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Review

Phase angle and vector analysis in the evaluation of body composition in sarcopenic obesity: a systematic review

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ABSTRACT

Background: Sarcopenic obesity (SO) is a condition characterized by low muscle mass and strength and high adiposity. Bioelectrical impedance analysis (BIA) derived phase angle (PhA) and bioelectrical impedance vector analysis (BIVA) are simple and inexpensive tools for the evaluation of body composition, with an emerging consensus in health research and application.
Aim: The aim of this systematic review was to analyze research on sarcopenic obesity using PhA or BIVA.
Methods: A bibliographic search was performed on 13 January 2025, using three databases: PubMed, Scopus and Web of Science. The search terms were: ("phase angle" OR BIVA) and (sarcopenic OR sarcopenia OR obesity). Studies addressing only obesity or sarcopenia were excluded. The quality of the studies was evaluated using the Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies, from the National Institute of Health. No meta-analysis was conducted.
Results: Nine studies were selected, mostly published in 2022 (89%) or later and focused on clinical applications (55.6%). The reviewed studies showed substantial methodological variability. Diagnostic criteria included the ESPEN–EASO algorithm as well as protocols based on different definitions of sarcopenia and obesity. Indices and cut-offs used to define body composition varied accordingly. Variability was also observed in population samples and in bioimpedance devices. All selected studies used PhA and two of them used BIVA. Although quantitative results are variable, with PhA values ranging from 3.9° to 7.1°, and mostly below 5.6°. The qualitative pattern of bioelectrical characteristics associated with body composition in SO is broadly consistent across studies: PhA is tendentially lower than in healthy subjects and patients with obesity and similar to those with sarcopenia; the specific vector is longer.
Conclusions: Research is still quite heterogeneous in terms of methods and diagnostic procedures, which limits the comparability of the results. However, the observed tendencies confirm the suitability of PhA for recognizing the reduced muscle mass associated with sarcopenia, while specific BIVA also appears capable of detecting excess fat mass related to obesity. Further research is needed to standardize procedures for characterizing sarcopenic obesity and monitoring its progression.

Introduction

Sarcopenic obesity (SO) is characterized by low muscle mass and strength and high adiposity [1]. Accurate assessment of body composition is a critical step in the recognition and treatment of sarcopenic obesity. The consensus statement on the definition and diagnostic criteria published by the European Society for Clinical Nutrition and Metabolism (ESPEN) and the European Association for the Study of Obesity (EASO) [1,2] recommends the use of dual-energy X-ray absorptiometry (DXA) or other advanced imaging techniques, such as magnetic resonance imaging and computed tomography. However, these techniques require expensive equipment and specialized personnel, making them impractical for widespread use, especially in community settings. In these contexts, the consensus statement suggests the use of bioelectrical impedance analysis (BIA), which is portable, affordable, and widely available [1,2].

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Indeed, BIA is widely used in the analysis of sarcopenic obesity, including in research.

The conventional BIA approach uses regression equations calibrated against a gold standard technique. This procedure allows the evaluation of indices of muscle mass, whose values can be compared with cut-off values for diagnosis. The equations should be used on samples of similar age, sex and geographical ancestry to those against which they were calibrated, as they make constant assumptions about body proportions and fat-free mass hydration. Indeed, expert panel criteria recommend this selective use [1,2]. However, for theoretical and technical reasons, this is not always feasible or ideal. In fact, the same concept of population is rather arbitrary and vague, and an accurate definition in terms of genetic ancestry, sex, age, health status is often difficult, if not impossible. In addition, the intra-group variability, which is particularly high in older people, does not allow population-specific equations to be applied consistently to all individuals. Furthermore, commonly used devices often do not disclose the equations used and, when an equation can be selected, operators may not have the theoretical background necessary to choose the most appropriate one. Finally, the use of different equations, although appropriate for each sample, reduces the comparability of results.

Alternative approaches based on BIA, namely phase angle (PhA) and bioelectrical impedance vector analysis (BIVA), are based on the direct analysis of raw bioelectrical data and therefore have the advantage of not requiring the use of equations, thus avoiding a potential source of error, while retaining the advantages of availability, affordability and portability of BIA.

Phase angle: technical overview

Phase angle is an index derived from the relationship between reactance (Xc, ohm) and resistance (R, ohm), typically measured at a frequency of 50 kHz. It reflects the quantity and integrity of cell membranes, which act as capacitive elements, storing charge and causing the current to lag behind the voltage, resulting in a phase shift [3].

PhA has been shown to be associated with body cell mass and is considered a proxy for fat-free mass and skeletal muscle mass [4]. It is also considered a surrogate marker for muscle quality, particularly as an expression of muscle composition [5], and of muscle function, as evidenced by its independent relationship with grip strength and functional tests [6]. PhA also shows a strong negative association with the extracellular/intracellular water ratio [4,7]. The association with body fat is weaker and non-linear, being initially positive, then stable, and becoming negative at higher values [8]. PhA has also been negatively associated with inflammatory status [9].

Reflecting differences in body composition, the phase angle varies between individuals in relation to: sex, being higher in men [10]; age, showing increasing values with growth [10] and decreasing values with aging [10,11]; lifestyle, showing higher values in athletes and in physically active people [12]; geographic ancestry, being higher in populations with greater muscle mass, such as Afro-Americans, and lower in Asian groups [13,14]; health status, being considered a predictor of malnutrition [15] and adverse outcomes, length of hospital stay, and mortality risk in several clinical conditions [16].

A limitation of PhA is that it does not recognize different hydration conditions [17] or relative amounts of FM% [18]. This variability is captured by the vector approach.

Bioelectrical impedance vector analysis: technical overview

Similar to phase angle, the vector approach analyses raw bioelectrical data, but provides more information about body composition by allowing contextual analysis of both phase angle and vector length [17].

Resistance and reactance are the coordinates of the vector, with the slope corresponding to the phase angle and the length to the impedance. Two analytical approaches can be applied: tolerance and confidence ellipses [17]. Tolerance ellipses are probability plots showing the percentile distribution of bioelectrical values of the reference population (Fig. 1). Body composition is interpreted from the position of individual or mean vectors within the sex-specific ellipses. Confidence ellipses allow comparison between groups, which can also be done statistically using Hotelling's T^2 test. In general, groups represented by non-overlapping ellipses are significantly different.

There are two different BIVA approaches, classic [17] and specific BIVA [19], and they differ in the way the bioelectrical values are standardized: by height in classic BIVA, in order to eliminate the effect of conductor length, and by height and an estimate of cross section dimensions in specific BIVA, to eliminate the effect of body volume.

The phase angle is not affected by the standardization and therefore the minor axis of tolerance ellipses, which is mainly characterized by phase angle variations, can be interpreted in the same way in classic and specific BIVA, and similarly to the interpretation of the phase angle alone.

Differences in interpretation arise when considering the major axis, which is mainly related to vector length. There is strong evidence that classic BIVA is adequate for the study of body hydration, with dehydration indicated by the upper pole of the ellipses [17]. In contrast, specific BIVA has shown accuracy in estimating the percentage of fat mass, with obesity conditions characterized by longer vectors [19]. This property enhances the information provided by the phase angle. Indeed, the classic vector length can distinguish different hydration conditions for a given PhA [17], and the specific vector length can distinguish different amounts of FM% [18].

Both phase angle and specific bioelectrical impedance vector analysis have been considered as potential tools for receiving information on body composition in sarcopenic obesity [2]. Indeed, a growing body of literature has highlighted the association between low phase angle values and sarcopenia. However, the use of alternative BIA approaches in sarcopenic obesity has been less investigated.

The aim of this systematic review is to discuss the use of phase angle and bioelectrical impedance vector analysis in the study of sarcopenic obesity, in order to delineate their potential relevance as methods for body composition assessment in this context.

Methods

Literature search

This systematic review was conducted using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [20] and was registered in the PROSPERO database (https://www.crd.york.ac.uk/PROSPERO/) Registration number: CRD420251020207.

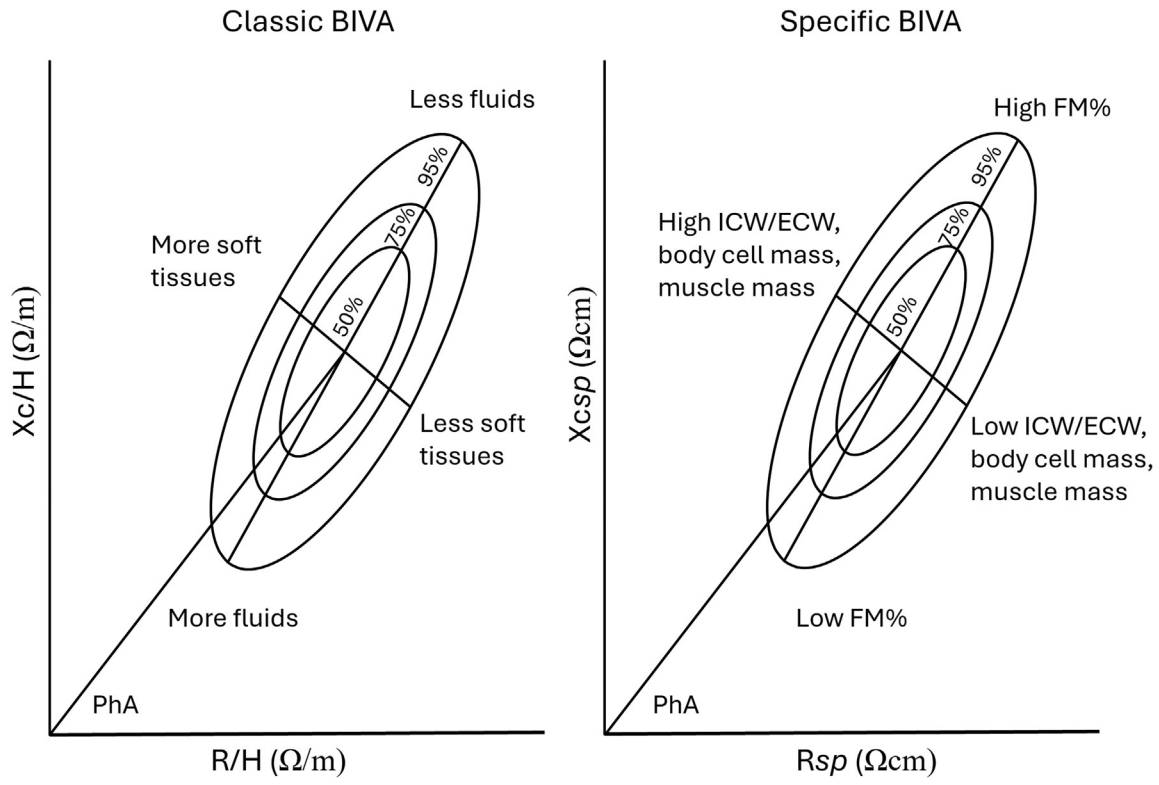

Fig. 1. Classic and specific BIVA tolerance ellipses.

The bibliographic search was carried out on 13 January 2025, using three databases: PubMed, Scopus and Web of Science. The search was conducted using the following search terms [All fields]: ("phase angle" OR BIVA) AND (sarcopenia OR sarcopenic OR obesity). Inclusion criteria were peer-reviewed studies, accessible in English full-text, on phase angle or BIVA applied to the analysis of sarcopenic obesity. The main reasons for exclusion were: (1) the lack of bioelectrical values specifically related to sarcopenic obesity, (2) the inclusion of individuals with obesity alone, and (3) the inclusion of individuals with sarcopenia alone.

Selection process and data collection

All retrieved records were imported into Zotero, and duplicates were removed. Three authors (FF, KMP, VS) independently screened the articles according to the inclusion criteria. In cases of uncertainty, disagreements were discussed and resolved in consultation with all authors. Two reviewers (FF, KP) extracted the following information from the eligible studies: year of publication, study design, authors, sample size, participants' characteristics (sex, country, age, clinical condition), study objectives and results, SO definition, SO prevalence, diagnostic methods and cut-off values, bioelectrical values.

Synthesis methods

Findings were discussed narratively and summarized in tables and figures. No meta-analysis was conducted.

Quality Assessment

Studies quality was evaluated using the Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies, from the National Institute of Health, U. S. Department of Health and Human Services [21]. This checklist includes 14 items that assess methodological aspects, such as study design, sample selection, exposure and outcome measurement, and confounding control. Studies were classified into three categories based on their overall score: Good (more than or equal to 70% of "yes" answers), Fair (between 50–59%) or Poor quality (less than 50%).

Results

Selection of studies

The selection process (Fig. 2) initially identified a total of 1606 articles. After removing

770 duplicates using Zotero software, 836 articles were included in the search. Based on the screening of both titles and abstracts, 792 studies were excluded because they did not meet the inclusion criteria. The full text of 44 potentially relevant papers was then examined and 9 studies were considered suitable for the systematic review.

Study characteristics

The main characteristics of the selected articles are shown in Table 1. All studies were published between 2012 and 2025, especially in 2022 or later (89%), and were conducted in Brazil [22], China [23], Israel [24], Italy [25–27], Japan [28], Mexico [29], Turkey [30].

The study designs were prospective cohort studies [24,25,29] and cross-sectional studies [22,23,26–28,30]. All studies were rated as good, according to the Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies [21]. The mean quality score was 88.8%, with scores ranging from 75% to 100% (Table S1).

The total number of participants included was 14971, with sample sizes ranging from 51 [22] to 10312 [23]. The mean age ranged from 53 [23] to 76.3 years [27]. All studies included both sexes and, in most cases, were aggregated by sex [22,24,25,28–30]. The groups defined as sarcopenic obese referred to samples with body composition characteristics indicative of SO,

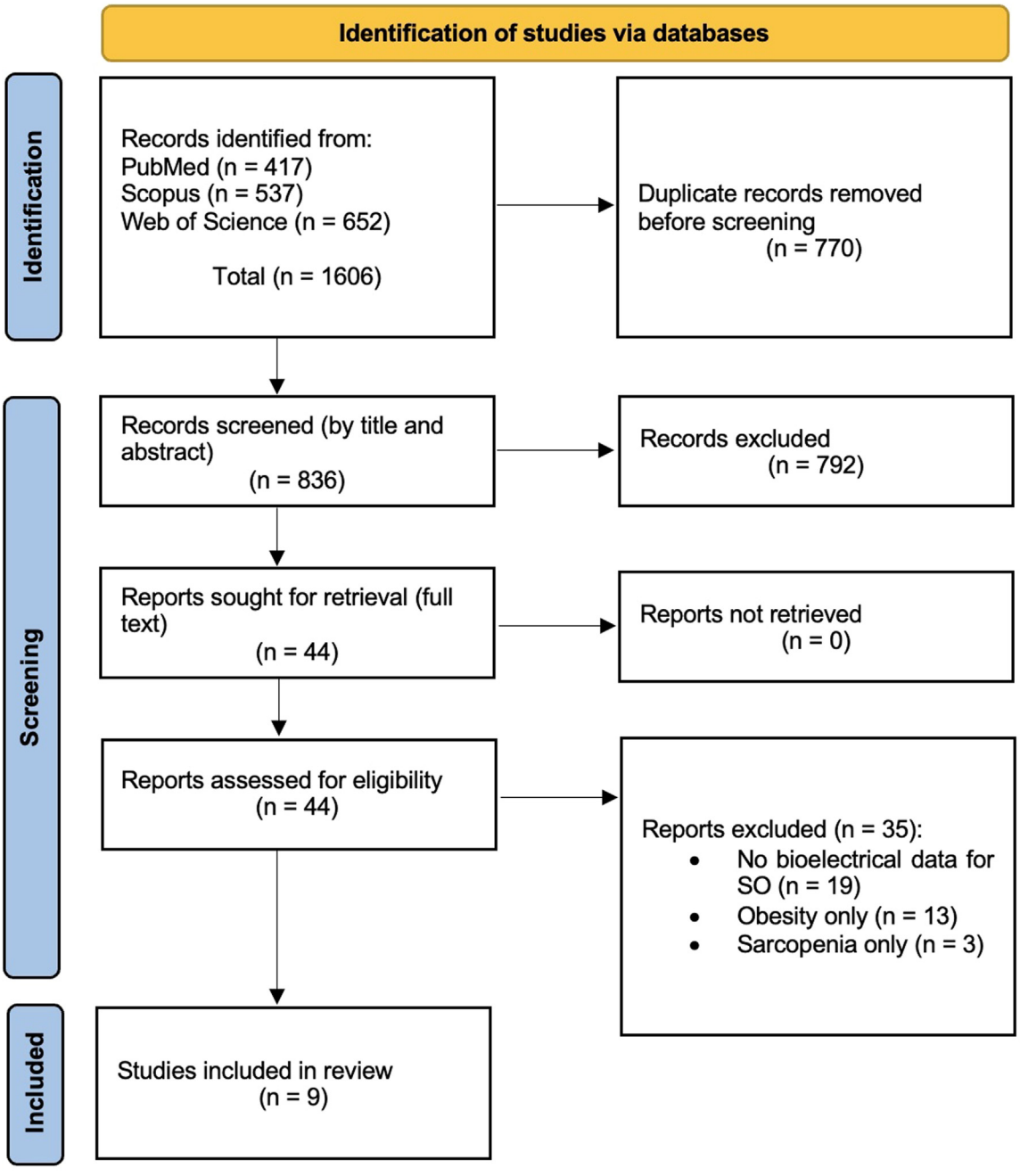

Fig. 2. Flowchart on the search and selection of articles to be included in the review.

according to expert panel criteria. Four studies evaluated the general population [22,23,26,27], while other studies considered subjects undergoing haemodialysis [24], post-stroke patients [28], patients with obesity [25], type 2 diabetes mellitus [30], head and neck cancer [29].

General aims of the selected studies

The included studies had a range of different aims (Table 2). Most studies analyzed the phase angle in relation to various influencing factors, mainly nutritional status, quality of life, and clinical outcomes. The bioelectrical characteristics of the groups classified as 'SO' were compared with those of healthy subjects, in relation to the progression of the condition, or with those of the groups classified as sarcopenic (S), obese (O), or both sarcopenic and obese groups. In a few cases a cut-off predictive of sarcopenic obesity was proposed.

Methods

Skeletal muscle functional parameters

Hand grip strength (HGS) was assessed using different instruments and different cut-offs (Table 2).

Two studies also analyzed physical performance [22,30].

Table 1
General characteristics of selected studies

Reference	Country	Sample size (n)	Sex (n) M F	Age (mean±SD)	Sample characteristics
Araújo et al. [22]	Brazil	51	6 45	M = 69.8 ± 3.8 F = 69.7 ± 6.3	General population (84.3% with frailty)
Beberashvili et al. [24]	Israel	261	151[†] 84[†]	EWGSOP = 72.4 ± 11.9 FNIH = 72.1 ± 10.7	Haemodialysis[‡]
Brunani et al. [25]	Italy	2004	762 1242	Overall = 56.0 ± 14.0 SO = 64.4 ± 12.4	Obesity
Hafızoğlu et al. [30]	Turkey	322	119 203	72.5 ± 5.8	Type 2 diabetes mellitus; FM% values indicate widespread obesity
Luo and Jin [23]	China	10312	5415 4897	M = 53.47 ± 10.84 F = 53.17 ± 10.29	General population
Marini et al. [26]	Italy	207	75 132	M = 75.8 ± 6.9 F = 70.8 ± 4.0	General population
Marini et al. [27]	Italy	915	396 519	M = 74.6 ± 8.8 F = 76.3 ± 8.8	General population
Sat-Muñoz et al. [29]	Mexico	139	107 32	63.5 ± 13.0	Head and neck cancer[§]

EWGSOP, European Working Group on Sarcopenia in Older People; FNIH, Foundation for the National Institutes of Health; HGS, hand grip strength; SD, standard deviation; SO, sarcopenic obesity.
[†]Sex data available for sarcopenic and SO individuals, unknown for 26 others.
[‡]Patients with a life expectancy of less than six months were excluded.
[§]The sample included different disease stages; patients with two or more malignant neoplasms, autoimmune diseases, and chronic kidney or lung diseases were excluded.

Body composition

Different criteria were used to define the body composition of individuals with sarcopenic obesity (Tables 2 and 3). Four studies applied the ESPEN-EASO criteria [25,27,28,30].

Other studies defined SO based on the coexistence of body composition characteristics of sarcopenia and obesity [22–24,26].

In these cases, sarcopenia was diagnosed according to the first European Working Group on Sarcopenia in Older People (EWGSOP) guidelines [32], the Foundation for the National Institutes of Health (FNIH) criteria [33], or the Asian Working Group for Sarcopenia criteria (AWGS) [34].

Along with the heterogeneity of the criteria used to define sarcopenic obesity or sarcopenia, the diagnostic indices and cut-off values for muscle mass also varied among reviewed studies (Table 3). When using the ESPEN-EASO criteria [1,2], the measures of total (SMM), or appendicular (ASM) skeletal muscle mass, in some cases also defined as appendicular lean mass (ALM), were standardized by weight (SMM/W, ASM/W, ALM/W); in other cases the values were divided by squared height (SMM/H^2 or ASM/H^2), or by BMI (ALM/BMI).

The cut-off values for defining muscle or fat mass also varied among studies, depending on the indices used and the sampled populations (Tables 2 and 3).

The diagnosis of obesity was based on BMI (thresholds used ranged from 24 to 30 kg/m^2), and/or waist circumference, and/or body fat percentage (thresholds used: 23.8–31% in men; 35–43% in women) (Tables 2 and 3). This definition may have led to the inclusion of overweight individuals in some samples.

BIA analysis was performed using seven different impedance devices, including both supine [22,24–27,29,30], standing [23], or not specified [28] positions. Marini et al. [26,27] also applied DXA (Table 2).One study used classic BIVA [26] and two studies used specific BIVA [26,27]. In these cases, the EWGSOP or ESPEN-EASO criteria were adopted to define body composition, without taking hand grip strength into account. Consequently, the samples could include presarcopenic individuals, as defined by EWGSOP [32].

Overall results

The prevalence of SO varied considerably across the selected studies, ranging from 1.4% [23] to 38.3% [24], probably due to differences in diagnostic criteria, study populations, and clinical conditions (Table 2).

Phase angle

In line with theoretical expectations, and consistently with the variability in the general population, the reviewed studies showed that PhA was: negatively associated with age ($P < 0.01$) [22,23] and fat mass % ($P < 0.01$) [23]; non-linearly associated with body mass index and waist circumference ($P < 0.001$) [23]; positively correlated with muscle mass ($P < 0.05$ or $P < 0.01$) [22,23,26]. It was also negatively associated with the progression of concomitant diseases and mortality risk [29].

The mean PhA values in individuals with SO varied among studies, ranging from 3.9° [28] to 5.6° [27], with an outlier high value of 7.1° [22]. The only studies that considered the sexes separately reported PhA values of 4.3° [25], 5.1° [23] and 5.6° [27] in men and 4.1° [25], 4.6° [23] and 4.8° [27] in women (Table 2). Some authors proposed cut-off values for the prediction of sarcopenic obesity: 4.3° for men and 3.8° for women in a sample of Japanese post-stroke older individuals [28], 4.4° for both sexes combined in a sample of patients with type 2 diabetes [30], and 5.5° for men and 4.8° for women in a sample of the general Chinese population [23]. Such values correspond to sensitivity values ranging between 0.57 [30] and 0.76 [23] and specificity between 0.61 [30] and 0.84 [28].

Individuals with SO exhibited significantly lower PhA values than healthy participants ($P < 0.001$) in two out of three possible comparisons [23,27], while the third study [26] detected a significant difference when considering the combined group of SO and S samples. This pattern was confirmed in a cohort of cancer patients ($P = 0.023$) [29] and in post stroke patients [28]. Araújo [22] detected similar, albeit non-significant, differences in frail individuals.

Individuals with SO also showed significantly lower PhA values compared to individuals with obesity ($p < 0.001$) in three of the four possible comparisons, with sexes combined [28,30], or only in females [27], whereas Brunani [25] detected the same tendency, but no significant difference.

The SO samples showed similar PhA compared to individuals with sarcopenia in five out of six comparisons [22,26,27,28,29], while one study showed higher PhA among SO ($P = 0.04$, when classified using EWGSOP criteria and $P < 0.001$ when classified using FNIH criteria) [24].

In summary, the possible following general patterns can be identified (Table 2 and Fig. 3). Where the comparison was possible, the phase angle values in sarcopenic obesity were:

- lower than in healthy conditions [23,26,27], or than in control groups in studies focusing on diseased samples [28,29];
- lower than in obesity [27,28,30];
- similar to [22,26,27,28,29] or higher than [24] in sarcopenia.

Bioelectrical impedance vector analysis

The two studies that used specific BIVA [26,27] highlighted the potential utility of this approach in characterizing the bioelectrical features of individuals with sarcopenic obesity. These features

Table 2
Methods and results of selected studies

Reference	Objective	SO definition	SO prevalence[†]	Methods for diagnosis	Diagnostic parameters and cut-offs	Results	Bioelectrical values
Araújo et al.[22]	To investigate the association between PhA and frailty/pre-frailty, nutritional and clinical aspects in older people	Coexistence of sarcopenia (EWGSOP) and obesity	11.7% (51)	-BIA (Sanny BIA 1010) -HGS (Saehan SH5001)-Physical performance (gait speed)	-ASMMI (ASMM/H[†]) < 8.87 kg/m[‡] M, < 6.42 kg/m[‡] F. -HGS < 30 kg M, < 20 kg F. -BF% ≥ 28% M, ≥ 40% F. -gait speed > 5.31" and 5.27" M, > 5.72" and 5.63" F	PhA of SO was higher than control group, (characterised by a high prevalence of frailty)	- PhA in SO: 7.10° ± 2.19. -PhA in S: 6.73° ± 1.50. -PhA in non-SO: 6.46° ± 0.91[‡]
Beberashvili et al. [24]	To examine differences in nutritional status, QoL and clinical outcomes between non-obese S and patients with SO in MHD	Coexistence of sarcopenia (EWGSOP and FNIH criteria) and obesity	31.5% (EWGSOP), 38.3% (FNIH) (261)	-BIA (Nutriguard-M DataInput) -HGS (Harpenden)	EWGSOP: -SMMI (SMM/H[‡]) < 8.87 kg/m[‡] M, < 6.42 kg/m[‡] F. -HGS_{BMI}[§]. FNIH: -SMI (ALM/BMI) < 0.789 M, < 0.512 F. - HGS_{BMI}[§]. -FM% ≥ 27% M, ≥ 38% F	PhA was significantly higher in SO than sarcopenic individuals	-PhA in SO: 4.5° ± 0.9. -PhA in S: 4.0° ± 1.2 (EWGSOP) 3.7° ± 0.8 (FNIH)[‡]
Brunani et al. [25]	To determine whether a weight-loss programme worsens or improves HGS and body composition in patients with SO	ESPEN-EASO	9.4% (2004)	-BIA (BIA 101 Akern) -HGS (JAMAR)	-SMMI (SMM/W ×100) < 37% M, < 27.6% F. -HGS < 27kg M, < 16kg F. -BMI > 30 kg/m[‡]	After the weight loss programme, 42.6% of SO patients were no longer sarcopenic. Improvements in HGS and PhA raised the probability of no longer being SO to 93%	- Baseline PhA in SO: M = 4.31° ± 0.83, F = 4.07° ± 0.82, Post-intervention PhA: -No $SO_{discharge}$ 4.18° ± 0.87, -$SO_{discharge}$ 4.06° ± 0.8
Hafızoğlu et al. [30]	To evaluate the relationship between SO and PhA among diabetic adults	ESPEN-EASO	19.6% (322)	-BIA (Bodystat Quadscan 4000) -HGS (Takei TKK 5401) -Physical performance (CST, TUG)	-SMMI (SMM/W × 100) ≤ 37% M, ≤ 27.6% F. -HGS <27 kg M, <16 kg F. -BMI ≥ 30 kg/m[‡]. -FM% >31% M, >43% F. -CST ≥17 s	Low PhA was significantly related to SO. PhA can be considered a potential biomarker for SO in adults with type 2 DM	-PhA in SO: 4.30° (3.70-5.30). -PhA in non-SO 4.80° (4.10-5.50)[†]. Cutoff of PhA for predicting SO was 4.4°
Luo and Jin [23]	To establish PhA reference data for the SO population and to investigate the relationship between PhA and SO	Coexistence of sarcopenia (AWGS) and obesity	1.4% (10312)	-BIA (InBody 720) -HGS[‖]	-ASMI (ASMM/H[‡]) < 7kg/m[‡] M, < 5.7kg/m[‡] F -HGS <28 kg M, <18 kg F -BMI ≥ 24kg/m[‡] -WC ≥ 90cm M, ≥ 85cm F FM% ≥ 25% M, ≥ 35% F	PhA was negatively associated with SO, independently of age and sex. PhA could be considered as a potential biomarker for SO	-PhA in SO: M = 5.08° ± 0.68, F = 4.55° ± 0.74. -PhA in non-SO: M = 5.81° ± 0.66, F = 5.03° ± 0.54. Cutoff values of PhA for predicting SO were 5.55° for men and 4.79° for women
Marini et al. [26]	To investigate whether BIVA can be a suitable technique for sarcopenia and to evaluate the potential use of specific BIVA as an indicator of SO	Coexistence of sarcopenia (EWGSOP) and obesity. Focused on body composition, HGS not performed	4.35% (8 men and 1 woman) (207)	-BIA (BIA 101 Akern) -Classic BIVA -Specific BIVA -DXA (Hologic QDR-4500 W)	-SMI (SMM/H[‡]) < 7.26 kg/m[‡] M, < 5.45 kg/m[‡] F. -FM% > 23.8% M, >36.4% F	BIVA is useful for detecting muscle-mass variations in S[¶]. Specific BIVA can discriminate between S and SO	-PhA in SO: 5.3° ± 0.9. -PhA in S: 4.7° ± 1. -PhA in non-S: M = 6.1° ± 1.1.
Marini et al. [27]	To investigate the suitability of specific BIVA in the analysis of SO	ESPEN-EASO for body composition, HGS not performed	4.70% (915)	-BIA (BIA 101 Akern) -Specific BIVA -DXA (Hologic QDR-4500A)	-ASM/W × 100 < 25.72 % M, < 19.43 % F -FM% >31% M, >43 % F	Groups with obesity (O and SO) had longer vectors than those with S. SO vectors were located in the upper-right quadrant	-PhA in SO: M = 5.6° ± 1, F = 4.8° ± 0.6. -PhA in S: M = 5.2 ± 0.9, F = 4.6 ± 0.6. -PhA in obesity: M = 6.0 ± 1.2, F = 6.1 ± 1.1. -PhA in others: M = 7.2 ± 1.2, F = 6.2 ± 1.3.

(*continued on next page*)

Table 2 (*Continued*)

Reference	Objective	SO definition	SO prevalence[†]	Methods for diagnosis	Diagnostic parameters and cut-offs	Results	Bioelectrical values
Sat-Muñoz et al. [29]	To determine the role of PhA in the of head and neck cancer outcomes in patients with a high prevalence of overweight and obesity	Coexistence of sarcopenia (EWGSOP) and obesity	27.3% (139)	-BIA (mBCA 514 SECA) -HGS (Jamar)	-SMMI (SMM/H[‡]) < 8.87 kg/m[‡] M, < 6.42 kg/m[‡] F -BMI ≥ 25kg/m[‡]	Low PhA was associated with an adverse prognosis in pts with sarcopenia and SO	-PhA in SO 4.2° ± 0.84, -PhA in S 4.0° ± 0.91, -PhA in non-S 4.7° ± 0.83[‡]
Yoshimura et al. [28]	To investigate the association between PhA and SO, sarcopenia and obesity in post-stroke patients	ESPEN-EASO	4.5% (760)	-BIA (InBody S10) -HGS	-SMM/W × 100 < 31.5% M, < 22.1% F. -HGS < 28 kg M, <18 kg F. -FM%> 29.7% M, >37.2% F	PhA was negatively associated with SO	Median PhA: -SO 3.9° (3.75-4.10), -S 4.1° (3.73-4.40), -obese 4.5° (4.30-4.72), -others 5.0° (4.68-5.70)[‡] Cut-off values of PhA for predicting SO were 4.29° for men and 3.84° for women

ALM, appendicular lean mass; ASM, appendicular skeletal mass; ASMMI, appendicular skeletal muscle mass index; AWGS, Asian Working Group for Sarcopenia; BIA, bioelectrical impedance analysis; BIVA, bioelectrical impedance vector analysis; BMI, body mass index; CST, chair stand test; DM, diabetes mellitus; DXA, dual-energy X-ray absorptiometry; ESPEN-EASO, European Society for Clinical Nutrition and Metabolism European Association for the Study of Obesity; EWGSOP, European Working Group on Sarcopenia in Older People; FNIH, Foundation for the National Institutes of Health; FM%, fat mass percentage; H, height; HGS, hand grip strength; MHD, maintenance hemodialysis; QoL, quality of life; S, sarcopenia; SMMI, skeletal muscle mass index; SMI, skeletal muscle index; SO, sarcopenic obesity; TUG, timed up and go test; W, weight; WC, waist circumference.

[†]The number in parentheses represents the total sample size.

[‡]No distinction between sexes for PhA values.

[§]values are adjusted for BMI and cut-offs vary according to BMI.

[‖]dynamometer model not specified.

[¶]PhA values for SO and BIVA analysis available for males only.

Table 3
Variability of diagnostic indices and cut-offs applied in the included studies[†]

Obesity			
Parameter	Cut-offs used in the selected studies		
BMI	24 kg/m[‡] 25 kg/m[‡] 30 kg/m[‡]		
FM%	≥ 28% M, ≥ 40% F ≥ 27% M, ≥ 38% F ≥ 25% M, ≥ 35% F > 23.8% M, > 36.4% F > 29.7% M, > 37.2% F > 31% M, > 43% F		
WC	≥ 90 cm M, ≥ 85 cm F		
Sarcopenia			
Criteria	Steps for diagnosis	Muscle mass indices	Cut-offs used in the selected studies
AWGS	1: Muscle strength: HGS 2: Physical performance 3: Muscle mass	DXA or BIA: ASM/H[‡ ‡]	BIA: M < 7.0 kg/m[‡] F < 5.7 kg/m[‡]
EWGSOP[§]	1: Physical performance: gait speed 2: Muscle strength: HGS 3: Muscle mass	DXA: skeletal muscle mass index (SMI) BIA: skeletal muscle mass index (SMI) or absolute muscle mass values	DXA: M < 7.26 kg/m[‡] F < 5.5 kg/m[‡] BIA: M < 8.87 kg/m[‡] F < 6.42 kg/m[‡]
FNIH	1: Muscle strength: HGS 2: Muscle mass 3: Physical performance: mobility, gait speed	DXA: ASM_{BMI}[‡]	M < 0.789 F < 0.512

Sarcopenic obesity			
Criteria	Steps for diagnosis	Parameters	Cut-offs
ESPEN-EASO	1: High BMI or WC 2: Altered skeletal muscle functional parameters: HGS, chair stand test 3: Altered body composition: FM% and reduced muscle mass	DXA: ASM/W[‡] BIA: SMM/W	Population specific cut-offs

ASM, appendicular skeletal mass; AWGS, Asian Working Group for Sarcopenia; BIA, bioelectrical impedance analysis; BMI, body mass index; DXA, Dual-Energy X-ray absorptiometry; ESPEN-EASO, European Society for Clinical Nutrition and Metabolism – European Association for the Study of Obesity; EWGSOP, European Working Group on Sarcopenia in Older People; FM%, fat mass percentage; FNIH, Foundation for the National Institutes of Health; H, height; HGS, hand grip strength; SMM, skeletal muscle mass, W, weight; WC, waist circumference.
[†]The diagnostic indices are those provided by the criteria, whereas the cut-offs are those used by the mentioned studies.
[‡]ASM is also called ALM in the reviewed criteria.
[§]The same group of researchers published an updated version of the criteria, defined the EWGSOP2 criteria, but none of the studies used this version.

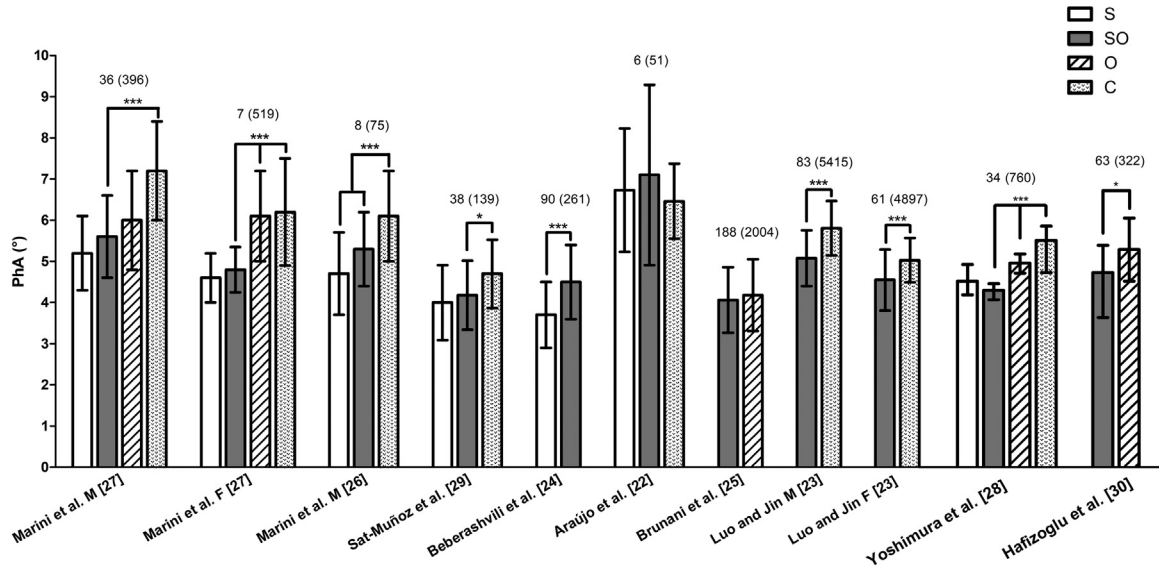

Fig. 3. Phase angle values across different groups in the selected studies S, sarcopenia; SO, sarcopenic obesity; O, obesity; C, controls. The first number above the bars refers to cases with sarcopenic obesity and, in parentheses, the total sample size. The figure shows significant comparisons only involving the sarcopenic obesity group. Control groups referred to healthy individuals in Luo and Jin [23], Marini [26], and Marini [27], and included different clinical conditions in the remaining studies. In Beberashvili [24], we considered the PhA values based on the FNIH criteria as results.

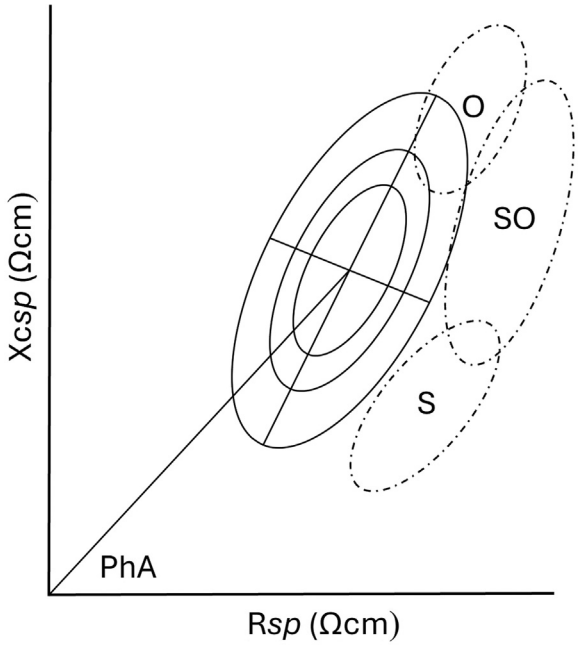

Fig. 4. Potential areas for sarcopenic obesity (SO), sarcopenia (S), and obesity (O) in specific BIVA.

include low phase angle values, as discussed above, as well as long bioelectrical vectors, which indicate high FM% values. Notably, SO individuals' vectors were located in a recognizable area in the upper right quadrant, outside the tolerance ellipses and partially overlapping the overweight-obesity area defined by BIVA, but shifted to the right, closer to the S group [26,27]. Within the SO area, the position of the vectors among men was associated with body composition impairment : those in the lower-right quadrant, characterized by lower PhA values, were associated with significantly lower ASM/W values ($P = 0.016$) [27].

The sole study using classic BIVA [26] demonstrated its ability to detect variations in muscle mass among individuals of the S group. However, classic BIVA was unable to distinguish differences in body composition between S and SO individuals ($P = 0.318$).

Discussion

Phase angle and BIVA are widely and increasingly used in research and applications. However, their use in analyzing body composition in sarcopenic obesity is still limited.

The reviewed studies yielded heterogeneous quantitative results. The prevalence of sarcopenic obesity ranged from 1.4% in the general Chinese population [23] to 38.3% in a sample of hemodialysis patients [24]. The mean PhA values associated with SO ranged from 3.9° [28] to 7.1° [22], although they were mostly below 5.6°. The proposed cut-off points for sarcopenic obesity also varied across samples, ranging from 3.8° in women [28] to 5.5° in men [23].

Such variability is largely attributable to methodological differences across studies, including diagnostic criteria (the ESPEN-EASO algorithm or other approaches for defining sarcopenia and obesity separately), indices (ASM or SMM standardized by height, weight, or BMI; BMI, waist circumference, or FM%), cut-offs (population specific thresholds for body composition), samples characteristics (including diseased samples and possibly overweight or presarcopenic individuals), and bioimpedance devices (mono- or multi-frequency, used in the supine or standing position).

Furthermore, most analyses were performed on data aggregated by sex. Given the significant sexual dimorphism of bioelectrical values [10,19], the observed estimates may be biased by different proportions of males and females. In this review, the only studies that distinguished between the sexes [23,25,27] showed that the mean PhA values were 0.2−0.8 degrees higher among SO men than women.

All of these factors hinder the comparability and generalizability of results for both estimates of sarcopenic obesity prevalence and for proposed cut-off values. In light of this variability, many researchers and expert panels recommend standardizing phase angle values according to sex, age, and population [35]. However, the appropriateness of this approach requires careful consideration. Standardization may be appropriate in certain cases, such as when using different devices or when comparing sexes. Conversely, standardization by population may lead to misleading results when populations are not correctly defined or if relevant differences in body composition that are important for diagnosis, are artificially removed (Marini, 2025, in prep).

Further criticisms on the diagnostic utility of PhA was raised by Norman et al. [36], who argued that a disease-specific cutoff is unlikely to be meaningful, as PhA provides no information on aetiology and lacks specificity.

Despite the above limitations − regardless of sex, population and of methodological protocol used - the bioelectrical pattern associated with the body composition characteristics of sarcopenic obesity appears to be informative. PhA was significantly lower in SO than in healthy subjects [23,26,27] and patients with obesity [27,28,30]. PhA appeared similar to that in individuals with sarcopenia [22,24,26,27,28,29], with one exception showing higher values [24].

The low PhA values observed in SO individuals indicate their impaired body composition and are likely due to a relatively low quantity and quality of muscle mass, as well as low functionality. Indeed, mean PhA values in healthy adults (19−48 years) have been estimated at 6.9−7.2 in men and 6.1−6.3 in women [37], i.e. 1−2° higher than most values associated with SO. In line with the present review, the literature indicates that sarcopenia is associated with lower phase angle values [38]. The lower PhA values compared to obesity are also consistent with expectations, as sarcopenic obesity combines and amplifies the adverse health outcomes and risks associated with both obesity and sarcopenia [1]. On this basis, PhA may be used to monitor level and progression of sarcopenic obesity, and the efficacy of interventions, and possibly identify individuals with sarcopenic obesity within the broader context of obesity, as defined by anthropometry.

On the other side, the similar PhA values in SO compared to sarcopenia would suggest a similar quantity and quality of muscle mass. At this regard, it should be noted that PhA appears inappropriate to distinguish the body composition characteristics of sarcopenic obesity from those of sarcopenia, as it has demonstrated a poor ability to detect changes in fat mass [8].

To obtain a complete evaluation of body composition, including body fat, other techniques must be employed. Considering the limited availability of reference methods such as DXA, magnetic resonance imaging and computer tomography, the assessment of body fat must frequently rely on indirect techniques such as conventional BIA, anthropometry, or emerging ultrasound techniques. However, BMI is inaccurate because it is also determined by fat-free mass content, whereas estimates based on skinfolds are subject to substantial measurement error [39]. Ultrasound techniques show promise for measuring subcutaneous fat, although the accuracy of total body fat estimates is less well established, particularly in individuals with overweight or obesity [31]. The conventional BIA procedure is widely used and recommended by expert panels

[1,2], but it involves a risk of error related to the use of regression equations.

A suitable option is bioelectrical impedance vector analysis, particularly the specific approach.

Thanks to the contextual analysis of phase angle and vector length, specific BIVA can accurately recognize variations in muscle mass and quality, as well as in FM% [19]. Indeed, the specific vectors length demonstrated accuracy in estimating FM% in adults when validated against DXA (ROC areas: 0.84–0.92) [19], a finding repeatedly confirmed in samples differing in age, geographic origin and lifestyle. Consistently with theoretical expectations, in the reviewed studies, the vectors of SO samples are longer than those of healthy individuals or individuals with sarcopenia [26,27], and are more inclined, i.e. characterized by lower phase angles, than those of healthy or obese individuals [27]. Specific BIVA was also able to detect the internal variability of body composition characteristics of SO: among cases showing longer vectors, individuals with higher phase angles were characterized by greater muscle mass [27].

Thus, specific BIVA could be used to distinguish differences in body composition between individuals with sarcopenia (low phase angles and short vectors), sarcopenic obesity (long vectors and low phase angles), and obesity (long vectors and normal phase angles), without the need for different indices (Fig. 4). It could also allow the comparison of body composition variability among individuals with SO. This possibility would benefit from further investigation in more groups, in relation to muscle strength and function, and health status in general.

The only article using classic BIVA showed that it could detect significant differences between sarcopenic and healthy groups. However, it could not distinguish between the body compositions of sarcopenic and sarcopenic obese groups [26]. Indeed, unlike the specific BIVA vector, whose length reflects FM%, the information conveyed by the classic vector length is related to total body water. This suggests that the analyzed sample of individuals with obesity did not show significant fluid imbalance, emphasizing the need for further studies on different samples.

The main limitation of this review is the small number of available studies, as well as the substantial heterogeneity in their diagnostic procedures, BIA devices and study populations. In particular, the samples and their control groups varied considerably with respect to age and sex, with the latter often not specified. The SO and S groups were defined using different procedures, indices and cut offs. Some studies also focused on samples of people with diseases of varying severity. These factors inevitably limited the comparability of the results and reduced the strength of the evidence, particularly with regard to BIVA, which was only used in two studies, both of which were conducted by some of the authors of this review.

However, these limitations can also be viewed as key factors that strengthen the review's results, as they highlight the need for the international scientific community to make greater efforts to compare and harmonize procedures. Furthermore, despite the heterogeneity, the emerging tendencies suggest the potential of alternative BIA approaches for detecting body composition features related to sarcopenic obesity, which warrant further investigation.

Conclusions

This review shows that phase angle and BIVA are at the beginning of their potential use in sarcopenic obesity.

The studies reviewed showed a high level of methodological variability, encompassing diagnostic criteria, indices, cut-offs and bioimpedance devices. This makes it difficult to define typical ranges or diagnostic thresholds and emphasizes the importance of international efforts to establish standardized procedures to obtain comparable results.

However, the qualitative pattern of bioelectrical characteristics associated with body composition in SO is consistent with theoretical expectations, with previous research on other conditions, and across studies: PhA tends to be lower than in healthy individuals and in those with obesity, and is similar to individuals with sarcopenia; the specific vector is longer than in healthy individuals and in those with sarcopenia.

Therefore, PhA is a possible tool for distinguishing the impairment of body composition in sarcopenic obesity compared to a healthy state and obesity, although it does not allow discrimination from sarcopenia. The distinction with individuals with sarcopenia, whose muscle mass and quality appears similar, is possible using specific BIVA due to its ability to recognize differences in fat mass. Conversely, classic BIVA, whose vector length is sensitive to differences in body water, did not detect significant differences between individuals with sarcopenia and sarcopenic obesity.

These findings suggest the potential value of phase angle and, in particular, specific BIVA in characterizing and analyzing body composition impairments in sarcopenic obesity, and monitoring disease progression and the effectiveness of interventions. However, the standardization of the procedure, the definition of diagnostic cut-offs and the utility of classic BIVA require further research.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Lorenzo Maria Donini reports financial support was provided by European Union. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Karina Pozo: Writing – review & editing, Writing – original draft, Visualization, Formal analysis. **Federica Frau:** Writing – review & editing, Writing – original draft, Visualization, Formal analysis. **Valeria Succa:** Writing – review & editing, Formal analysis. **Lorenzo Maria Donini:** Writing – review & editing. **Elisabetta Marini:** Writing – review & editing, Writing – original draft, Conceptualization.

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Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.nut.2025.112960.

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