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Comparison of bioelectrical impedance analysis-derived phase angle in individuals with different weight status

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Objective: Obesity is characterized not only by an increase of fat mass but also by alterations in skeletal muscle. Bioimpedance analysis (BIA)-derived phase angle (PhA) may provide specific information on the inherent characteristics of fat-free mass, and is widely used as an index of poor nutritional status. The aim of this study was to describe whether and to what extent PhA varies depending on age, sex, and body mass index (BMI) in individuals with different weight status.
Methods: We selected 1877 participants for this retrospective study (two weight status groups): 983 individuals with obesity (age 40 ± 13.9 y; BMI 39.5 ± 7.2 kg/m^2) and 894 controls (age 40 ± 13.3 y; BMI 24.6 ± 2.7 kg/m^2). Anthropometry and PhA at 50 kHz for the whole body were performed in all participants.
Results: PhA was greater in men than in women, although a decline of PhA was observed with age, which was linear in women and occurred in men after 40 y of age. On the other hand, no significant differences were observed with increasing BMI in either sex; lower values might be observed when BMI >50 kg/m^2.
Conclusions: A more detailed appraisal of BIA-derived PhA in obesity is reported in the present study, providing basic data that might be taken into consideration in prevention and clinical nutrition. Further studies are needed to explore differences of PhA in individuals with different weight status.

Introduction

Obesity is characterized not only by an increased fat mass but also by alterations in metabolic and functional characteristics, as well as in the composition of skeletal muscle [1]. Excess body fat is directly linked to inter- and intramuscular fat infiltration [2], muscle-related metabolic abnormalities [2], and decreased strength and mobility [3].

Bioelectrical impedance analysis (BIA) is a widely used, noninvasive field method for assessing body composition. BIA evaluates the electrical characteristics of human tissues [4] in terms of impedance (Z) and phase angle (PhA). BIA is performed by injecting a small alternating current through the body at 50 kHz (single frequency) or at different frequencies (multifrequency and bioimpedance spectroscopy).

Reactance (R) or Z, almost always along with age, stature, and body weight [5], are included in predictive equations to estimate fat-free mass (FFM) and total body water (TBW), and less frequently, skeletal muscle mass (SM), appendicular skeletal muscle mass (ASM), body cell mass (BCM), extracellular water (ECW), and intracellular water (ICW). Although the accuracy at a group level and in the single individual must be considered with care [6,7], the BIA-derived estimates of FFM, SM and ASM are commonly employed in the clinical setting, for instance for the diagnosis of malnutrition or sarcopenia [8].

Alternatively, PhA at 50 kHz may provide additional information on the inherent bioelectrical characteristics (i.e., capacitance) of FFM [9]; high PhA suggests cellular integrity, greater cellularity (e.g., more BCM relative to FFM) and a low ECW/TBW ratio [9]. As an index of nutritional status, low PhA is associated with impaired muscle strength [10], and it is a significant predictor of poor outcomes such as frailty [11], incident disability [12], and mortality [4]; it is also related to impaired quality of life [13] and poor

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prognosis in various chronic diseases [9,14]. PhA values might be altered in individuals with obesity not only due to changes in BCM but also to those in tissue hydration, which occur because of a physiologically higher ECW/TBW ratio in adipose tissue or a fluid overload with edema [15].

A systematic review recently published [16] indicated that so far, and unexpectedly, only few papers have compared PhA between individuals with obesity and controls, with contradictory evidence suggesting lower values compared with controls only when excess body fat was very marked [16]. A decline in PhA values with age has also been reported [16], but, to our knowledge, no detailed analysis is available on the trend over decades. As far as the relationship with body mass index (BMI) is concerned, evidence is also not conclusive [17,18] especially for individuals with moderate to severe obesity, whereas a lower PhA might be observed in individuals with very severe obesity [16,18].

Considering this background, it is reasonable to address these issues in a group of individuals with different weight status. Thus, the present study aimed to provide detailed information on whether and to what extent PhA varies depending on age, sex, and BMI in a sample of individuals with obesity compared with controls.

Materials and methods

Individuals with obesity were selected for the present retrospective study (data from 2015 to 2020) in two tertiary centers for obesity care in Naples: Department of Clinical Medicine and Surgery, Federico II University and S. Maria della Pietà Hospital, Casoria. Control participants were drawn from a database comprising unpublished data (historical controls).

Inclusion criteria were both sexes and age ≥20 y. Individuals with liver, heart, lung, or kidney failure or peripheral vein thrombosis, those with abnormal body geometry (such as arm or leg amputation), and individuals with peripheral edema, as identified from physical examination (grading system for pitting edema) were excluded. Individuals with obesity had a BMI ≥30 kg/m^2 and controls a BMI <29 kg/m^2 by considering the distribution of BMI in the general population. The ethics committee of the Federico II University of Naples approved the research protocol. Participants provided written informed consent before participation.

Participants were tested by the same operator following standard procedures according to Lohman et al. [19]. Body weight was measured in duplicate to the nearest 0.1 kg using an extra-large weighting platform (7708 platform scale; Soehnle Industrial Solutions GmbH, Backnang, Germany), and stature was measured in triplicate to the nearest 0.1 cm using a wall-mounted stadiometer (Seca 222; Seca Hamburg, Germany) with participants wearing light clothes and no shoes. Mean values were used for calculating BMI as body weight (kg) divided by squared stature (m^2).

BIA was performed by a Human IM Touch phase-sensitive multifrequency device (DS Medica S.r.l., Milan, Italy), in standardized conditions (abstention from alcohol, smoking and rigorous physical activity for 24 h before the assessment, in fertile women during the follicular phase, ambient temperature 23–25°C, fasting >8 h, empty bladder, supine position for ≥10 min before starting the measurement) [20]. After cleaning skin surface, participants were asked to lay down with upper and lower limbs slightly abducted, so there was no contact between the extremities and trunk. A standard tetra-polar technique was used (disposable adhesive electrodes, FIAB S.r.l., Florence, Italy); measuring electrodes were placed on the anterior surface of the wrist and the ankle, and injecting electrodes on the dorsal surface of the hand and the foot. Z and PhA were measured at 50 kHz on both sides of the body for obtaining a more comprehensive evaluation of BIA variables. Mean values for dominant and non-dominant sides were considered for statistical analysis. Precision resistors and capacitors (reference electronic circuits) were routinely used for calibration. The reproducibility of the BIA was previously assessed in 10 healthy volunteers on subsequent days with a mean coefficient of variation of 1.5% for Z (at each of the different frequencies considered) and 2% for PhA at 50 kHz.

Statistical analysis

Taking into consideration the actual difference of PhA between men with obesity (n = 342) and control men (n = 413), as reported in Table 1, a statistical power of 0.99 was calculated for an α level of 0.01. Additionally, for correlation analysis, statistical power was 0.97 assuming r = 0.20, α level = 0.01 and a sample size of 342 participants (the lowest sample size among the four main groups).

Statistical analyses were carried out using SPSS version 26 (SPSS Inc., Chicago, IL, USA). The Kolmogorov–Smirnov test was used to assess normality of all numerical continuous variable and showed a normal distribution of variables. Results are expressed as mean ± SD unless otherwise specified. Levels of statistical significance was predetermined as P < 0.05. The generalized linear model (GLM) was used to assess the effects of variables of interest on PhA. One-way analysis of variance (with the Tukey post-hoc test) was used for the comparison between groups in either sex. The relationships between variables were evaluated by linear correlation, multiple regression analysis, and piecewise regression analysis (https://stats.oarc.ucla.edu/spss). The model with the best fit was the one with the smallest mean squared error.

Results

We studied 1877 individuals: 983 with obesity, 34.8% men; and 894 controls, 46.2% men. Tables 1 and 2 present their general characteristics by age groups and weight status. Men had greater weight and stature than women in both weight status groups, but similar age and BMI. Age and stature did not differ between the two weight status groups. No significant differences emerged between age groups, with only few exceptions (Tables 1 and 2).

Tables 1 and 2 also showed that Z was significantly greater in men than women, and in individuals with obesity compared with controls. In both sexes, mean PhA were found similar for the two weight status groups (6.80 ± 0.86 versus 6.86 ± 0.96 degrees in men; 6.21 ± 0.74 versus 6.16 ± 0.73 degrees in women) and for each age span (Tables 1 and 2). The GLM indicated that PhA varied depending on sex and age in both weight status groups, with a significant interaction between these two variables. As shown in Tables 1 and 2, PhA was greater (P < 0.001) in men than women similarly in individuals with obesity (+9.5%) and controls (+11.4%). The differences between sexes in PhA were lower in individuals >50 y of age than in those 20 to 30 y, being +4.3% versus +12.1% in individuals with obesity, and +5.7% versus +13.8% in controls.

PhA clearly differed with age; as reported in Tables 1 and 2, comparing the oldest with the youngest age group, PhA was lower in both individuals with obesity (−16% in men and −10% in women) and controls (−17% and −11%). Figure 1 shows the relationship between PhA and age by weight status in both sexes. Piecewise regression analysis indicated that PhA did not differ from 20 to 40 y with a subsequent variation (−0.050 degrees/y in men with obesity and −0.040 degrees/y in controls). On the other hand, in women a continuous decrease (around −0.018 degrees/y) was observed, again with no difference between the two weight status groups.

PhA weakly correlated with weight in men (both weight status groups) and in women with obesity (data not shown). PhA in different BMI groups is reported in Table 3: According to the GLM (also considering sex and age), no differences were observed in either sex between BMI groups up to ~50 kg/m^2, whereas there was a tendency toward lower values in the participants with BMI >50 kg/m^2. As a matter of fact, PhA was not significantly lower (P < 0.10) in those with BMI >50 kg/m^2 compared with individuals with BMI ≤50 kg/m^2, being 6.57 ± 0.83 versus 6.82 ± 0.86 degrees in men, and 6.04 ± 0.75 versus 6.23 ± 0.73 degrees in women. The absence of a firm relationship between PhA and BMI is shown in Figure 2, which also suggested that the variability of PhA did not depend on BMI.

Discussion

In this study we performed an evaluation of PhA in individuals with different weight status and no major comorbidities. In both weight status groups, our findings showed higher PhA in men than women, whereas a decline was observed with age, which was not

Table 1
Age, anthropometric data and bioimpedance analysis variables according to age subgroups in 755 men participating in the study

	Age groups, y				
	20–30	30–40	40–50	>50	All
Participants with obesity, n	106	82	70	84	342
Age, y	24 ± 3.6[*,†,‡]	35.7 ± 3[*,§,‖]	46.2 ± 2.7[†,§,¶]	59.4 ± 6[‡,‖,¶]	40 ± 14.2
Weight· kg	122.1 ± 22.4[‡]	122.2 ± 22.4[‖]	126.4 ± 28[¶]	112.2 ± 22.1[‡,‖,¶]	120.3 ± 24.4
Stature· cm	175.3 ± 7.4[‡]	175.2 ± 7.4[‖]	176.2 ± 6.1[¶]	172.1 ± 8[‡,‖,¶]	175.4 ± 7.3
BMI· kg/m^2	39.9 ± 7.3	39.3 ± 6.5	40.4 ± 7.5	37.8 ± 6.4	39.4 ± 7.2
Z at 50 kHz· ohm	424 ± 58[*,†,‡]	399 ± 52[*]	384 ± 48[†]	387 ± 54[‡]	401 ± 56
PhA· degrees	7.22 ± 0.63[†,‡]	7.11 ± 0.74 [§,‖]	6.68 ± 0.66[†,§,¶]	6.08 ± 0.87[‡,‖,¶]	6.80 ± 0.86
Controls· n	115	102	117	79	413
Age· y	23.8 ± 3[*,†,‡]	35.38 ± 3.2 [*,§,‖]	46.68 ± 3.3[†,§,¶]	59.5 8 ± 4.5[‡,‖,¶]	39.9 8 ± 13.3
Weight· kg	74.8 ± 10.2[*]	79.2 ± 11[*,§,‖]	75.6 ± 10.2[§]	72.8 ± 9.7[‖]	75.7 ± 10.5
Stature· cm	174.1 ± 7.3[‡]	176.2 ±	175.4 ± 7.1[¶]	172.1 ± 7.2[‡,‖,¶]	174.1 ± 7.3
BMI· kg/m^2	24.5 ± 2.6	25.5 ± 2.6	24.8 ± 2.7	24.6 ± 2.4	24.9 ± 2.6
Z at 50 kHz· ohm	481 ± 57	468 ± 56	475 ± 62	472 ± 62	474 ± 5
PhA· degrees	7.33 ± 0.84[†,‡]	7.22 ± 0.92[§,‖]	6.62 ± 0.87[†,§,¶]	6.07 ± 0.68[‡,‖,¶]	6.86 ± 0.96

BMI· body mass index; PhA· phase angle; Z· impedance
Data expressed as mean ± SD
No significant differences in PhA between individuals with obesity and controls
*$P < 0.05$ 20–30 y vs 30–40 y.
†$P < 0.05$ 20–30 y vs 40–50 y.
‡$P < 0.05$ 20–30 y vs >50 y.
§$P < 0.05$ 30–40 y vs 40–50 y.
‖$P < 0.05$ 30–40 y vs >50 y.
¶$P < 0.05$ 40–50 y vs >50 y.

Table 2
Age, anthropometric data, and bioimpedance analysis variables according to age subgroups in 1122 women participating in the study

	Age groups, y				
	20–30	30–40	40–50	>50	All
Participants with obesity, n	196	130	158	157	n *641*
Age, y	23.8 ± 3.2[*,†,‡]	35.7 ± 2.8[*,§,‖]	45.1 ± 2.8[†,§,¶]	58.5 ± 6.3 cef	40.0 ± 13.8
Weight· kg	101.4 ± 19.1	106.3 ± 2.1[‖]	106.6 ± 23.3	97.2 ± 17.7 ef	103.4 ± 20.1
Stature· cm	162.3 ± 6.2[‡]	162.2 ± 6.7[‖]	161.2 ± 5.3[‖]	157.4 ± 6.2 cef	161.6 ± 6.6
BMI· kg/m^2	38.3 ± 6.6 [†]	40.4 ± 7.6	40.8 ± 8.5 [†]	39.3 ± 6.7	39.6 ± 7.4
Z at 50 kHz· ohm	500 ± 62 [*,†,‡]	469 ± 65[*]	455 ± 69[†]	470 ± 61c	476 ± 66
PhA· degrees	6.44 ± 0.70[†,‡]	6.34 ± 0.63 [‖]	6.19 ± 0.69 [†,¶]	5.83 ± 0.76 cef	6.21 ± 0.74
Controls· n	131	117	120	113	n *481*
Age· y	24.1 ± 3[*,†,‡]	35 ± 2.8 [*,§,‖]	45.4 ± 3[†,§,¶]	58.7 ± 5.3 cef	40.2 ± 13.3
Weight· kg	62.5 ± 9.5	64.3 ± 8.1	65.4 ± 10.4	63 ± 9.7	63.8 ± 9.5
Stature· cm	162.8 ± 7.3[‡]	162.1 ± 6.3 [‖]	162.2 ± 7[¶]	159.6 ± 7.3 cef	161.3 ± 7.4
BMI· kg/m^2	23.8 ± 2.7 [†,‡]	24.3 ± 2.8	24.8 ± 2.7 [†]	24.9 ± 3.1 c	24.4 ± 2.8
Z at 50 kHz· ohm	584 ± 67 [*,†]	558 ± 64 [*]	558 ± 70 [†]	575 ± 82	569 ± 72
PhA· degrees	6.44 ± 0.60 [†,‡]	6.36 ± 0.73 [§,‖]	6.07 ± 0.72 [†,§,¶]	5.74 ± 0.67 cef	6.16 ± 0.73

BMI· body mass index; PhA· phase angle; Z· impedance
Data expressed as mean ± SD
No significant differences of PhA between participants with obesity and controls
*$P < 0.05$ 20–30 y vs 30–40 y.
†$P < 0.05$ 20–30 y vs 40–50 y.
‡$P < 0.05$ 20–30 y vs >50 y.
§$P < 0.05$ 30–40 y vs 40–50 y.
‖$P < 0.05$ 30–40 y vs >50 y.
¶$P < 0.05$ 40–50 y vs >50 y.

linear in men (marked decrease after the age of 40 y). No differences emerged compared with controls. No significant relationships were observed between PhA and BMI.

In theory, PhA values might be altered in individuals with severe obesity not only due to changes in BCM but also to those in tissue hydration, which could occur because of edema or physiologically higher ECW/TBW ratio in adipose tissue [17]. Overall, a recently published systematic review [16] showed still incomplete evidence regarding PhA in individuals with obesity with respect to differences compared with controls, as well as changes due to age and sex. Evidence on the relationship with BMI is also not conclusive [17,18], possibly with a lower PhA in individuals with very severe obesity [16,18]. From a clinical point of view, a more comprehensive understanding of PhA variability in obesity might be of interest for identifying alteration in FFM/muscle mass composition, which may be linked to low muscle strength (and sarcopenia).

Considering this background, the present study was carried out with a relatively large group of individuals with obesity compared with controls. Mean whole-body PhA, which is predominantly weighted to the lean soft tissues of upper and lower limbs, was 6.80 degrees in men and 6.20 degrees in women with obesity, which is in accordance with some previous studies [17,21,22], but slightly lower compared with others [23–25], possibly because of a higher mean age. On the other hand, there is no overt explanation for the discrepancy with a recent paper [18] reporting much

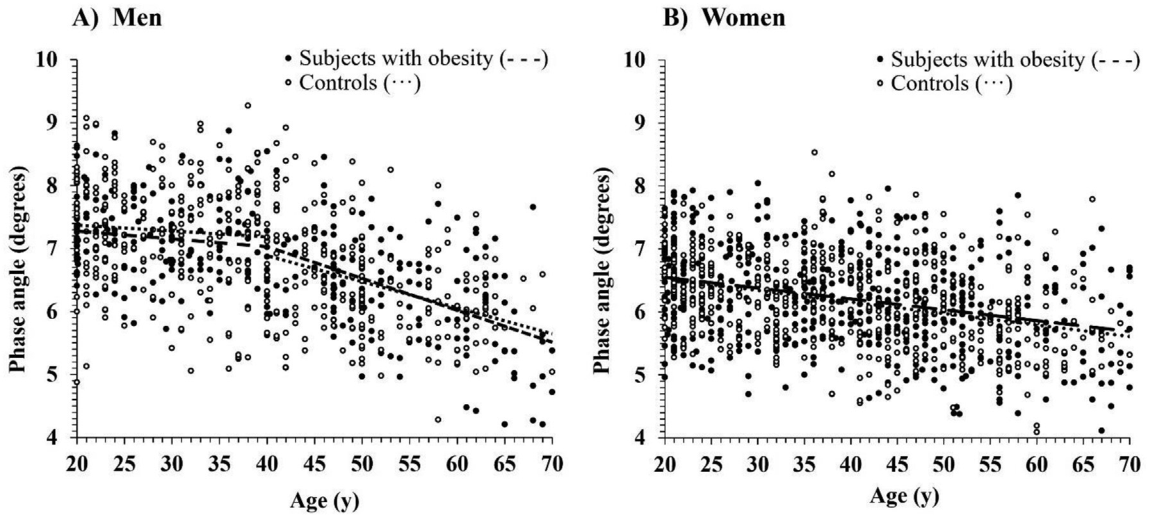

Fig. 1. Relationship between phase angle and age in either sex according to weight status. (**A**) Men with obesity : NS for age 20–40 y, and β= –0.050 degrees/y* for age >40 y. Control men : NS for age 20–40 y, and β= –0.040 degrees/y* for age >40 y.(**B**) Women with obesity β = –0.017 degrees/y*. Control women β = –0.019 degrees/y*. *P < 0.001. NS, not significant.

Table 3
Age, anthropometric data, and BIA variables according to BMI subgroups in 755 men and 1122 women participating in the study

	BMI groups, kg/m^2			
	20–30	30–40	40–50	>50
Men, n	413	205	111	26
Age, y	39.95 ± 13.3	40.9 ± 14.1	38.8 ± 14.2	38.3 ± 12
Weight, kg	76.2 ± 10.1*,†,‡	106.4 ± 13.2$^{*,\S,\|\|}$	142.2 ± 20†,§,¶	171.4 ± 18.2$^{\ddagger,\|\|,¶}$
Stature, cm	174.4 ± 7.2	174.1 ± 7.3	175.6 ± 7.1	175.5 ± 7.3
BMI, kg/m^2	24.9 ± 2.6*,†,‡	34.9 ± 3$^{*,\S,\|\|}$	46.1 ± 5.6†,§,¶	55.6 ± 4.6$^{\ddagger,\|\|,¶}$
Z at 50 kHz, ohm	474 ± 59*,†,‡	416 ± 51$^{*,\S,\|\|}$	387 ± 50†,§,¶	334 ± 59$^{\ddagger,\|\|,¶}$
PhA, degrees	6.86 ± 0.96	6.87 ± 0.87	6.73 ± 0.84	6.57 ± 0.83
Women, n	481	381	260	65
Age, y	40.2 ± 13.3	39.6 ± 14.2	40.5 ± 13.2	42.2 ± 12.9
Weight, kg	64.4 ± 10.2*,†,‡	90.4 ± 9.2$^{*,\S,\|\|}$	121.1 ± 17.1†,§,¶	142.2 ± 15.1$^{\ddagger,\|\|,¶}$
Stature, cm	161.3 ± 7.7	161.2 ± 6.5	161.3 ± 6	160 ± 6.6
BMI, kg/m^2	24.4 ± 2.8*,†,‡	34.7 ± 2.8$^{*,\S,\|\|}$	46.8 ± 6†,§,¶	55.4 ± 4.5$^{\ddagger,\|\|,¶}$
Z at 50 kHz, ohm	569 ± 72*,†,‡	504 ± 55$^{*,\S,\|\|}$	449 ± 55†,§,¶	391 ± 48$^{\ddagger,\|\|,¶}$
PhA, degrees	6.16 ± 0.73	6.25 ± 0.71	6.18 ± 0.77	6.04 ± 0.75

BMI, body mass index; PhA, phase angle; Z, impedance
Data expressed as mean ± SD
PhA significantly greater in men than women in all BMI groups
$^*P$ < 0.05 20–30 vs 30–40 kg/m^2
$^\dagger P$ < 0.05 20–30 vs 40–50 kg/m^2
$^\ddagger P$ < 0.05 20–30 vs >50 kg/m^2
$^\S P$ < 0.05 30–40 vs 40–50 kg/m^2
$^{\|\|}P$ < 0.05 30–40 vs >50 kg/m^2
$^{¶}P$ < 0.05 40–50 vs >50 kg/m^2

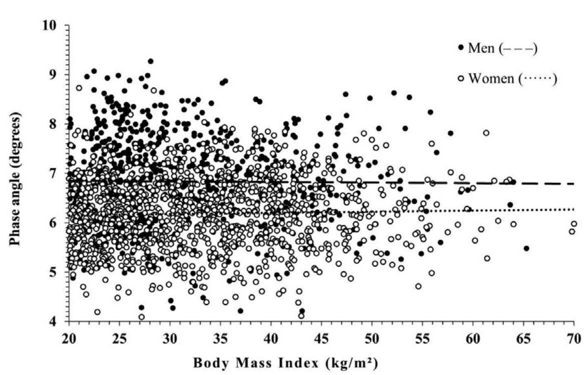

Fig. 2. Relationship between phase angle and BMI according to sex in 755 men – and 1122 women. BMI, body mass index; NS, not significant.

lower values; of note, in that paper there was no control group and individuals with comorbidities were not excluded. Mean values for controls were also in agreement with the available literature [5,17,26,27].

A major aim of the present study was to assess whether PhA differed because of weight status (see section on BMI). We found no significant difference in PhA between individuals with obesity and controls in either sex, and this was true also for the different age groups (Tables 1 and 2), strongly supporting the findings of previous studies [21,28]. Indeed, it is worth noting that differences versus controls might have been expected in individuals with obesity and fluid overload (i.e., due to heart failure [29], edema [30], or inflammation [31]).

As a second point, differences between sexes have been examined, considering that differences between men and women have been reported in individuals with obesity by some papers [16,17], but not by others [18,23]. The present study showed greater PhA (~10%) in men than in women independent of weight status; percentiles of PhA in individuals with obesity ages 20 to 50 y were also derived: the 1st, 3rd,5th, and 15th percentiles were 5.55, 5.80, 5.93, and 6.34 degrees in men and 4.86, 5.08, 5.21, and 5.58 degrees in women.

As for variations due to age [5,17,32], in the general population, PhA increases progressively over the first 2 decades of life [17,33–36] and then declines after 40 y of age [17,32]. In a comprehensive analysis compared with previous papers [17,32], our data show that PhA declined with a non-linear trend in men (i.e., after 40 y of age) and linearly in women; the changes of PhA were more pronounced in men than women, but not distinguishable between the two weight status groups. Additionally, the difference between sexes tended to become smaller with age, as already indicated in individuals with obesity [17] and the general population [17,32].

Finally, relationships between PhA and BMI have been only partially evaluated. In a large study in the general population [17], PhA tended to increase up to a BMI of 35 kg/m^2 and then decreased in both sexes. In athletes, Torres et al. showed that PhA was positively correlated with BMI [35], and similarly, Koury et al. [34] observed a positive association with PhA and both weight and BMI; indeed, in both cases BMI may be influenced by differences in muscle mass. In individuals with obesity, two papers showed lower PhA in female patients with grade III than grade I–II obesity [37] or when BMI was >40 kg/m^2 [17]; similarly, another study [38] showed that the lowest values of PhA were significantly associated with the severity of obesity. On the other hand, one study [25] found no variation in PhA depending on BMI. The findings of the present study support the idea that there is no significant difference in PhA related to BMI, at least up to a value of 50 kg/m^2; a slightly lower PhA was observed when the BMI was >50 kg/m^2, but there were too few participants to reach firm conclusions. There is no clear explanation for the discrepancy with previous papers [17,18,37,38], but it could be attributed to different participant characteristics and to the inclusion of patients with comorbidities and peripheral edema. Overall, further studies should evaluate the relationships between PhA and whole-body or segmental lean mass to give a more reliable assessment of FFM and muscle mass in individuals with obesity.

We conducted this retrospective study in a quite large sample of individuals using recognized and well-documented methods and standardization procedure performed by highly experienced personnel. Nevertheless, these findings have some limitations. Data are retrieved from a database including individuals with obesity not selected from the general population but evaluated in the past 7 y in two tertiary centers for obesity. The occurrence of peripheral edema was excluded based on physical examination (grading system of pitting edema); we think that this is reasonable considering that the study was carried out in the clinical setting. Additionally, there were not so many individuals with a BMI >50 kg/m^2 (actually, they are rare in the general population). Moreover, body composition was not assessed by criterion techniques such as dual-energy x-ray absorptiometry. Indeed, it should be mentioned that PhA is expected to give some information on the inherent characteristics rather than on the amount of FFM (and muscle mass), considering that there is not a definite criterion method to assess BCM, ECW/ICW ratio, and the proportion of body BCM to FFM in the clinical setting.

Conclusions

A detailed appraisal of BIA-derived PhA in obesity is reported in the present paper providing basic data that might be taken into consideration (in prevention and clinical nutrition) for identifying alteration in FFM/muscle mass composition.

PhA was similar in individuals with obesity and controls in either sex. PhA was greater in men than women, whereas a decline of PhA was observed with age, which was linear in women and occurred in men after 40 y of age. No significant differences were observed with increasing BMI in either sex; lower values might be observed when BMI >50 kg/m^2.

BIA is a simple and reproducible method for assessing the electrical properties of the human body that may be used in the nutrition care of individuals with obesity. From this perspective, further research is needed to relate PhA with body composition, muscle structure and strength, and change in metabolic functions.

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