8, +163.5]; p=0.55	−118.2 [−483.5, +247.1]; p=0.52
Fat Mass %	−2.5 [−1.0, −4.0]; p=0.003	−1.4 [−0.1, −2.7]; p=0.04	−1.14 [−3.04, +0.76]; p=0.23	−3.3 [−0.6, −1.7]; p=0.03	−1.7 [−0.6, −2.7]; p=0.003	−1.58 [−4.36, +1.19]; p=0.25	−1.7 [−0.5, −3.0]; p=0.01	−2.1 [−0.4, −3.7]; p=0.02	+0.36 [−1.57, 2.29]; p=0.70
SMM/ weight	0.017 [0.003, 0.03]; p=0.02	0.011 [0.003, 0.02]; p=0.005	0.006 [−0.007, 0.019]; p=0.32	0.020 [0.01, 0.03]; p=0.01	0.012 [0.005, 0.02]; p=0.002	+0.0072 [−0.012, 0.026]; p=0.45	0.011 [0.0002, 0.02]; p=0.054	0.016 [0.01, 0.02]; p<0.001	−0.006 [−0.09, 0.0074]; p=0.39
VAT, L	−1.0 [−2.2, 0.1]; p=0.08]	−0.6 [−1.19, −0.1]; p=0.03	−0.38 [−1.49, +0.72]; p=0.48	−0.5 [−1.5, 0.5]; p=0.16	−0.8 [−1.4, −0.2]; p=0.01	+0.32 [−1.43, +2.06]; p=0.71	−1.0 [−1.9, 0.02]; p=0.055	−0.6 [−1.3, 0.02]; p=0.055	−0.33 [−1.42, +0.76]; p=0.54

	Definition 4			Definition 5		
	Sarcopenia	**Non-Sarcopenia**	**Difference**	**Sarcopenia**	**Non-Sarcopenia**	**Difference**
	n=29	**n=15**		**n=26**	**n=18**	
Weight kg	−4.68 [−3.18, −6.19]; p<0.001	−4.55 [3.26-,5.85]; p<0.001	−0.12 [−2.37, 2.13]; p=0.91	−4.51 [−2.86, −6.17]; p<0.001	−4.83 [−3.64, −6.01]; p<0.001	+0.31 [−1.85,+2.48]; p=0.77
30s STS, reps	+3.14 [1.64, 4.65]; p<0.001	+3.13 [0.41, 5.85]; p=0.03	+0.01 [−2.74, 2.76]; p=0.99	+3.56 [2.05, 5.07]; p<0.001	+2.56 [0.11, 5.00]; p=0.04	+1.00 [−1.63, 3.64]; p=0.45
Gait Speed m/s	−0.008 [–0.067, +0.051]; p=0.78	−0.085 [−0.18, +0.011]; p=0.08	−0.077 [−0.18, 0.026]; p=0.14	−0.006 [−0.073, +0.06], p=0.84	−0.08 [−0.16, +0.005]; p=0.06	−0.069 [−0.169, 0.031]; p=0.17
6MWT, m	+46.7 [+8.6, +84.9]; p=0.02	+33.7 [−17.9, +85.3]; p=0.18	+13.0 [−47.8, 73.8]; p=0.67	+48.7 [6.0, 91.4]; p=0.03	+33.2 [−9.9, +76.2]; p =0.12	+15.5 [−43.5, 74.6]; p=0.59
LLFDI	+7.69 [3.28, 12.1]; p=0.001	+4.27 [0.59, 7.95]; p=0.03	+3.42 [−3.14, 9.99]; p=0.30	+8.0 [3.3, 12.6]; p=0.002	+4.4 [0.5, 8.4]; p=0.03	+3.562 [−2.80, 9.83]; p=0.27
REAP-S	+5.62 [4.03, 7.21]; p<0.001]	+2.67 [0.74, 4.59]; p=0.01	+2.95 [0.42,5.49]; p=0.02	+5.3 [3.6, 7.0]; p<0.001	+3.6 [1.6, 5.6]; p=0.001	+1.70 [−0.85,+4.24]; p=0.19
ASA-24	−178.8 [−426.5, +68.8]; p=0.15	−38.5 [−307.2, +230.3]; p=0.76	−140.4 [−522.1, 241.4]; p=0.46	−151.5 [−420.2 117.1]; p=0.26	−99.8 [−350.0, 150.5]; p=0.41	−51.8 [−422.7, +319.1]; p=0.79
Fat Mass %	−1.99 [−0.86,−3.11];p=0.002	−0.92 [−3.74,+0.42];p=0.10	−0.33 [−2.37,1.72] p=0.75	−2.00 [0.81,−3.19];p=0.003	−1.69 [−3.50,+0.11];p=0.06	−0.31 [−2.28,+1.66]; p=0.75
SMM/ weight	0.0127 [0.003, 0.02]; p=0.01	0.0146 [0.01, 0.02]; p=0.002	−0.0019 [−0.016, 0.012] p=0.78	0.012 [0.002, 0.02]; p=0.02	0.015 [0.01, 0.02]; p=0.002	−0.0031 [−0.016, +0.010]; p=0.64
VAT, L	−0.94 [−1.60, −0.28]; p=0.01	−0.51 [−1.28, 0.28]; p=0.23	−0.43 [−1.55, +0.69]; p=0.44	−0.92 [−0.09, −1.75]; p=0.03	−0.61 [0.15, −1.37]; p=0.11	−0.31 [−1.41, 0.79]; p=0.56

* Tables reflect values on participants who completed the intervention (n=44)

Values represented as mean and 95% Confidence Interval. Overall difference represents values between participants with and without sarcopenia between baseline and follow-up. Abbreviations: 30STS: 30 second sit to stand test; 6MWT: 6-minute walk test; Kg: Kilogram; LLFDI: Late-Life Function and Disability Instrument; m: Meter; Non-SO: Non-Sarcopenic obesity; REAP-S: Rapid Eating and Activity Assessment for Patients short version; SMM – skeletal muscle mass, kg; VAT: Visceral Adipose Tissue

Sarcopenic obesity is defined as fulfilling the criteria as follows:

Definition #1: body fat %: males ≥31%, females ≥43%; Skeletal muscle mass %: males ≤37.6%, females ≤27.6%; grip strength: males ≤ 35.5kg, females ≤ 20 kg.

Definition #2: body fat %: males ≥31%, females ≥43%; Skeletal muscle mass %: males ≤37.6%, females ≤27.6%; grip strength: males ≤ 27 kg, females ≤ 16 kg

Definition #3: body fat %: males ≥31%, females ≥43%; Skeletal muscle mass %: males ≤37.6%, females ≤27.6%; Sit-to-stand: 65–69 y: ≤ 16; 70–74 y: ≤ 15; 75–79 y ≤ 14; 80–84 y: ≤ 13; 85–89 y: ≤ 11 repetitions; females: Sit-to-Stand - 65–69 y: ≤ 15; 70–74 y: ≤ 14; 75–79 y ≤ 13; 80–84 y: ≤ 12; 85–89 y: ≤ 11 repetitions.

Definition #4: body fat %: males ≥31%, females ≥43%; Skeletal muscle mass %: males ≤37.6%, females ≤27.6%; grip strength: males ≤ 35.5kg, females ≤ 20 kg. OR Sit-to-stand: 65–69 y: ≤ 16; 70–74 y: ≤ 15; 75–79 y ≤ 14; 80–84 y: ≤ 13; 85–89 y: ≤ 11 repetitions; females: Sit-to-Stand - 65–69 y: ≤ 15; 70–74 y: ≤ 14; 75–79 y ≤ 13; 80–84 y: ≤ 12; 85–89 y: ≤ 11 repetitions

Definition #5 Definition #1: body fat %: males ≥31%, females ≥43%; Skeletal muscle mass %: males ≤37.6%, females ≤27.6%; grip strength: males ≤ 35.5kg, females ≤ 20 kg OR Sit-to-stand: 65–69 y: ≤ 16; 70–74 y: ≤ 15; 75–79 y ≤ 14; 80–84 y: ≤ 13; 85–89 y: ≤ 11 repetitions; females: Sit-to-Stand - 65–69 y: ≤ 15; 70–74 y: ≤ 14; 75–79 y ≤ 13; 80–84 y: ≤ 12; 85–89 y: ≤ 11 repetitions

Table 4:

Changes in Key Outcomes between Weight Loss Responders and Non-Responders

	Definition 1						Definition 2					
	Responder			Non-Responder			Responder			Non-Responder		
	Sarcopenia	No Sarc	p	Sarcopenia	No Sarc	p	Sarcopenia	No Sarc	p	Sarcopenia	No Sarc	p
	N=13	N=9		N=9	N=13		N=4	N=18		N=2	N=20	
Weight kg	−8.42±2.87	−6.43±1.90	0.06	−1.15±2.36	−2.66±1.61	0.09	−7.10±1.57	−7.27±2.69	0.90	−2.99±0.38	−1.94±2.12	0.50
30s STS, reps	4.56±4.39	3.23±5.18	0.53	0.78±3.03	3.75±3.31	0.048	5.75±4.11	3.33±4.95	0.38	−1±0	2.84±3.44	0.14
Gait Speed m/s	0.03±0.16	0.03±0.16	0.93	0.01±<0.01	0.04±0.13	0.78	−0.08±0.06	0.5±0.16	0.71	0.01±0	0.04±0.13	0.72
6MWT, m	70.3±73.8	66.6±84.2	0.93	−3.0±46.1	28.0±83.6	0.43	52.8±102.6	72.2±74.1	0.71	41.5±0	13.8±73.0	0.72
LLFDI	10.6±9.06	6.15±7.81	0.24	3.22±12.38	6.38±11.7	0.55	11±6.78	7.28±8.78	0.44	7±1.41	4.9±12.4	0.82
REAP-S	7.67±4.97	3.15±4.18	0.03	5.00±2.29	3.69±3.75	0.36	6.75±5.56	4.61±4.90	0.45	8.5±0.71	3.8±3.07	0.047
Fat Mass %	−3.22±2.75	−1.85±2.12	0.31	−1.93±2.29	−0.97±2.91	0.48	−2.53±1.00	−2.41±2.71	0.94	−5.4±0	−1.12±2.47	0.12
SMM/weight	0.10±1.09	−0.18±0.36	0.49	0.76±1.41	−0.04±0.49	0.13	0.70±1.28	−0.27±0.40	**0.04**	0.16±0	0.33±1.08	0.88
VAT, L	−2.00±1.79	−1.10±0.54	0.20	−0.18±1.26	−0.15±1.29	0.96	−0.3±0.282	−1.65±1.19	0.15	−0.9±0	−0.11±1.26	0.56
	Definition 3						Definition 4					
	Responder			Non-Responder			Responder			Non-Responder		
	Sarcopenia	No Sarc	p	Sarcopenia	No Sarc	p	Sarcopenia	No Sarc	p	Sarcopenia	No Sarc	p
	N=12	N=10		N=12	N=10		N=15	N=7		N=14	N=8	
Weight kg	−7.58±3.08	−6.83±1.60	0.49	−1.20±2.15	−3.04±1.42	0.03	−7.66±2.74	−6.34±1.67	0.26	−1.49±2.11	−3.00±1.61	0.10
30s STS, reps	4.58±3.92	2.80±5.77	0.40	2.55±3.08	2.40±4.00	0.93	4.20±4.20	2.86±6.20	0.56	1.92±3.20	3.38±3.89	0.36
Gait Speed m/s	−0.01±0.16	0.07±0.15	0.30	0.03±0.14	0.05±0.12	0.82	−0.01±0.14	0.12±0.16	0.11	0.03±0.12	0.06±0.14	0.72
6MWT, m	89.2±97.1	44.5±38.5	0.28	−3.10±41.7	32.0±88.6	0.36	86.9±86.2	31.2±36.2	0.20	2.13±39.0	35.8±103.6	0.39
LLFDI	9.67±9.30	5.90±7.18	0.31	6.67±14.36	3.20±8.10	0.51	9.60±9.09	4.43±5.88	0.19	5.64±13.9	4.13±7.66	0.78
REAP-S	6.33±5.16	3.40±4.43	0.17	4.58±2.78	3.80±3.82	0.58	6.33±5.18	2.14±3.08	0.06	4.86±2.71	3.13±3.94	0.24
Fat Mass %	−2.65±2.97	−2.15±1.62	0.72	−0.76±0.97	−2.01±3.58	0.36	−2.38±2.84	−2.58±1.01	0.90	−1.59±1.96	−1.05±3.66	0.70
SMM/weight	−0.13±0.90	−0.32±0.39	0.27	0.59±1.27	0.05±0.55	0.32	0.01±0.02	0.02±0.01	0.67	0.01±0.02	0.01±0.01	0.90
VAT, L	−1.70±1.61	−1.15±0.41	0.43	−0.08±1.22	−0.23±1.31	0.84	−1.57±1.45	−1.18±0.21	0.61	−0.24±−1.1	−0.07±1.51	0.81

	Definition 5					
	Responder			**Non-Responder**		
	Sarcopenia	**No Sarc**	**p**	**Sarcopenia**	**No Sarc**	**p**
	N=13	**N=9**		**N=13**	**N=9**	
Weight kg	−7.66±2.97	−6.63±1.56	0.35	−1.36±2.14	−3.02±1.50	0.06
30s STS, reps	4.77±3.81	2.33±5.92	0.25	2.25±3.11	2.78±4.06	0.74
Gait Speed m/s	−0.01±0.15	0.10±0.15	0.16	0.03±0.13	0.05±0.13	0.71
6MWT, m	89.8±90.9	36.2±34.6	0.20	2.48±41.7	30.6±95.6	0.46
LLFDI	9.15±9.09	6.22±7.53	0.44	6.77±13.7	2.67±8.40	0.44
REAP-S	5.77±5.43	3.89±4.40	0.40	4.85±2,82	3.33±3.74	0.29
Fat Mass %	−2.72±2.78	−1.92±1.71	0.57	−1.28±1.79	−1.53±3.58	0.86
SMM/weight	0.02±0.01	0.01±0.01	0.72	0.01±0.02	0.02±0.01	0.42
VAT, L	−1.55±1.55	−1.28±0.30	0.71	−0.20±1.16	−0.13±1.39	0.92

Reponse status is defined as a participant losing ≥5% of their body weight from baseline. Values represented as mean ± standard deviation. Abbreviations: 30STS: 30 second sit to stand test; 6MWT: 6-minute walk test; Kg: Kilogram; LLFDI: Late-Life Function and Disability Instrument; m: Meter; REAP-S: Rapid Eating and Activity Assessment for Patients short version; Sarc – Sarcopenia; SMM – skeletal muscle mass, kg; VAT: Visceral Adipose Tissue

Sarcopenic obesity is defined as fulfilling the criteria as follows:

Definition #1: body fat %: males ≥31%, females ≥43%; Skeletal muscle mass %: males ≤37.6%, females ≤27.6%; grip strength: males ≤ 35.5kg, females ≤ 20 kg.

Definition #2: body fat %: males ≥31%, females ≥43%; Skeletal muscle mass %: males ≤37.6%, females ≤27.6%; grip strength: males ≤ 27 kg, females≤ 16 kg

Definition #3: body fat %: males ≥31%, females ≥43%; Skeletal muscle mass %: males ≤37.6%, females ≤27.6%; Sit-to-stand: 65–69 y: ≤ 16; 70–74 y: ≤ 15; 75–79 y ≤ 14; 80–84 y: ≤ 13; 85–89 y: ≤ 11 repetitions; females: Sit-to-Stand - 65–69 y: ≤ 15; 70–74 y: ≤ 14; 75–79 y ≤ 13; 80–84 y: ≤ 12; 85–89 y: ≤ 11 repetitions.

Definition #4: body fat %: males ≥31%, females ≥43%; Skeletal muscle mass %: males ≤37.6%, females ≤27.6%; grip strength: males ≤ 35.5kg, females ≤ 20 kg. OR Sit-to-stand: 65–69 y: ≤ 16; 70–74 y: ≤ 15; 75–79 y ≤ 14; 80–84 y: ≤ 13; 85–89 y: ≤ 11 repetitions; females: Sit-to-Stand - 65–69 y: ≤ 15; 70–74 y: ≤ 14; 75–79 y ≤ 13; 80–84 y: ≤ 12; 85–89 y: ≤ 11 repetitions

Definition #5 Definition #1: body fat %: males ≥31%, females ≥43%; Skeletal muscle mass %: males ≤37.6%, females ≤27.6%; grip strength: males ≤ 35.5kg, females ≤ 20 kg OR Sit-to-stand: 65–69 y: ≤ 16; 70–74 y: ≤ 15; 75–79 y ≤ 14; 80–84 y: ≤ 13; 85–89 y: ≤ 11 repetitions; females: Sit-to-Stand - 65–69 y: ≤ 15; 70–74 y: ≤ 14; 75–79 y ≤ 13; 80–84 y: ≤ 12; 85–89 y: ≤ 11 repetitions