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RESEARCH ARTICLE

Normal Weight Obesity and Normal Weight Central Obesity is Associated with Geriatric Syndromes in Hospitalized Older Adults

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Abstract

Background and aims: Current evidence shows that it is possible to find excessive body fat and central obesity in the normal range of Body mass index. These obesity phenotypes are recognized as Normal Weight Obesity (NWO) and Normal Weight Central Obesity (NWCO). Our study aimed to evaluate the prevalence of NWO and NWCO and its associated factors in hospitalized older adults.

Methods: This is a cross-sectional study involving older patients at a University Hospital in Northeastern of Brazil. The NWO was determined by the coexistence of normal BMI (18.5-25 kg/m^2) and high fat percentage (> 33.5% for men and > 42.8% for women). The NWCO was determined by the coexistence of normal BMI and a very increased waist circumference (≥ 102 cm for men and ≥ 88 cm for women). Demographic data, clinical, geriatric, behavior and nutritional aspects were also collected.

Results: The prevalence of NWO was 8% and NWCO was 7.4%. NWO was associated to weight loss ($p = 0.006$), calf circumference ($p < 0.001$), low muscle mass ($p < 0.001$) and sarcopenia ($p < 0.001$). The frequency of NWCO was higher in women ($p < 0.001$), also in those who presented weight loss ($p = 0.04$), in patients with lower calf circumference ($p < 0.001$), low muscle mass ($p < 0.001$), low muscle strength ($p = 0.018$), in sarcopenic ($p < 0.001$), in fragile ($p = 0.049$) and those with functional dependency ($p = 0.004$).

Conclusion: The risk factors associated with NWO were weight loss ≥ 5%, low muscle mass and sarcopenia. The risk factors to NWCO were sex (women), weight loss ≥ 5%, functional dependency, low muscle mass, low muscle strength, sarcopenia and frailty.

Keywords

Older adults, Obesity, Nutritional status, Body composition

Introduction

Obesity is an abnormal or excessive accumulation of body fat and it is currently a significant public health issue. The incidence of obesity has reached epidemic proportions worldwide and it is a risk factor for chronic diseases [1,2]. The most commonly used criteria for diagnosing obesity are the Body Mass Index (BMI) ≥ 30 kg/m^2 [1]. However, although BMI is important for population-based studies, it has limitations. BMI cannot distinguish between body compartments and does not fully reflect the percentage of body fat and its distribution [3]. To overcome the BMI limitations, it is essential to use more accurate and reliable assessment methods, such as Bioelectrical Impedance (BIA) to assess body fat and distinguish between different body tissues [4].

Current evidence shows that individuals with a normal BMI (18.5-25 kg/m^2) [1] may have an excessive amount of body fat that is masked by their normal weight, which is referred to as normal weight obesity (NWO) [5]. In addition, normal weight central obesity (NWCO) is another obesity phenotype, which is defined

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by the coexistence of a normal BMI and abdominal obesity, as measured by waist circumference (WC) [6]. Several studies have reported different prevalence ratios of NWO and NWCO [6-8], and have suggested that the ageing process increases the prevalence of both NWO and NWCO due to the changes in body composition, including decrease of lean body mass and rearrange of adipose tissue [2,4,6,9]. Among older adults, NWO has been reported in 27.9% of the population [10], while NWCO has been reported in 12.7% [11].

Despite the growing body of evidence on the presence of NWO and NWCO, particularly in individuals of advanced age, there is still a lack of research that explores the frequency of these conditions in older populations. As a result, our study sought to address this gap by examining the prevalence of NWO and NWCO in hospitalized older adults, with a particular focus on geriatric syndromes, including sarcopenia and frailty, as well as muscle abnormalities and function. Through our investigation, we aimed to shed further light on the factors that contribute to these obesity phenotypes in older adults and provide valuable insights for future research and clinical practice.

Methods

Design, local, population and eligibility criteria

This is a cross-sectional study, involving older adults who attended to a University Hospital in Northeast of Brazil, from March to September 2021. Clinical and surgical patients of both sexes, who aged ≥ 60 years and had BMI > 18.5 kg/m^2 were included.

We excluded the patients who were unable to undergo anthropometric assessment, clinically serious conditioned and those unable to answer the questionnaires, such as hemiparesis, restricted to bed, presence of ascites and/or edema.

Sample size

Sample size was calculated using the Epi Info® software, version 6.04, in the STATCALC module. We considered the number of hospitalizations of older patients in the same study period of the previous year (total hospitalizations in 7 months = 300), a prevalence of 34.1% NWO [2], a confidence level of 95% and a standard error of 5%. The minimum n = 161 patients was obtained. To cover any losses, 10% was added to the minimum sample quantity, totaling a sample size of 172 individuals.

NWO and NWCO evaluation

NWO was determined by the coexistence of eutrophic BMI (18.5-25 kg/m^2 [1] and high body fat percentage, determined by the highest tercile for sex (> 33.5% for men and > 42.8% for women) [9,10]. NWCO was determined by the coexistence of eutrophic BMI and a very increased waist circumference (≥ 102 cm for men and ≥ 88 cm for women) measured by the midpoint between the last rib and the iliac crest [1]. Body fat was obtained by the estimated body fat percentage, using the Biodynamics® tetrapolar Bioelectrical Impedance Device (BIA) Model 310e. Body fat percentage was estimated through equation: impedance = $\sqrt{R^2+X^2}$, where R is Resistance and X is Reactance [12-15].

Demographical and clinical data

We registered demographic data such as age, sex, per capita family income (stratified into < 2 minimum wages and ≥ 2 minimum wages) and scholarly level (obtained in years of study and dichotomized into ≤ 9 years and > 9 years) [16]. Regarding to clinical data, we considered the presence of comorbidities, such as systemic arterial hypertension (SAH), type 2 diabetes mellitus (DM), and the diagnosis of the moment of hospitalization.

Clinical diagnoses at the moment of hospitalization were categorized into three groups 1); Malignancies (all types of cancers); 2) Non-malignant organic disorders (digestive disorders, endocrine disorders, infectious diseases, nervous system diseases, respiratory diseases, systemic autoimmune diseases, kidney and ureteral diseases); 3) Psychiatric disorders (depressive episode, somatoform disorders, anxiety disorders, obsessive-compulsive disorder, bipolar affective disorder and schizophrenia) [17].

Functionality measurement

Functional capacity was assessed using the Barthel Index. Those with the maximum score (100 points) were considered totally independent; mild dependence (99 to 76 points); moderate dependence (75 to 51 points); severe dependence (50 to 26 points); total dependence (25 or less points) [18]. For statistical analysis, we classified the functional capacity into functional independence (independence and mild dependence) and functional dependence (moderate to severe dependence).

Behavior variables

Information on smoking, alcohol intake and level of physical activity were collected. Smoking was categorized into: Smokers (individuals who maintained the habit of smoking), non-smokers (individuals who reported never having smoked) and ex-smokers (individuals who reported smoking for some time in their lives, but who did not use at the time of application of the questionnaire). The alcoholic consumption was considered by self-reporting the intake of alcoholic beverages in the 30 days prior to the application of the questionnaire. The level of habitual physical activity was assessed using the International Physical Activity Questionnaire (IPAQ), in its short version. Individuals who performed less than 150 minutes per week in activities were considered not sufficiently active [19].

Weight loss and nutritional status assessment

Weight loss was defined by self-report of unintentional weight loss by ≥ 5% of body weight in the last 12 months. The percentage of weight loss (%WL) was calculated from the equation: %WL = (Usual weight - Current weight) × 100/Usual weight [17]. For nutritional status assessment, we considered BMI and calf circumference (CC). BMI was obtained from the quotient between weight (kg) and height $(m)^2$ [1]. The patients were classified based on the cutoff points established by the WHO [1]: BMI > 18.5 to 24.9 kg/m^2 (eutrophic); ≥ 25 kg/m^2 (overweight); and ≥ 30.0 kg/m^2 (obesity). The CC was measured in the region with the largest volume of the calf. Values of ≤ 34 cm for men and ≤ 33 cm for women were considered low [20].

Sarcopenia and frailty measurement

Sarcopenia was determined by the presence of both reduced strength and muscle mass [21]. Muscle strength was measured from handgrip strength (HS), using the JAMAR® digital dynamometer [21,22]. Values of HS < 27 kg/F for men and HS < 16 kg/F for women was defined as low muscle strength [21]. Appendicular Skeletal Muscle Mass (ASM) was obtained from the equation by Sergi, et al. [23]: ASM = (0.227 × resistance index (RI)) + (0.064 × reactance (Xc)) + (0.095 × weight (W)) + (1.384 × sex) - 3.964. The resistance measurement was obtained by the BIA. From the results of Sergi's equation, the Appendicular Skeletal Mass Index (ASMI) was calculated using the formula: $ASM/Height^2$ [21]. We adopted the cut-off points validated for the Brazilian population. Values ≤ 7.7 kg/m^2 in men and ≤ 5.62 kg/m^2 are defined as low muscle mass [20].

Frailty was established based on Fried's phenotype [24], which considers frailty when three or more of the following five criteria are identified: 1) Unintentional weight loss; 2) Exhaustion assessed by self-report of fatigue; 3) Decreased HS; 4) Low level of physical activity; and 5) Decreased walking speed. Fatigue was defined based on exhaustion assessed by self-reported fatigue, indicated by two questions from the Center for Epidemiological Studies - Depression (CES-D) [25]. Physical performance was measured using the Gait Speed (GS) test, according to the model proposed by the International Academy on Nutrition and Aging (IANA) [26]. A low GS was defined when the speed was < 0.8 meters/second [21,27]. Weight loss, HS and level physical activity was assessed using the aforementioned methods.

Ethical aspects

All procedures performed our study were in accordance to the ethical standards of the institutional and/or national research committee and to the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Data collection was performed after consideration and approval by the Research Ethics Committee (CAAE: 54023221.4.0000.8807). Informed consent was obtained from all participants included in the study. Patients consented to participate in the research and have their data published.

Statistical analysis

The SPSS® statistical program version 20.0 (SPSS Inc., Chicago, IL, USA) was used to data analysis. The normality of continuous variables was measured by the Kolmogorov-Smirnov test. Normal distributions were described as mean and standard deviation. Non-normal distributions were described as median and interquartile interval. The association of NWO and NWCO with co-variables was assessed using Pearson's chi-square or Fisher's Exact test. Significance was found when the results presented $p < 0.05$.

Results

A total of 172 eligible patients were recruited to our study but 9 of them were excluded due to lack of BIA data or data inconsistency. Our final sample consisted in 163 patients. The mean age was 69.9 ± 8.1 years and 55.8% of the patients were male. The prevalence of SAH and DM was 71.2% and 44.8%, respectively. 57.7% of our sample were overweight, while abdominal obesity was found in 55.2%. We found a high percentage of reduced CC and ASMI (59.5% and 57.8%, respectively). High percentages of sarcopenia and frailty were also observed (65.0% and 35.4%, respectively) (Table 1).

The study found that 8.0% of the participants had NWO, while 7.4% had NWCO (Table 2). NWO was associated with weight loss, reduced waist circumference, reduced appendicular skeletal muscle mass index (ASMI), and sarcopenia ($p < 0.05$) (Table 3). On the other hand, NWCO was more common in women, patients who reported weight loss in the past 12 months, individuals with functional dependence, those with reduced waist circumference, reduced ASMI, low muscle strength, sarcopenia, and frailty ($p < 0.05$) (Table 4). However, demographic, clinical, and behavioral factors were not associated with NWO and NWCO ($p > 0.05$).

Discussion

Our study stands out for addressing two frequently underdiagnosed nutritional conditions, especially in hospitalized older individuals: NWO and NWCO. In addition, we conducted an investigative analysis on how these conditions are associated with clinical conditions, abnormalities in body composition, and muscular function, due to their impact on adverse outcomes. Thus, our research contributes to a better understanding of the prevalence of these nutritional conditions and their associations with clinical conditions and abnormalities in body composition and muscular function in hospitalized older patients.

Table 1: Sociodemographic, clinical, lifestyle and nutritional characteristics in hospitalized older patients (n = 163).

Variables	N	%
Sex		
Men	91	55.8
Age		
60-69 years	94	57.7
70-79 years	49	30.1
≥ 80 years	20	12.3
Racial classification		
White	59	36.2
Multiracial	65	39.9
Black	39	23.9
Scholarly level (years of study)		
≤ 9 years	116	71.2
Familiar income		
< 2 minimum wage	77	47.2
SAH	116	71.2
DM	73	44.8
Non-malignant disorders	110	67.9
Malignant disorders	57	35.0
Alcohol intake	35	21.5
Tabagism		
Smoker	15	9.2
Non-smoker	99	60.7
Ex-smokers	49	30.1
Weight loss (≥ 5%)	92	56.4
Nutritional status (BMI)		
Eutrophy (18.5-25 kg/m^2)	69	42.3
Excessive weight (≥ 25kg/m^2)	94	57.7
Abdominal Obesity	90	55.2
Low calf circumference	97	59.5
Insufficient physical active	129	79.1
Slightly functional dependence	115	70.6
Low ASMI	93	57.8
Low muscle strenght	97	59.5
Sarcopenia	57	35.4
Frailty	106	65.0

SAH: Systemic Arterial Hypertension; DM: Diabetes Mellitus; BMI: Body Mass Index; ASMI: Appendicular Skeletal Muscle Mass Index

Table 2: Normal-weight obesity (NWO) and normal-weight central obesity (NWCO) in hospitalized older patients (n = 163).

Variables	N	%
BMI x Body fat		
Weight and normal body fat	55	33.7
NOW	13	8.0
Excessive weight and normal body fat	55	33.7
Obesity and increased body fat	40	24.5
BMI X Waist circumference		
Eutrophy without central obesity	57	35.0
NWCO	12	7.4
Excessive weight without central obesity	16	9.8
Excessive weight and central obesity	78	47.9

BMI: Body Mass Index; NWO: Normal Weight Obesity; NWCO: Normal Weight Central Obesity

In the past few decades, attention has been directed to the prognostic value of obesity, especially defined by the body mass index. BMI has high specificity in detecting excessive body adiposity, however it has low sensitivity, proving to be a poor discriminator of fat mass and body fat-free mass [4,5]. On the other hand, NWO and NWCO studies are raising and are currently described as conditions related to higher risk for cardiometabolic diseases, mortality and lower survival [5-7,28].

The prevalence of NWO found in our study (8.0%) is in concordance to results found by Kim, et al. (8.3%) [29] but in contrast to results found by Ji, et al. [4] that found a higher prevalence (10.7%) of NWO in older adults. In American population, evidence showed a variation in frequency of NWO (4.5-22%) [5]. It is important to note that the frequency of NWO and NWCO may vary due to epidemiological scenario and population characteristics, making it essential to investigate these conditions in different contexts and populations. Beyond that, the many cutoff values to determine body fat percentage and the different techniques of measurement can explain the variations in prevalence of NWO afore-mentioned. It may be a bias of comparison. Our study considered the highest tercile for both sexes [9,10] and it may be underestimated results.

Contrasting the results on NWCO prevalence found in our study (7.4%), Mohamed, et al.'s [6] study found a prevalence of 21.2% in adults living in Kenya. Mohamed, et al. [6] described that the prevalence of NWCO can vary from 18.1% to 38.1%, considering the variations of techniques to assess central obesity. Similar results were found by Shirasawa, et al.'s [30] study. They found a prevalence of NWCO in 19.9% of the population and used the combination of BMI and Waist to Hip Ratio (WHR) to determine NWCO. These differences may be related to the different WC measurement protocols and the different parameters used to define central obesity (WC, WHR) [30], waist-to-height ratio (WHtR) [31].

Studies evaluating the NWO and NWCO phenotypes showed that individuals with NWO had higher risk to develop cardiovascular diseases and metabolic syndrome [5,6,32], while NWCO was associated with decreasing in muscle mass or sarcopenia, lower energy expenditure, metabolic disorders and low functional capacity [28,33]. These results show us the importance of diagnosing these conditions, considering the fact that obesity phenotypes are not often identified, despite its association with cardiometabolic events and muscle abnormalities [5].

Table 3: Sociodemographic, clinical, lifestyle and nutritional factors associated with Normal Weight Obesity (NWO) in hospitalized older patients (n = 163).

Variables	Normal weight and normal body fat		NWO		Excessive weight and normal body fat		Excessive weight and increased body fat		p-value*
	n	%	n	%	n	%	n	%	
Sex									
Men	36	65.5	8	61.5	25	45.5	22	55.0	0.199
Women	19	34.5	5	38.5	30	54.5	18	45.0	
Age									
60-69 years	29	52.7	7	53.8	37	67.3	21	52.5	0.249
70-79 years	20	36.4	3	23.1	15	27.3	11	27.5	
≥ 80 years	6	10.9	3	23.1	3	5.5	8	20.0	
Racial Classification									
White	24	43.6	3	23.1	18	32.7	14	35.0	
Multiracial	17	30.9	7	53.8	24	43.6	17	42.5	0.709
Black	14	25.5	3	23.1	13	23.6	9	22.5	
Years of study									
≤ 9 years	41	74.5	9	69.2	37	67.3	29	72.5	0.856
> 9 years	14	25.5	4	30.8	18	32.7	11	27.5	
Familiar income									
< 2 MW	28	50.9	7	53.8	28	50.9	14	35.0	0.358
≥ 2 MW	27	49.1	6	46.2	27	49.1	26	65.0	
SAH									
Yes	35	63.6	10	76.9	41	74.5	30	75.0	0.508
No	20	36.4	3	23.1	14	25.5	10	25.0	
DM									
Yes	25	45.5	2	15.4	28	50.9	18	45.0	0.145
No	30	54.5	11	84.6	27	49.1	22	55.0	
Non-malignant disorders									
Yes	36	32.7	10	9.1	36	32.7	28	25.5	0.787
No	19	36.5	3	5.8	19	36.5	11	21.2	
Malignant disorders									
Yes	19	33.3	3	5.3	20	35.1	15	26.3	0.808
No	36	34.0	10	9.4	35	33.0	25	23.6	
Etilism									
Yes	11	20.0	3	23.1	12	21.8	9	22.5	0.989
No	44	80.0	10	76.9	43	78.2	31	77.5	
Tabagism									
Smoker	4	7.3	2	15.4	4	7.3	5	12.5	
Non-smoker	34	61.8	8	61.5	33	60.0	24	60.0	0.927
Ex-smoker	17	30.9	3	23.1	18	32.7	11	27.5	
Weight loss									
Yes	38	69.1	11	84.6	25	45.5	18	45.0	**0.006**
No	17	30.9	2	15.4	30	54.5	22	55.0	
Calf circumference									
Low	49	89.1	12	92.3	19	34.5	17	42.5	**< 0.001**
Normal	6	10.9	1	7.7	36	65.5	23	57.5	
Physical activity									
Sufficiently active	10	18.2	3	23.1	15	27.3	6	15.0	0.479
Non-sufficiently	45	81.8	10	76.9	40	72.7	34	85.0	

Barthel Index									
Independent or Slightly dependent	35	63.6	8	61.5	42	76.4	30	75.0	0.384
Moderate or severe dependent	20	36.4	5	38.5	13	23.6	10	25.0	
ASMI									
Low	48	87.3	13	100.0	13	23.6	19	50.0	**< 0.001**
Normal	7	12.7	0	0	42	76.4	19	50.0	
Muscle strenght									
Low	36	56.4	6	69.2	29	52.7	23	57.5	0.487
Normal	19	34.5	4	30.8	26	47.3	17	42.5	
Sarcopenia									
Yes	31	56.4	6	69.2	5	9.1	12	31.6	**< 0.001**
No	24	43.6	4	30.8	50	90.9	26	68.4	
Frailty									
Yes	40	72.7	10	76.7	30	54.5	26	65.0	0.179
No	15	27.3	3	23.1	25	45.5	14	35.0	

MW: Minimum Wage; SAH: Systemic Arterial Hypertension; DM: Diabetes Mellitus; BMI: Body Mass Index; ASMI: Appendicular Skeletal Muscle Mass Index; *Pearson chi-square.

Table 4: Sociodemographic, clinical, lifestyle and nutritional factors associated with normal weight central obesity (NWCO) in older hospitalized patients (n = 163).

Variable	Eutrophy without abdominal obesity		NWCO		Excessive weight without abdominal obesity		Excessive weight with abdominal obesity		p-value*
	n	%	n	%	n	%	n	%	
Sex									
Men	44	77.2	7	8.3	13	81.3	33	42.3	**< 0.001**
Women	13	22.8	11	91.7	3	18.8	45	57.7	
Age									
60-69 years	33	57.9	3	25.0	10	62.5	48	61.5	0.377
70-79 years	17	29.8	6	50.0	5	31.3	21	26.9	
≥ 80 years	7	12.3	3	25.0	1	6.3	9	11.5	
Racial Classification									
White	20	35.1	7	58.3	3	18.8	29	37.2	0.342
Multiracial	20	35.1	4	33.3	8	50.0	33	42.3	
Black	17	29.8	1	8.3	5	31.3	16	20.5	
Years of study									
≤ 9 years	44	77.2	7	58.3	13	81.3	52	66.7	0.316
> 9 years	13	22.8	5	41.7	3	18.8	26	33.3	
Familiar income									
< 2 MW	30	52.6	6	50.0	8	50.0	33	42.3	0.680
≥ 2 MW	27	47.4	6	50.0	8	50.0	45	57.7	
SAH									
Yes	36	63.2	10	83.3	9	56.3	61	78.2	0.099
No	21	36.8	2	16.7	7	43.8	17	21.8	
DM									
Yes	20	35.1	7	58.3	6	37.5	40	51.3	0.192
No	37	64.9	5	41.7	10	62.5	38	48.7	
Non-malignant disorders									

Yes	38	34.5	8	7.3	12	10.9	52	47.3	0.935
No	19	36.5	4	7.7	4	7.7	25	48.1	
Malignant disorders									
Yes	19	33.3	4	7.0	5	8.8	29	50.9	0.951
No	38	35.8	8	7.5	11	10.4	49	46.2	
Etilism									
Yes	11	19.3	3	25.0	4	25.0	17	21.8	0.946
No	46	80.7	9	75.0	12	75.0	61	78.2	
Tabagism									
Smoker	5	8.8	1	8.3	1	6.3	8	10.3	0.937
Non-smoker	34	59.6	9	75.0	9	56.3	47	60.3	
Ex-smoker	18	31.6	2	16.7	6	37.5	23	29.5	
Physical activity									
Sufficiently active	13	22.8	0	0	5	31.3	16	20.5	0.226
Non-sufficiently Active	44	77.2	12	100.0	11	68.8	62	79.5	
Weight loss (≥ 5%)									
Yes	40	70.2	10	83.3	6	37.5	36	46.2	**0.004**
No	17	29.8	2	16.7	10	62.5	42	53.8	
Calf circumference									
Low	51	89.5	11	91.7	7	43.8	28	35.9	**< 0.001**
Normal	6	10.5	1	8.3	9	56.3	50	64.1	
Barthel Index									
Independent or Slightly dependent	41	71.9	3	25.0	13	81.3	58	74.4	**0.004**
Moderate or severe dependent	16	28.1	9	75.0	3	18.8	20	25.6	
ASMI									
Low	53	93.0	9	75.0	10	62.5	21	27.6	**< 0.001**
Normal	4	7.0	3	25.0	6	37.5	55	72.4	
Muscle strenght									
Low	34	59.6	12	100.0	7	43.8	44	56.4	**0.018**
Normal	23	40.4	0	0	9	56.3	34	43.6	
Sarcopenia									
Yes	32	56.1	9	75.0	4	25.0	12	15.8	**< 0.001**
No	25	43.9	3	25.0	12	75.0	64	84.2	
Frailty									
Yes	40	70.2	11	91.7	8	50.0	47	60.3	**0.049**
No	17	29.8	1	8.3	8	50.0	31	39.7	

MW: Minimum Wage; SAH: Systemic Arterial Hypertension; DM: Diabetes Mellitus; BMI: Body Mass Index; ASMI: Appendicular Skeletal Muscle Mass Index; *Pearson chi-square.

Evidence have showed that the aging process leads to a gradual increase in body fat and a decrease in lean mass. Considering this, the isolated evaluation based on BMI alone cannot accurately correspond to the body composition of individuals and may mask the occurrence of NWO and NWCO phenotypes. The misdiagnosis of these conditions results in a lack of multimodal interventions that may prevent and treat the related cardiometabolic events [2,5]. These facts highlight the importance of investigating the different obesity phenotypes beyond BMI. Although BMI is an easy, quick, and conventional index [2,7,34], it has limitations due to its low sensitivity (around 50%) in detecting excessive body fat [5,33,35].

Our results showed that NWCO phenotype was more frequent in women. Similar results were found in previous studies [6,35,36]. There are reasons that may explain this finding, such as reduced postmenopausal estrogen levels increase body fat and women can engage in less physically strenuous activities compared to men,

causing them to have less muscle mass and more body fat [4,5]. Contrasting to the results found in our study among the frequency of NWO and NWCO, Ji, et al.'s [4] study showed that NWO increased with age. There are several possible explanations for these findings. First, body fat content gradually increases, while muscle mass decreases with age [37]. Second, the risk of tooth loss increases with age, resulting in reduced chewing ability, which can restrict optimal nutrition. Also, older adults over the age of 80 may have insufficient protein intake, leading to muscle breakdown [4].

Our other results showed no association of NWO and NWCO with sociodemographic data. Similar results were found in Madeira, et al.'s [38] study. They also did not found relationship between the obesity phenotypes and scholarly level, income, and marital status. No association of NWO and NWCO with clinical variables was found in our study, in contrast with the results found by Rakhmat, et al.' [39]. They found an association of NWO with SAH and DM. Other studies showed that NWO individuals had higher systolic and diastolic pressure when compared to people without this obesity phenotype [9,40]. It has also been reported that NWO and NWCO may influence in metabolic factors, leading to insulin resistance, dyslipidemia and inflammation [41,42].

No relationship between NWO and NWCO and lifestyle data were found in our study. Contrasting to our results, Mannisto, et al. [43] observed that NWO was related to physical inactivity, smoking, alcoholic intake, in addition to inadequate dietary habits, such as low intake of roots, cereals and fish, in addition to a high sugar intake.

Regarding to physical activity, Wijayatunga and Dhurandhar [5] reported that individuals with NWO are less involved to physical activities when compared to individuals without this obesity phenotype. Other evidence showed that individuals with NWO had lower physical fitness [44]. It could be partially explained by the lower lean body mass content [45]. The higher frequency of NWO and NWCO in individuals with weight loss greater than 5% has not been sufficiently described in scientific literature. It is known that hospitalization is an important predictor of weight loss and this weight reduction during acute care can mainly affect lean body mass [46]. In this sense, the adipose tissue would be better preserved, justifying the high percentage of fat in normal weight.

Our results showed an association of NWO and NWCO with low muscle mass and sarcopenia. Similar results were found by Di Renzo, et al.'s [47] study. They described a lower muscle mass in women with NWO when compared to those without this obesity phenotype. In accordance to our results, Kim, et al. [34] showed that adult individuals with NWO had reduced appendicular skeletal muscle mass ($p < 0.001$), while Di Renzo, et al. [48] described an association of NWO and sarcopenia.

There are many factors that may explain these findings. The high percentage of body fat tend to have higher levels of tumor necrosis factor-alpha (TNF-a), which is a cytokine involved in chronic inflammation and may lead to anorexia and weight loss. In addition, TNF-a seems to be involved in the metabolic regulation and connection between muscle and adipose tissue, promoting abnormalities in body composition marked by tissue replacement. As a consequence of these mechanisms, body experiences a reduction in muscle mass and increase in fat deposits, despite normal BMI [3,34].

Other studies also demonstrated that patients with NWO had lower muscle mass when compared to groups of non-obese and obese individuals with a high fat percentage [49]. In addition, obesity characteristics in older adults are related to increased fat mass, fat infiltration into muscles, and decrease in muscle mass and muscle quality [4].

In our study, NWCO was associated with functionality assessed by the Barthel Index. Similar results were described by Batsis, et al. [11], who found that older adults with NWCO had greater risk of decline in function and physical activity. In addition, it was also described that older women with NWO had greater impairment in basic activities of daily living (ADLs). Corroborating to this, evidence shows that the aging process is related to decline in muscle quality and functional capacity [50,51]. In addition, the aging process leads to abnormalities in body composition, marked by greater deposition of body fat and lower lean mass among women. It may increase the risk of developing obesity and lower muscle strength. Additionally, the fat infiltration in muscle can also lead to a decrease in strength and muscle quality, which can decrease functionality in older adults [35].

Our results showed an association of frailty with NWCO. This relationship has not yet been fully explored in the scientific literature, but can be explained since abdominal obesity increases the chance of frailty [52]. So, this relationship may occur even in the presence of a normal BMI.

Our study has some limitations that need to be acknowledged. The study design was cross-sectional and lacks a control group, which may limit causal inferences. In addition, we included older patients from a single hospital unit, which limits the generalization of results. However, this study's main strength is the investigation of associated factors with two important obesity phenotypes. It helps to summarize the risk profile of these conditions. Another strong point of our study is the evaluation of conditions that are often underdiagnosed and understudied.

Conclusion

NWO and NWCO were not uncommon in hospitalized elderly. It demonstrates that BMI may fail to represent excessive body adiposity and abnormal fat distribution in older adults. The risk profile for NWO development was: weight loss ≥ 5%, reduced muscle mass and sarcopenia, while for NWCO was being women, weight loss ≥ 5%, functional dependence, reduced muscle mass, reduced muscle strength, sarcopenia and frailty.

In health sciences there are still many gaps on NWO and NWCO exploration. In this sense, it is important that other studies may explore its etiology and define the profile of patients at greater risk for these conditions. The results found in our study suggest the need of combine the BMI with other anthropometric parameters, such as percentage of body fat and measurements of central adiposity, as a path to improve the screening of obesity in its all phenotypes and to properly treat these conditions.

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Statement of Authorship

All authors made substantial contributions to the conception and design of the study, acquisition, analysis and interpretation of data. They also contributed to the manuscript drafting and critical review of the intellectual content. All authors critically revised the manuscript, agree to be fully accountable for ensuring the integrity and accuracy of the work, and read and approved the final manuscript.

Conflicts of Interest Statement

The authors declare that there are no conflicts of interest.

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