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Waist and Calf Circumferences are Independent Predictors of Low Muscle Strength in Brazilian Adults with Obesity: a Cross-Sectional Study

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Abstract

Introduction: Low skeletal muscle strength (SMS) in individuals with obesity is a key component of sarcopenic obesity, contributing to functional decline and adverse metabolic outcomes. This study aimed to identify predictive factors of low SMS among demographic, anthropometric, adiposity, and body composition variables in adults with obesity receiving outpatient care.

Material and Methods: This cross-sectional study included 100 Brazilian adults with grades I-II obesity attending public health outpatient clinics. Anthropometric measurements and central adiposity indices were obtained. Handgrip strength (HGS) was assessed the SMS using a handheld hydraulic dynamometer. Low HGS, defined as sex- and age-specific values below the 50th percentile of a healthy reference Brazilian adult population, indicated muscle weakness. Skeletal muscle mass (SMM), fat mass (FM) and fat-free mass (FFM) were estimated by multifrequency bioelectrical impedance analysis. Physical performance was assessed via a 4-m gait speed test. Associations between low HGS and independent variables were analyzed using binary logistic regression.

Results: Both waist circumference (WC) and calf circumference (CC) were independent predictors of low muscle strength among the 100 adults with obesity evaluated (mean age 42.8 ± 11.7 years; 61% women). Each 1-cm increase in WC was associated with higher odds of low SMS by 7% (OR=1.07; 95% CI: 1.02–1.12), whereas each 1-cm increase in CC decreased the odds of low SMS by 16% (OR=0.84; 95% CI: 0.73–0.97).

Conclusion: Simple and low-cost anthropometric measures, especially waist and calf circumferences, allow rapid identification of adults with obesity who are at risk of low muscle strength. Incorporating these measures into routine clinical screening may improve early detection of sarcopenic obesity and guide preventive strategies in public healthcare settings.

Keywords: Adults; Anthropometry; Muscle Strength; Obesity; Public Health; Sarcopenia; Screening

Abbreviations: SMS, skeletal muscle strength; HGS, handgrip strength; WC, waist circumference; CC, calf circumference; FM, fat mass; FFM, fat-free mass; SMM, skeletal muscle mass.

Introduction

Obesity is a multifactorial, systemic, chronic metabolic disease characterized by excessive fat mass accumulation in adipose tissue, both subcutaneously and within specific organs, resulting from an imbalance between energy intake and expenditure [1]. Clinically, obesity is defined as a body mass index (BMI) ≥30 kg/m². It arises from complex interactions among genetic, epigenetic, behavioral, and environmental factors, including socioeconomic status, excessive caloric intake, low physical activity, and disturbances in the gut microbiota [2]. Individuals with obesity are at increased risk of developing chronic diseases such as hypertension, type 2 diabetes mellitus, nonalcoholic fatty liver disease, dyslipidemia, metabolic syndrome, sarcopenia, osteoarticular disorders, obstructive sleep apnea, and several types of cancer, contributing to reduced quality of life, higher comorbidity burden, and elevated all-cause mortality [3]. The management of obesity imposes significant economic burdens on families and public health systems worldwide [4].

Disturbances in body composition, referring to the relative proportions of muscle, fat, bone, and other tissues, are associated with aging and pathological conditions such as obesity [5, 6]. Over the life span, individuals with obesity are at increased risk of progressive skeletal muscle loss manifested as declines in strength, mass, and performance resulting in functional impairment. Probable sarcopenia, defined primarily by low muscle strength, is a key geriatric syndrome but can also affect adults with excessive adiposity [7]. The co-occurrence of sarcopenia and obesity, termed sarcopenic obesity (SO), elevates the risk of adverse clinical outcomes, including premature mortality [8, 9]. Thus, timely identification and management of individuals with SO is a strategic priority in public healthcare [10].

Handgrip strength testing is a simple and reliable means of assessing isometric muscular strength and is recognized as an important indicator of overall functional status [11, 12]. Anthropometric and obesity-related indices are extensively utilized to estimate both the total amount and body distribution of adiposity in individuals with obesity [13-16]. There is ongoing interest in the adoption of simple, cost-effective, and noninvasive anthropometric tools as proxies for obesity-related health risk in adults [17]. While the association between obesity and low muscle strength has been extensively studied in older adults, this relationship remains underexplored among adults with obesity. Particularly in primary care settings, efficient and accessible screening measures for probable sarcopenic obesity are highly valuable.

Accordingly, the present study aimed to identify predictors of low skeletal muscle strength among demographic, anthropometric, adiposity, body composition, and physical performance variables, using binary logistic regression models, in a sample of adults with obesity receiving outpatient health care in public health system.

Methods

Study Design and Population

This single-center, observational, cross-sectional study was conducted in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [18]. One hundred adults (age >18 and <60 years) with a clinical diagnosis of grade I (BMI 30.0–34.9 kg/m²), grade II (35.0–39.9 kg/m²), or grade III (≥40.0 kg/m²) obesity were recruited between April 2020 and December 2023 from a public outpatient clinic in Vitória da Conquista, Bahia, Brazil. The overall sample comprised 100 participants (mean age: 42.8 ± 11.7 years; male/female ratio = 1:1.5). A separate sample of 100 healthy-weight adults (BMI 18.0–24.9 kg/m²) was investigated for comparative reference only.

All participants were physically independent and demonstrated preserved cognitive function. Data were collected using validated questionnaires, anthropometric examinations, body composition assessments, handgrip dynamometry, and gait speed measurement.

Inclusion and Exclusion Criteria

Inclusion criteria were adulthood (age >18 and <60 years); any sex; obesity grades I–III; ability to complete questionnaires and participate in clinical examinations. Exclusion criteria included: diagnosis of acute inflammatory disease, uncontrolled comorbidities, history of locomotor disease or limb sequelae, or cancer treatment within the previous five years.

Anthropometric Measurements and Adiposity Indices

Anthropometric measurements were obtained by trained professionals following international protocols [19]. Height was determined using a fixed stadiometer (Cescorf, Porto Alegre, Brazil). Body weight was measured to the nearest 0.1 kg using a calibrated scale (Omron® HBF222-T, Kyoto, Japan). BMI was calculated as weight (kg)/height (m) ² [20].

Waist circumference (WC) was measured midway between the iliac crest and the lowest rib with a nonelastic tape (to the nearest 0.1 cm); hip circumference was measured at the widest part of the hips. Abdominal obesity (AO) was defined as WC ≥88 cm for women or ≥102 cm for men [21]. Waist-to-height ratio (WHtR) was calculated as WC/height.

Waist-corrected BMI (wBMI) was calculated as WC (m) × BMI (kg/m²) [22]. A body shape index (ABSI) was calculated as WC/ (BMI^ (2/3) × height^ (1/2)) [23]. Body roundness index (BRI) was also calculated [24]. Conicity index (CI) was determined as WC/ (0.109 × √ [body weight/height]) [25]. Calf circumference (CC) was measured at the point of greatest circumference on each leg, averaged over two measures [26].

Body Composition Assessments

Bioelectrical impedance analysis (BIA) (InBody120, Seoul, South Korea) was used to estimate total body water, fat-free mass (FFM), fat mass (FM), and percentage fat mass (%FM). The examination was performed after overnight fasting, with participants avoiding alcohol and strenuous activity before assessment [27].

Muscle Mass Estimative

Skeletal muscle mass (SMM) was estimated via BIA, and the skeletal muscle mass index (SMI) calculated as SMM/height² [28].

Muscle Strength Assessment

Skeletal muscle strength (SMS) was evaluated as the maximum handgrip strength (HGS) measured in kgf, using a hydraulic dynamometer (Jamar® PC5030J1, Brazil). Each participant performed three trials with each hand; the highest value was selected. Low muscle strength was defined as HGS below the sex-, age-, and hand-dominance-adjusted 50th percentile for a healthy Brazilian population [29].

Physical Performance

Physical performance (PP) was assessed by the 4-meter gait speed (4m-GS) test. Gait speed <0.8 m/s was classified as poor performance [30].

Data Analyses

Descriptive statistics were computed for all variables. The normality of continuous data was evaluated using the Shapiro-Wilk test. Between-group comparisons were performed using Student's t-test for independent samples (or Mann–Whitney U test when normality was not assumed) and Pearson's chi-square or Fisher's exact tests for categorical variables. Effect sizes were estimated using Hedges' g (for mean differences) and Cramer's V (for categorical associations). Variables associated with low handgrip strength at $p < 0.20$ in bivariate analysis were entered into a binary logistic regression model using a backward likelihood ratio method (p-out > 0.10). Multicollinearity was assessed through Spearman's correlation matrix ($\rho > 0.80$), variance inflation factor (VIF > 10) and tolerance (< 0.1). Model calibration and fit were verified using the Hosmer–Lemeshow goodness-of-fit test and Nagelkerke's R^2. All analyses were performed in SPSS® software (version 25.0; IBM®, Armonk, NY, USA), using a two-sided significance level of $p < 0.05$.

Results

Sample Characteristics

Table 1: summarizes the anthropometric and adiposity indices, body composition, and physical performance parameters (n=100). The cohort was predominantly female (n=40; 60%) and mean age was 42.8±11.7 years. Mean body weight was 93.9±16.3 kg and mean height was 1.66±0.10 m. By BMI classification, 69% were grade I, 25% grade II, and 6% grade III obesity. Mean skeletal muscle mass was 31.3±8.0 kg (men: 38.7±6.6 kg; women: 26.3±4.1 kg). Mean HGS was 33.2±9.0 kgf (range 20.0–50.0). Abdominal obesity was present in all participants; excessive visceral fat was identified in 91%.

Parameters	Mean ± SD	P25	P50	P75
Anthropometric and adiposity indices				
Weight (Kg)	93.9 ± 16.3	81.4	91.3	103.8
Height (m)	1.65 ± 0.11	1.58	1.65	1.72
BMI (Kg/m^2)	34.2 ± 3.8	31.0	33.2	36.0
Hip (cm)	110.3 ± 11.2	100.9	109.9	120.4
WC (cm)	109.2 ± 10.1	100.0	108.0	117.8
CC (cm)	39.9 ± 3.6	38.0	40.0	42.0
ABSI ($m^{11/6}$ $kg^{2/3}$)	0.08 ± 0.01	0.08	0.08	0.09
WHtR (cm)	0.66 ± 0.04	0.63	0.66	0.69

CI	1.3 ± 0.1	1.3	1.3	1.4
wBMI	3.2 ± 0.4	2.9	3.2	3.5
BRI	6.9 ± 1.2	6.1	6.9	7.6
Body composition (BIA)				
FFM (Kg)	56.1 ± 13.2	44.6	53.8	65.6
FM (Kg)	37.9 ± 8.6	31.9	36.2	43.6
%FM	40.7 ± 7.4	35.5	41.2	46.7
SMIheight	18.7 ± 3.7	15.7	18.2	21.4
Physical performance				
4-mGS (m/s)	1.21 ± 0.48	1.01	1.19	1.30

Bivariate Associations

Associations between HGS and selected demographic, anthropometric and adiposity indices, body composition and physical performance variables were analyzed among participants classified as having normal or low muscle strength.

Table 2: Bivariate analysis between handgrip strength (HGS) and anthropometric, adiposity indices, body composition, and physical performance parameters in adults with obesity.

Parameters	**Adults with Obesity**			
	HGSNormal (n = 60)	**HGSLow (n = 40)**	**p**	***g*Hedges**
Anthropometric and adiposity indices				
Weight (Kg)	93.7 ± 16.7	93.9 ± 16.0	0.98	0.01
Height (m)	1.64 ± 0.1	1.66 ± 0.1	0.42	0.17
CC (cm)	40.2 ± 3.7	39.3 ± 3.2	0.18	0.26
Hip (cm)	108.5 ± 11.0	112.9 ± 11.1	0.054	0.40
WC (cm)	107.4 ± 9.8	111.7 ± 10.1	**0.04**	**0.42**
ABSI ($m^{11/6}$ $kg^{2/3}$)	0.07 ± 0.0	0.08 ± 0.0	**0.01**	**0.51**
WHtR (cm)	0.65 ± 0.0	0.67 ± 0.1	**0.04**	**0.43**
CI	1.3 ± 0.1	1.3 ± 0.1	**0.01**	**0.58**
wBMI	3.1 ± 0.4	3.3 ± 0.4	**0.02**	**0.50**
BRI	6.6 ± 1.1	7.1 ± 1.3	**0.048**	**0.41**
Body composition				
FFM (Kg)	54.7 ± 12.7	58.1 ± 13.8	0.21	0.26
FM (Kg)	39.2 ± 8.6	35.7 ± 8.3	**0.047**	**0.41**
%FM	42.0 ± 6.7	38.4 ± 7.9	**0.02**	**0.49**
SMM	30.7 ± 8.0	32.1 ± 8.0	0.39	0.18

SMIheight:	18.4 ± 3.9	19.0 ± 3.5	0.42	0.16
Physical performance				
4-mGS (m/s)	1.24 ± 0.6	1.15 ± 0.2	0.37	0.18

Legend: Data are presented as mean ± SD. Group comparisons were tested using independent Student's t- test; effect sizes are Hedges' g. Bold values indicates $p < 0.05$.**Abbreviations:** HGS: handgrip strength, WC: waist circumference, WHtR: waist-to-height ratio, ABSI: A body shape index, CI: conicity index, wBMI: waist-body mass index, BRI: body round index, CC: calf circumference, FFM: fat-free mass, FM: fat mass %FM: fat mass/body weight percentage, SMM: skeletal mass muscle, SMI height: skeletal muscle mass index, 4-mGS: 4-meters gait speed.

Reduced HGS occurred in 51.3% of men and 32.8% of women ($\chi^2 = 3.39$; $p = 0.07$; $V = 0.18$). A significant association emerged between age group and HGS classification ($\chi^2 = 16.70$; $p < 0.001$; $V = 0.41$). Participants aged 20–29 years had the highest prevalence of normal strength (92.9%), whereas reduced strength was more frequent among those aged 30-39 years (61.5%) and 50–60 years (51.5%).

BMI category (obesity I–II) was not significantly associated with HGS classification ($\chi^2 = 4.03$; $p = 0.13$; $V = 0.20$). Visceral fat levels were likewise not significantly associated with muscle strength status ($\chi^2 = 1.00$; $p = 0.32$; $V = 0.10$). Participants with higher visceral fat showed a slightly greater prevalence of reduced muscle strength (61.5%) compared with those with desirable levels (44.4%).

CC measurement was categorized according to national reference cut offs, also showed no significant association with HGS ($\chi^2 = 0.88$; $p = 0.35$; $V = 0.09$). Individuals with reduced CC demonstrated a slightly higher frequency of low muscle strength (60.0%) compared with those with normal CC (38.9%).

The Table 2 displays the bivariate analysis assessing the association between handgrip strength status and continuous independent variables.

Multivariable Analysis

Table 3 summarizes binary logistic regression for prediction of low HGS in adults with obesity. The final model (Hosmer-Lemeshow p=0.572, Nagelkerke R^2=0.134) indicated that higher WC increased the odds of low muscle strength (OR=1.07, 95%CI 1.02–1.12, p=0.01), while higher CC decreased odds of muscle weakness in adults with obesity (OR=0.84, 95%CI 0.73–0.97, p=0.02). In this way, a 1-cm increase in WC increased the risk of low muscle strength by 7%, whereas a 1-cm increase in CC reduced risk of low muscle strength by 16%.

Table 3: Binary logistic regression analyses for prediction of low handgrip strength (HGS) in adults with obesity.

Parameters	**Low handgrip strength in adults with obesity**			
	Crude Model OR (IC95%)	**p**	**Adjusted Model OR (IC95%)**	**p**
Gender (female)	0.85 (0.18-4.03)	0.84	n.s	n.s
Age (years)	1.02 (0.98-1.06)	0.23	n.s	n.s
CC (cm)	0.88 (0.75-1.04)	0.14	0.84 (0.73-0.97)	**0.02**
WC (cm)	1.02 (0.92-1.14)	0.60	1.07 (1.02-1.12)	**0.01**
FM (%)	0.95 (0.86-1.05)	0.34	n.s	n.s
BRI	1.21 (0.64-2.29)	0.54	n.s	n.s

Binary logistic regression model of low HGS adjusted for gender, age, CC and WC measurements, FM, BW, and BRI. Odds Ratio (OR) was significant with $p<0.05$ (bold). **Abbreviations:**HGS: hand grip strength,WC: waist circumference,CC: calf circumference, FM: fat mass, BW: body weight, BRI: body round index.

Discussion

In this cross-sectional study, low skeletal muscle strength was diagnosed in 40% of adults with obesity. Two simple anthropometric measurements waist and calf circumference- were identified as independent predictors of low muscle strength in this population. Obesity progression is often accompanied by reductions in muscle strength and quality, which exacerbate functional limitations and increase the risk of disabilities [8]. Although individuals with obesity may exhibit higher absolute muscle strength compared to healthy-weight peers, strength relative to body mass is typically reduced [31-33]. Our results are consistent with prior studies indicating an age- and sex-dependent decline in HGS [34-36]. Prevalence of low muscle strength was substantial in adults with obesity (51.3% in men, 32.8% in women), although prevalence was higher among men, the difference was not statistically significant, and the small effect size indicated a weak association between sex and muscle strength.

Several pathophysiological mechanisms account for the link between obesity and muscle wasting, including chronic low-grade inflammation, hormonal dysregulation, oxidative stress, and ectopic fat deposition within muscle tissue [37-40]. These mechanisms are thought to promote the development of sarcopenic obesity, particularly with advancing age [41, 10]. Among anthropometric measures, BMI is widely used but does not reflect body fat distribution [20]. WC is recognized as a superior predictor of visceral adiposity [42]. A larger WC is strongly linked to low-grade, systemic chronic inflammation, which is caused by inflammatory markers produced by the excess of abdominal fat [43]. It has been shown that larger WC is associated with a high risk of metabolic and cardiovascular comorbidities and many poor health outcomes, including mortality [44]. Our findings demonstrate that higher WC is a significant risk factor for skeletal muscle weakness in adults with obesity, supporting previous research [45-47]. Further, indices such as WHtR, ABSI and CI also capture aspects of fat distribution and visceral adiposity [48-51]. Importantly, CC emerged as a novel protective factor, with higher values associated with reduced risk of low muscle strength. This measure is recognized as a surrogate for skeletal muscle mass and has shown value in sarcopenia screening among older adults [52, 53]. Our study is among the first to demonstrate its predictive role for low muscle strength in adults with obesity. The integration of CC and WC measurement into routine clinical assessment could refine screening for individuals at risk of sarcopenic obesity.

Study limitations include the cross-sectional design (precluding causal inference), modest sample size from a single center, convenience sampling, and the use of BIA rather than gold-standard imaging techniques for body composition. Future multicenter studies with larger, population-based samples and longitudinal design are warranted to validate these findings.

Conclusion

Low muscle strength is common among Brazilian adults with obesity. Waist and calf circumferences, as simple, noninvasive anthropometric measures, can facilitate the early identification of individuals at higher risk for sarcopenic obesity in all public health care settings. The integration of these anthropometrical measures into routine screening may contribute to the application of earlier intervention strategies targeting metabolic health and skeletal muscle preservation in adults with obesity.

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Ethical Considerations

The study was approved by the Institutional Ethics Committee of the Faculdade Independente do Nordeste (Fainor), Vitória da Conquista. Brazil (CAAE: 50251721.0.0000.5578. Protocol No: 4.931.111). All participants provided written informed consent.

Conflict Of Interest

The authors declare no conflicts of interest.

Authors' Contributions

All authors contributed significantly to the development of this manuscript. Santa-Júnior, V: investigation, methodology, data curation, manuscript editing. Pereira, L.M.B: methodology, statistical analysis, data curation. Ruas, H.M.S: investigation, data curation. Benitez, JFD: investigation, data curation. Dias, K.S.P.A: investigation, methodology, data curation. Bittencourt, F.O: investigation, methodology, data curation. Duarte, S.F.P: formal analysis, review, manuscript editing. Monteiro-Junior, RS: investigation, methodology, writing – review, editing. Santos, SHS: investigation, methodology, writing – review, editing. Haikal, DS: methodology, statistical analysis, formal analysis, writing – review, editing. De Paula, A.M.B: conceptualization, methodology, writing – original draft, funding, project administration. All authors approved the final manuscript.

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