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Short report

# Vector bioimpedance detects situations of malnutrition not identified by the indicators commonly used in geriatric nutritional assessment: A pilot study

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ABSTRACT

*Objective:* To compare body composition as assessed by conventional and vector bioelectrical impedance analysis according to the nutritional cataloging using body mass index (BMI) in a group of institutionalized elderly.
*Methods:* Cross-sectional study in 38 institutionalized elderly. Body composition was estimated by bioimpedance analysis. Differences in body composition were analyzed using *t*-test and ANOVA, or their corresponding non-parametric tests. Statistical significance was set at $p < 0.05$.
*Results:* Based on BMI, the sample showed overweight (average BMI: 26.4 kg/m$^2$), and women had higher BMI values than men (28.9 vs. 25.5 kg/m$^2$). Based on waist circumference, abdominal obesity was detected in 60.7% of men and 80% of women. Conventional bioimpedance analysis (BIA) yielded high fat mass values and slightly depleted skeletal muscle mass, compatible with sarcopenic obesity. All individual impedance vectors were located on the right of the major axis of the tolerance ellipses, reflecting body-cell-mass depletion in all subjects, regardless of BMI cataloging.
*Conclusions:* Bioelectrical impedance vector analysis (BIVA) detects body compartment changes in institutionalized elderly that are not identified by the most widely used clinical practice nutritional indicators, such as BMI, waist circumference, and BIA-estimated body composition.



## 1. Introduction

The elderly constitute a population group with a high risk of malnutrition. In Spain, the prevalence of undernutrition among the institutionalized elderly has increased up to 60%, and overweight and obesity affect 25% of women and 18% of men aged ≥65 years (Abajo-del-Álamo et al., 2008).

Undernutrition in the elderly is associated with the onset of complications for those with acute or chronic conditions and with a worse health-related quality of life; and obesity leads to increased risk of chronic diseases, including type 2 diabetes, hypertension, and cardiovascular disease, and to increased risk of mobility limitation and loss of function (Abajo-del-Álamo et al., 2008).

Nutritional assessment is essential in preventing malnutrition. The body mass index (BMI) is difficult to interpret in the elderly because of age-related changes in body composition (BC) (Camina-Martín et al., 2014). Bioelectrical impedance vector analysis (BIVA) assesses soft tissues, hydration status, and cell integrity using a resistance–reactance graph (R–Xc graph) with the two direct impedance vector components normalized by subject height (i.e., R/H and Xc/H). Both BC and hydration status are then assessed semiquantitatively by directly interpreting the impedance vector (Norman et al., 2007). The vector length indicates tissue hydration (short vector: overhydration; long vector: dehydration), while vector direction (i.e., phase angle) provides information about the amount of soft tissue cell mass (a small phase angle indicates undernutrition) (Piccoli et al., 1994).

The aim of this study was to compare the body composition assessed by conventional and vectorial bioimpedance approaches according to the BMI-established nutritional cataloging in a group of elderly people living in a nursing home.

*Abbreviations:* BC, body composition; FFM, fat free mass; FFMI, fat free mass index; FM, fat mass; FMI, fat mass index; R, resistance; R/H, resistance normalized by height; SMI, skeletal muscle index; SMM, skeletal muscle mass; WC, waist circumference; Xc, reactance; Xc/H, reactance normalized by height; *Z*-FFMI, fat free mass Z-score; *Z*-FM, fat mass Z-score; *Z*-SMI, skeletal muscle index Z-score.

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**Table 1**
Descriptive statistics of the anthropometric measurements.

| | All (n = 38) | Males (n = 28) | Females (n = 10) |
|---|---|---|---|
| Weight (kg) | 65.2 (10.7) | 65.8 (10.1) | 63.4 (12.5) |
| Height (m) | 1.57 (0.1) | 1.61 (0.09)* | 1.49 (1.45–1.51) |
| BMI (kg/m$^2$) | 26.4 (4.05) | 25.5 (3.4)* | 28.9 (4.7) |
| AC (cm) | 28.6 (3.7) | 28.2 (3.4) | 29.8 (4.3) |
| WC (cm) | 97.3 (10.8) | 96.7 (9.7) | 99.0 (14.0) |
| TC (cm) | 45.9 (4.1) | 45.4 (4.0) | 47.4 (4.2) |
| CC (cm) | 33.2 (2.6) | 32.9 (2.6) | 33.8 (2.6) |

BMI, body mass index; AC, arm circumference; WC, waist circumference; TC, tight circumference; CC, calf circumference.
Results are expressed as mean (SD) or *median* (*interquartile range*).
* $p < 0.05$ with respect to females.

## 2. Materials and methods

Cross-sectional study carried out between February and March 2015 in the residential care center San Juan de Dios (Palencia, Spain). Inclusion criteria were: Caucasian ethnicity and BMI between 16 and 34 kg/m$^2$. Individuals were excluded if they showed clinical signs of hydration imbalance, had ongoing acute illness, had a history of body weight change ≥5% within the last month, or had pacemakers or metal implants. In the end, 38 institutionalized older-adults aged 77.4 y (95% CI: 75.3–79.6 y; range: 68–80 y) participated in the study. Written informed consent was obtained from all participants. This study was conducted in accordance with the Declaration of Helsinki and all procedures involving human participants were approved by the East Valladolid Healthcare Area (*CEIC*) Clinical Research Ethics Committee.

Body weight (W; kg) was measured to the nearest 100 g using a SECA scale (Hamburg, Germany); height (H; m) was measured to the nearest 0.1 cm using a SECA stadiometer (Hamburg, Germany); and body circumferences were measured to the nearest 0.1 cm with a flexible, inelastic measuring tape. BMI was calculated as weight (kg) divided by height squared (m$^2$). All participants were grouped according to BMI cutoffs, as per the WHO classification (WHO, 1995): underweight (<18.5 kg/m$^2$), normal weight (18.5–24.9 kg/m$^2$), overweight (25.0–29.9 kg/m$^2$, and obese (≥30.0 kg/m$^2$).

Whole body impedance measurements were made using a standard protocol (Lukaski, 1991). A 50-kHz tetra-polar phase-sensitive BIA (BIA-101; AKERN-Srl, Florence, Italy) introduced a sinusoidal, alternating current of 400 mARMS to measure R and Xc. These two values were normalized for all subjects by height (R/H and Xc/H, Ω/m) and transformed into *Z*-scores using the reference R/H and Xc/H values for healthy older-adult population (Piccoli et al., 1995).

Fat free mass (FFM) and skeletal muscle mass (SMM) (kg) were estimated using the BIA equations developed by Kyle et al. (2001) and by Janssen et al. (2000). Fat mass (FM; kg) was calculated as W – FFM. The indices for these values (FFMI, FMI and SMI, respectively) were then calculated as FMI (kg/m$^2$) = FM/H$^2$; FFMI (kg/m$^2$) = FFM/H$^2$; and SMI (kg/m$^2$) = SMM/H$^2$. Finally, FMI, FFMI and SMI were converted to age- and sex-specific standard deviation (SD) scores (Z-scores) for all subjects using the reference BC data for whites (Schutz et al., 2002; Janssen et al., 2004).

For BIVA, all participants' R and Xc values were normalized by subject height (R/H and Xc/H, Ω/m) and transformed into Z-scores using reference R/H and Xc/H values for healthy older-adult population (Piccoli et al., 1995). After transforming impedance measurements with respect to their reference population, R/H and Xc/H Z-scores were plotted on the RXc-score graph to assess BC and hydration status in each individual. This procedure allows comparing subjects of different ages and sexes in the same RXc-score graph, eliminating the need to consider the effects of age and sex on bioelectrical variables (R, Xc and phase angle) reported by several researchers (Piccoli et al., 2002; Buffa et al., 2003).

Finally, the 95% confidence ellipses for mean vectors of the BMI-groups were drawn to compare the BMI group-related differences.

### 2.1. Statistical analysis

The normality of variable distribution was checked using the Kolmogorov Smirnov or Shapiro-Wilk tests. ANOVA and Scheffe post hoc contrasts were used to assess differences in BC and in bioelectrical variables (described as Z-scores) according to the BMI cataloging. Statistically significant differences between the mean vectors were assessed with Hotelling's $T^2$ test for vector analysis, and distance between groups with Mahalanobis distance. Statistical significance was set at $p < 0.05$. Statistical analysis was performed with SPSS® version 19.0 (SPSS, Chicago, IL, USA).

## 3. Results

The anthropometric characteristics of the sample are shown in Table 1. Significant differences between males and females were observed in height and BMI. Although there were no significant differences in mean WC values according to sex (Table 1), 60.7% of men had abdominal obesity (WC > 102 cm), while 80% of women did (WC > 88 cm). Overall, 65.8% of the sample had abdominal obesity. With regard to BMI, 42.1% of subjects were of normal weight (BMI between 18.5 and 24.9 kg/m$^2$), 31.6% were overweight (BMI between 25 and 29.9 kg/m$^2$), and 26.3%, obese (BMI ≥ 30 kg/m$^2$) (Table 2).

Table 3 shows the bioelectrical variables and the estimated BC variables. As shown, R/H, FM percentage, and FMI were significantly higher in women, while FFM and SMM percentages were significantly higher in men. However, the FFMI and SMI Z-scores were significantly higher in women. The FMI Z-score was also higher in females, but did not reach statistical significance.

There were statistically significant differences in FMI, FFMI, and SMI *Z*-scores (i.e. Z-FMI, Z-FFMI, and *Z*-SMI, respectively) between normal-weight, overweight, and obese subjects (Table 4). Normal-weight subjects showed a decrease in FFMI and SMI Z-scores (SD −1.09 and −0.78, respectively) together with a FMI Z-score within normal limits (SD −0.40); overweight subjects showed a FMI Z-score of about SD 0.69 together with normal FFMI and SMI Z-score values (0.07 and −0.43 SD, respectively); and obese subjects showed a high level of fatness (FMI Z-score: SD 1.92) together with normal SMI Z-scores (SD 0.13).

As can be observed in Table 4, there were no significant differences in the bioelectrical variables among groups with different nutritional status (BMI classes). The only exception was the R/H Z-score, which was significantly higher in the normal-weight subjects than in the obese individuals.

**Table 2**
Nutritional status according to the body mass index.

| | All (n = 38) | Males (n = 28) | Females (n = 10) |
|---|---|---|---|
| Undernutrition (BMI ≤ 18.5 kg/m$^2$) | 0 (0.0) | 0 (0.0) | 0 (0.0) |
| Normal weight (BMI 18.5–24.9 kg/m$^2$) | 16 (42.1) | 14 (50.0) | 2 (20.0) |
| Overweight (BMI 25–29.9 kg/m$^2$) | 12 (31.6) | 9 (32.1) | 3 (30.0) |
| Obesity (BMI ≥ 30 kg/m$^2$) | 10 (26.3) | 5 (17.9) | 5 (50.0) |

Results are expressed as absolute and relative frequencies: n (%).

**Table 3**
Bioelectrical variables and body composition.

| | All (n = 38) | Males (n = 28) | Females (n = 10) |
|---|---|---|---|
| PhA (°) | 5.1 (0.7) | 5.16 (0.7) | 5.0 (0.8) |
| R/H (Ω/m) | 337.5 (45.5) | 327.9 (45.9)* | 364.3 (33.4) |
| Xc/H (Ω/m) | 30.2 (5.9) | 29.6 (5.4) | 31.9 (7.0) |
| FM (%) | 30.6 (7.7) | 27.5 (5.1)* | *40.8 (36.7–44.2)* |
| FFM (%) | 69.4 (7.7) | 72.5 (5.1)* | *59.2 (55.8–63.3)* |
| SMM (%) | 33.3 (6.4) | 36.1 (4.2)* | *23.9 (22.4–27.7)* |
| FMI (kg/m$^2$) | 8.32 (3.3) | 6.31 (2.2)* | 11.6 (3.7) |
| FFMI (kg/m$^2$) | 18.1 (1.5) | 18.3 (1.5) | 17.3 (1.4) |
| SMI (kg/m$^2$) | 8.6 (1.1) | 9.1 (0.8)* | 7.3 (0.7) |
| *Z*-FMI (SD) | 0.56 (1.1) | 0.47 (1.1) | 0.79 (1.2) |
| *Z*-FFMI (SD) | −0.14 (1.1) | −0.45 (1.0)* | 0.72 (0.9) |
| Z-SMI (SD) | −0.43 (0.8) | −0.65 (0.7)* | 0.19 (0.7) |

PhA, phase angle; R/H, resistance/height; Xc/H, reactance/height; FM, fat mass; FFM, fat-free mass; SMM, skeletal muscle mass; FMI, fat mass index; FFMI, fat-free mass index; SMI, skeletal muscle index; *Z*-FMI, fat mass index *Z*-score; Z-FFMI, fat-free mass index *Z*-score; Z-SMI, skeletal muscle index Z-score.
Results are expressed as mean (SD) or median (interquartile range).
* $p < 0.05$ with respect to females.

Male/female confidence ellipses are shown in Fig. 1. No statistically significant differences were observed between the groups. Regarding the tolerance ellipses based on the BMI cataloging (Fig. 2), most subjects had lower Xc values, independently of the BMI cataloging. This difference was not observed with R. In the R-Xc graph, no specific BMI-related pattern was observed, but the majority of the individual impedance vectors were located to the right of the major axis of the reference population; this indicated low body cell mass even among the obese subjects (BMI ≥ 30 kg/m2).

## 4. Discussion

In our sample there was a high prevalence of overweight and obesity in women and a higher prevalence of normal weight in males, which has already been documented in other studies conducted with institutionalized elderly (Slee et al., 2015).

The discrepancy observed in nutritional cataloging according to the criteria used is remarkable in the case of male subjects: BMI classified 17.9% of men as obese, while the WC cutoffs showed abdominal obesity in 60.7% of men. For women, the results obtained were more consistent: 50% and of women had BMI-rated obesity and 80% had WC-calculated excess abdominal adiposity.

The discrepancy observed between BMI and WC in this sample reveals the need to analyze BC in assessing geriatric nutrition, because BMI is masking a significant SMM depletion. The average FMI and SMI *Z*-scores were 0.56 and −0.43, respectively, which indicates a slight sarcopenic-obesity condition. These data are consistent with those obtained in previous studies (Camina-Martín et al., 2015).

The results obtained using BIVA are consistent with those obtained from BIA, especially considering SMI and FMI. The SMI Z-scores were higher in women than in men, suggesting that women in this sample

**Table 4**
Body composition and bioelectrical variables Z-scores according to the body mass index.

| | Normal weight (n = 16) | Overweight (n = 12) | Obesity (n = 10) |
|---|---|---|---|
| **Z-FMI (SD)** | −0.40 (0.7)[a,b] | 0.69 (0.4)[b] | 1.92 (0.7) |
| **Z-FFMI (SD)** | −1.09 (0.8)[a,b] | 0.07 (0.4) | 1.12 (0.5) |
| **Z-SMI (SD)** | −0.78 (0.9)[b] | −0.43 (0.5) | 0.13 (0.7) |
| **Z-PhA (SD)** | −1.16 (0.7) | −0.79 (0.7) | −1.32 (0.7) |
| **Z-R/H (SD)** | 0.81 (1.2)[b] | 0.45 (0.6) | −0.3 (0.8) |
| **Z-Xc/H (SD)** | −0.42 (0.9) | −0.30 (0.9) | −1.2 (0.8) |

Z-FMI, fat mass index Z-score; Z-FFMI, fat-free mass index Z-score; Z-SMI, skeletal muscle index Z-score; Z-PhA, phase angle Z-score; Z-R/H, resistance/height Z-score; Z-Xc/H, reactance/height Z-score.
Results are expressed as mean (SD).
[a] $p < 0.05$ with respect to overweight.
[b] $p < 0.05$ with respect to obesity.

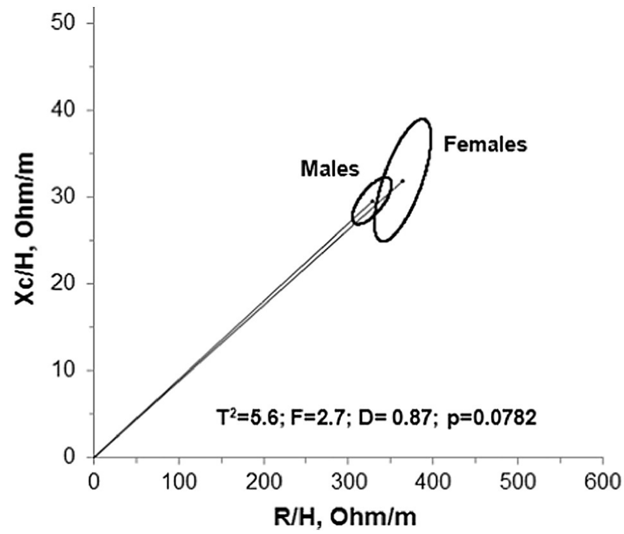


**Fig. 1.** Confidence ellipses by sex. There were no statistically significant differences between males and females. Nevertheless, the confidence ellipses showed higher values of resistance and reactance normalized by height (R/H and Xc/H, respectively) in females.

had SMI values more similar to the SMI values of healthy elderly women. This was evidenced by BIVA, given that, although without reaching statistical significance, the confidence ellipses showed higher R/H and Xc/H values for women (Fig. 1). This suggests a higher relative amount of FM and (largely SMM) cellular mass These results are similar to those of Marini et al. (2012), who found that BIVA detects muscle-mass variations in sarcopenic individuals.

All the individual impedance vectors in the sample were found on the right of the major axis of the tolerance ellipses (Fig. 2). This indicates cell mass depletion throughout the study sample (regardless of BMI). Most of the impedance vectors of the overweight and obese subjects were also in the lower right quadrant, while most of the vectors of the normal-weight subjects were located in the upper right quadrant.

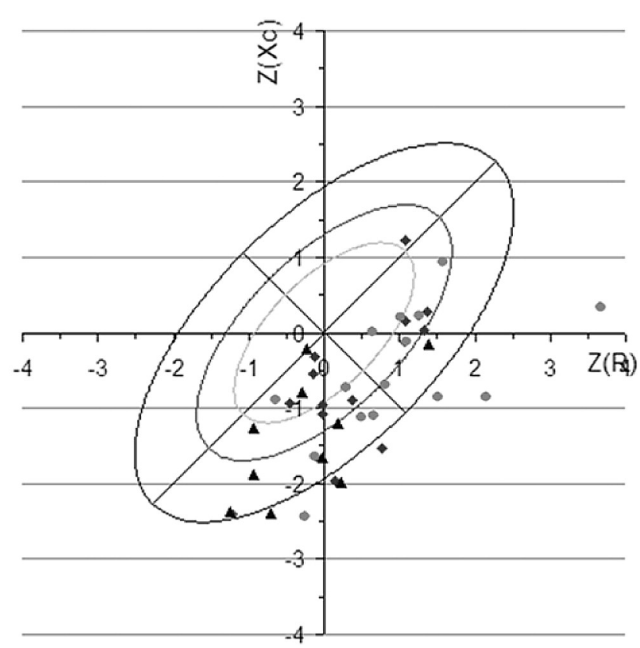


**Fig. 2.** RXc-score graph by nutritional cataloging according to the BMI. In the RXc-score graph no specific pattern was observed according to the BMI, but the position of the majority of the individual impedance vectors was to the right of the major axis of the reference population. Legend. Circles, normal-weight (n = 16); triangles, overweight (n = 12); rhombus, obesity (n = 10).

Marini et al. (2013) evaluated the performance of both classic and specific BIVA in estimating body composition in elderly people by comparing those techniques with Dual-energy X-ray absorptiometry (DXA). Those researchers found that classic BIVA did not recognize significant differences between groups established based on fat mass percentage, although it did identify significant differences between individuals with a BMI ≥ 30 kg/m$^2$ and those with 18.5 ≤ BMI ≤ 25 kg/m$^2$. As mentioned earlier, in this study all the individual impedance vectors of the sample were located on the right of the major axis of the tolerance ellipses, reflecting cell mass depletion throughout the participants, regardless of BMI and the BIA-estimated body composition. Therefore, our results are in line with that of Marini et al. (2013) as regards the limited sensitivity of classic BIVA in identifying differences in body fatness. With regard to the impedance vector migration patterns between groups established based on BMI, Marini et al. (2013) found that classic BIVA was effective in detecting significant BMI changes. We did not find statistically significant differences in the impedance vector migration pattern between our BMI-established groups (data not shown). However, most of the impedance vectors of the overweight and obese subjects were shorter than those of the normal-weight patients (Fig. 2). Given that this is in line with the results of Marini et al. (2013), it could consequently be considered an effect of increasing fat mass, as well as fluid overload (Marini et al., 2013).

Another noteworthy fact is that 50% (n = 6) and 20% (n = 2) of the individual impedance vectors for overweight and obese subjects, respectively, showed an abnormal impedance vector. That is, the impedance vectors displaced downward on the RXc graph, out of the 75% ellipse (Piccoli and Italian CAPD-BIA Study Group, 2004). This may be due to hydration status alterations, indicating a high ratio of extracellular/intracellular water in overweight and obese subjects (i.e., clinically undetected edema); this could in turn invalidate the results obtained using BIA. According to Piccoli et al. (1998), obese subjects with impedance vectors located outside the lower pole of the 75th percentile of the tolerance ellipses and below the boundary line have at least 4 or 5 L of fluid overload.

The main limitation of this study is the small sample size. However, this is a pilot study that will continue in the coming years, and it demonstrates that BIVA detects changes in BC and hydration.

## 5. Conclusions

Bioelectrical impedance vector analysis detects changes in body compartments in institutionalized elderly that are not identified by the most widely used nutritional indicators in clinical practice, such as BMI, waist circumference, and body composition estimates with conventional bioimpedance.

## Conflicts of interest

None.

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