

Bioelectrical impedance vector analysis, phase-angle assessment and relationship with malnutrition risk in a cohort of frail older hospital patients in the United Kingdom

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Abstract

Objective

Bioelectrical impedance vector analysis (BIVA) and phase angle (PA) have been shown previously to indicate relative nutritional status in patients. The aim of this study was to investigate the application of BIVA and PA assessments in a cohort of frail older hospital patients and compare these assessments with malnutrition risk screening by MUST (Malnutrition Universal Screening Tool), and the MNA-SF® (Mini-Nutritional Assessment-Short Form).

Methods

Sixty-nine patients (n = 44 men; n = 25 women; age 82.1 ± 7.6 y [range 62–96 y]; body mass index 25.8 ± 5.4 kg/m² [range 16.6–45.1 kg/m²]) were recruited from hospital wards specializing in the care of frail older individuals from the United Kingdom. Bioelectrical impedance assessment was performed at 50 kHz frequency, BIVA was performed using raw impedance data, PA was calculated, and data were compared against reference population groups. Patients were categorized by malnutrition risk by MUST and MNA-SF.

Results

BIVA indicated that the men and women in the study were significantly different from reference population groups ($P < 0.0001$), with a noticeable reduced capacitive reactance (xC) component. The group mean PA was $4.6^\circ \pm 1.1^\circ$ (2.4° – 9.2°). The mean PA for men was $4.7^\circ \pm 1.3^\circ$ (2.4° – 9.2°), and for women it was $4.5^\circ \pm 0.7^\circ$ (2.8° – 6.0°). Group PA correlated with MNA-SF score ($P = 0.05$). MUST categorized patients predominantly at low risk for malnutrition (80%); whereas MNA-SF was at risk (46%) and malnourished (45%).

Conclusions

The significant reduction in xC component and PA is consistent with other studies and is indicative of a reduced body cell mass and nutritional status with aging and illness. The general trend in MNA-SF

scoring was more consistent with these patterns as a group; but requires clarification in larger cohorts. Future studies are necessary with an aim to improve and optimize care of frail older people.

Keywords

Frailty;

Bioelectrical impedance assessment;

Phase angle;

Malnutrition;

MUST;

MNA

Introduction

Aging and frailty are associated with physiological and potentially pathological changes that may increase the risk for malnutrition, including a reduction in appetite and food intake, a decrease in body protein, body cell mass (BCM), and skeletal muscle mass (SMM) [1], [2], [3] and [4]. The frailty phenotype may increase risk for morbidity and mortality, and frail older people may suffer from a range of acute and chronic illness, and present with sarcopenic, cachectic, and wasting conditions [1], [4], [5] and [6]. Hence, the ability to accurately determine nutritional status in older people in hospitals and long-term care (LTC) facilities has high clinical importance and specific nutritional risk-screening tools have been developed and endorsed [7]. Currently in the United Kingdom, the MUST (Malnutrition Universal Screening Tool) is the gold standard used routinely in hospitals and LTC facilities in the screening of malnutrition and is endorsed by the British Association of Parenteral and Enteral Nutrition [7] and [8]. The MNA (Mini-Nutritional Assessment) also has been validated for use in older populations [7], [9], [10] and [11].

Bioelectrical impedance assessment (BIA) is an established, noninvasive portable tool for assessing body composition, and has potential use in assessing nutritional and clinical status [12], [13] and [14]. One issue of concern, however, is that BIA predictive equations may cause significant errors in older people and in comorbid states (e.g., due to potential hydration abnormalities, body measurement differences, and other unknown effects); thus use of raw impedance data, that is, the bioelectrical impedance vector analysis (BIVA) method by Piccoli and Pastori has been suggested [12], [13], [14], [15] and [16]. The methodology is based on the concept that body impedance (Z) is made up of two components—resistance (R) and reactance capacitance (x_C)—and that by normalizing R and x_C for height (H) in meters, and plotting relevant bivariate vectors in a graphical format, useful comparisons can be made (e.g., compared with reference populations with specified ages, sex, body mass index [BMI] and disease) [15] and [16]. The R component relates predominantly to water content and hydrated tissues and, in the normal healthy state, a decreased R/H correlates with body size (i.e., greater amount of hydrated tissue mass), and in illness may relate to edema and high water content. Similarly, a very high R in illness may relate to dehydration and wasting. The x_C component relates to the electrical capacitance or reactance effects of cellular tissues (i.e., cell

membrane, etc). Therefore, a high xC relates to higher BCM/lean mass and a low xC relates to lower BCM/lean mass. A lowering of xC is consistent with normal aging. More recently, a specific BIVA method was developed with demonstrated accuracy by using body circumference measurements [17].

The BIA phase angle (PA) reflects the contributions between R and xC [calculated using the equation: $PA \text{ (degrees)} = \arctan(Xc/R) \times (180/\pi)$]. It has been found to be associated with nutritional status and to have prognostic potential in different disease states and in older patients [14], [18], [19] and [20]. The usefulness of the clinical application of the BIVA and PA measurements in frail older people is yet to be realized and is at present unknown. Furthermore, at present there have been only a handful of studies performed globally and from the United Kingdom assessing the relationship between BIVA and PA in frail older people and the relationship with risk for malnutrition.

Therefore, the aims of this study were to investigate the use of BIVA and PA in frail older hospital inpatients and compare the relationship to malnutrition screening by MUST and MNA-SF.

Methods

Participants and study design

This cohort study was undertaken between September 2012 and May 2013. Patients who were able to provide written informed consent were recruited consecutively from admissions to two hospital wards in Lincoln, United Kingdom, specializing in care of frail older patients. Patients were diagnosed as being significantly frail and with a range of comorbidities that included cardiovascular disease, chronic heart failure, chronic kidney disease, chronic obstructive pulmonary disorder, cancer, diabetes, arthritis, and dementia. Patients were treated with polypharmacy. Full ethical approval was obtained from NHS Leicester, East Midlands Research Ethics Committee before study commencement. Ethical guidelines were followed and informed consent sought from all patients. Exclusion criteria from the study were inability or unwillingness to give informed consent, patients nil by mouth or were tube fed. BIA measures were contraindicated in patients with defibrillation or cardiac pacemaker devices. The aim was to recruit 100 to 150 patients in line with other similar studies; however the exclusion criterion of ability to consent and designated study time restraints dictated the current number.

Anthropometric measurements

Height (m) and weight (kg) measurements were completed by clinical staff. In some cases height had to be estimated (e.g., height from demi-span). BMI was calculated in kg/m².

Bioelectrical impedance measurements

BIA measurements were taken using a single-frequency (50 kHz) Maltron® 916 S, bioelectrical impedance analyzer (Maltron International Ltd., Rayleigh, Essex, UK). Measurements were taken using a standard hand-to-foot tetra-polar technique with participants in the supine position, in accordance with the manufacturer's guidelines. Raw impedance measurements of resistance, R and capacitance, xC in ohms and PA were recorded. The PA component was calculated using the equation: $PA \text{ (degrees)} = \arctan(Xc/R) \times (180/\pi)$. R and xC data was used for subsequent BIVA analysis according to previous studies [15] and [16]. Participants' R and xC were normalized for H

and group mean data \pm SD were calculated. Data for the male and female groups were inputted into BIVA software and compared with the reference healthy adult population using confidence ellipses. Additionally, BIVA was performed on different MNA-SF and MUST screening categories for men and women.

Nutritional assessment: MUST tool and MNA-SF screening

MUST and MNA-SF screening were undertaken by clinical staff according to instructions and scores recorded. Scores were converted into categories for nutritional status using MUST and MNA scoring criteria either low risk/normal (0 points MUST; 12–14 MNA-SF), medium risk/at risk (1 point MUST; 8–11 MNA-SF) and high risk/malnourished (\geq 2 points MUST; 0–7 MNA-SF).

Data analysis

Data is presented as mean average measurements \pm SD with a range (minimum–maximum) and (median) values. Data were grouped into whole-participant group, women and men, and where relevant into BMI and nutritional screening categories. Statistical analysis was performed using IBM SPSS Statistics, version 19 (New York, NY USA). t Tests, analysis of variance, and Pearson correlations were used for normally distributed data and Mann-Whitney U, Kruskal-Wallis, and Spearman correlations tests for nonparametric data. For BIVA bivariate group vector comparisons, the Hotelling's T2 test and Mahalanobis distances (D) between groups were analyzed. T2, F, P, D values are presented. A P value <0.05 was considered statistically significant.

Results

Participants

Study participants were predominantly white (2 men were Asian-Indian). In all, there were 69 participants (44 men and 25 women), with a mean age of 81.2 ± 7.4 y (age range: 62–96 y). Full participant details can be found in Table 1.

Table 1.

Participant characteristics with bioelectrical impedance values*

Group (N = 69)

Men (n = 44)

Women (n = 25)

Age (y)

82.1 ± 7.6 (62–96) [83]

81.2 ± 7.4 (62–92) [82]

83.6 ± 7.8 (68–96) [85]

Height (m)

1.68 ± 0.10 (1.37–1.85) [1.68]

1.72 ± 0.07 (1.57–1.85) [1.74]

1.64 ± 0.10 (1.37–1.78) [1.62]†

Weight (kg)

73.2 ± 15.0 (42.8–101.6) [71.2]

73.6 ± 15.1 (42.8–101) [73.5]

72.5 ± 15.0 (49.8–101.6) [70.3]

Body mass index (kg/m²)

25.8 ± 5.4 (16.6–45.1) [25.6]

24.7 ± 4.7 (16.7–35.3) [24.4]

28.0 ± 5.9 (18.5–45.2) [28.0]‡

Resistance at 50 kHz/height (Ω/m)

310.9 ± 67.3 (134.8–447.6) [310.1]

296.3 ± 65.1 (134.8–429.0) [297.6]

334.0 ± 67.7 (215.8–447.6) [335]‡

Reactance at 50 kHz/height (Ω/m)

25.2 ± 8.0 (5.6–51.3) [25]

24.5 ± 8.7 (5.6–51.3) [23.6]

26.3 ± 6.8 (11.0–36.0) [27.3]

Phase angle at 50 kHz (degrees)

4.6 ± 1.1 (2.4–9.2) [4.5]

4.7 ± 1.3 (2.4–9.2) [4.5]

4.5 ± 0.7 (2.8–6.0) [4.5]

MUST low risk (%)

55 (79.7)

32 (72.7)

22 (88)

MUST medium risk (%)

5 (7.3)

4 (9.1)

1 (4)

MUST high risk (%)

9 (13)

8 (18.2)

2 (8)

MNA-SF score

8.1 ± 2.8 (2–14) [8]

7.9 ± 2.7 (2–14) [8]

8.4 ± 2.9 (2–14) [8]

MNA-SF normal (%)

6 (8.7)

3 (6.8)

3 (12)

MNA-SF at risk (%)

32 (46.3)

22 (50)

10 (40)

MNA-SF malnourished (%)

31 (45)

19 (43.2)

12 (48)

*

Mean values presented ± SD, range (minimum–maximum) and [median] for the entire group; individual groups of men and women.

†

Significantly different compared with men ($P < 0.001$).

‡

Significantly different compared with men ($P < 0.05$).

The mean BMI was significantly higher in women than in men (28 versus 24.7 kg/m²), as was R/H (334 versus 296 Ω /m). Furthermore, the proportion of women within low-risk malnutrition score categories was numerically higher than men.

BIVA analysis

Table 1 shows impedance values for patient groups normalized for height (R/H and xC/H values). Group vector and confidence ellipses are shown in Figure 1. Study group men (M1) and women (F1) are plotted along with reference groups (M2-6, F2-6). Details of reference groups can be found in Table 2. Statistical comparison of groups also can be found in Figure 1 with Hotelling's T² test, F, P, and Mahalanobis distance, D. The M1 and F1 patients from the study were significantly different compared with M2-6 and F2-6 ($P < 0.00001$). Note also the difference between M1 and F1 was T² = 6.1, F = 3, P = 0.056 and D = 0.62.

Fig. 1.

BIA vectograph (R/H and xC/H) showing relative bivariate vector positioning and confidence ellipses for participant study groups male, M1 (n = 44) and female, F1 (n = 25). Reference male and female population vectors are plotted (M2–6; F2–6) and full statistical analysis of group comparisons performed and presented including Hotelling's T² test, F and P values and Mahalanobis distance, D (see comparison tables in Fig.). Reference data set details are found in Table 2.

Table 2.

Reference data groups used in BIVA Comparisons*

Group

Group details (race, sex, age, BMI, country, BIA system)

N

R/H (Ω /m)

xC/H (Ω /m)

Reference

M2

White males, 78 y, 28 kg/m², USA, RJL Systems

161

276 \pm 35.4

28.9 ± 9.2

[24]

M3

White males, 16–85 y, 16–31 kg/m² Italy, Akern-RJL Systems

354

298.6 ± 43.2

30.8 ± 7.8

[16]

M4

White males, 60–69 y, 19–25 kg/m², USA, Valhalla

230

270.4 ± 32.5

33.1 ± 5.3

[25]

M5

White men, 60–69 y, 25–30 kg/m², USA, Valhalla

97

304.5 ± 33.8

37.2 ± 6.0

[25]

M6

White men, 60–69 y, 30–35 kg/m², USA, Valhalla

111

248.3 ± 26.8

31.5 ± 5.1

[25]

F2

White women, 78 y, 27 kg/m², USA, RJL Systems

294

362.4 ± 45.6

32.8 ± 8.1

[24]

F3

White women, 16–85 y, 16–31 kg/m² Italy, Akern-RJL Systems

372

371.9 ± 49.0

34.4 ± 7.7

[16]

F4

White women, 60–69 y, 19–25 kg/m², USA

140

406.1 ± 49.3

45.0 ± 6.6

[25]

F5

White women, 60–69 y, 25–30 kg/m², USA, Valhalla

159

362.1 ± 38.1

42.9 ± 6.9

[25]

F6

White women, 60–69 y, 25–30 kg/m², USA, Valhalla

87

337.3 ± 44.6

39.6 ± 6.5

[25]

BIVA, bioelectrical impedance vector analysis; BMI, body mass index

*

Includes group details, number of participants (n), R/H (Ω/m), xC/H (Ω/m), and reference citations. Notes from BIVA guide—Valhalla BIA device used in M4–6 and F4–6 has higher impedance readings ($R \times 10 \Omega$ and $xC \times 12 \Omega$).

BIVA categorization by BMI in ages ≥ 70 y

The group characteristics were examined further by categorization of the participants (3 males and 1 female, 60–69 y were omitted from analyses) aged ≥ 70 by BMI groups: 18.5 to 24.9, 25 to 29.9, and ≥ 30 kg/m² (two men were omitted because BMI < 18.5 kg/m²). Data can be seen in Supplementary Table 1 and Figure 1. Key points include a significant difference between women 18.5 to 24.9 versus 25 to 29.9 and 18.5 to 24.9 and ≥ 30 kg/m² ($P = 0.02$). There was a visible trend for a shift to the right along the R/H axis and upward on the xC/H with decreasing BMI.

BIVA categorization by MNA-SF and MUST

The whole-study population was categorized by the MNA-SF screening score and data can be seen in Supplementary Table 2 and Figure 2. BIVA showed a trend for a shift to the right along the R/H axis between at-risk and malnourished groups. The difference between groups was not significant but there was a trend toward significance in women ($P = 0.07$) (and also included a visible downward shift in xC/H). BIVA categorization for MUST was performed in men in the low- and high-risk groups (see Supplementary Table 3 and Fig. 3). There was a similar trend with a shift toward the right on the R/H axis, which was significant ($P = 0.03$); however, note the high-risk vector ellipse has a large overlapping area. It was not possible to analyze medium-risk men or any female group comparisons due to lack of patient numbers.

Fig. 2.

The relationship between individual patient phase angle (PA) and MNA-SF scores ($N = 69$; 25 women, open circles and 44 men, closed circles). Graph indicates a high proportion of individual patients found within the at-risk and malnourished MNA-SF categories (e.g., scores 5–11) with PA $< 5^\circ$. A PA region of $\sim 5^\circ$ – 7° was chosen as a suitable range that is potentially linked to better health and lower risk for poor outcomes in this age range (e.g., nutritional risk, poor functional status, mortality, etc.). Region was selected based on previous data [14], [18], [19], [20], [21], [22] and [23]. Very high PA for older persons (e.g., 7° – 10°) also may indicate abnormalities and poor outcomes [20].

BIA phase angle

PA values are shown in Table 1. There were no significant correlations between PA and BMI or age, for the group as a whole or when taken separately by sex; although there was a trend toward significance for age ($P = 0.08$) with the whole group and with women. Grouping by BMI in patients ≥ 70 y, the mean PA (and median) values for men with BMI 18.5 to 24.9 kg/m² was 4.7° [4.5]; BMI 25

to 29.9 kg/m² was 4.5° [4.5]; BMI ≥30 kg/m² was 5.4° [4.6]. Mean PA (and median) values for women with BMI 18.5 to 24.9 kg/m² was 4.0° [4.0]; BMI 25 to 29.9 kg/m² was 5.0° [4.9]; and BMI ≥30 kg/m² was 4.5° [4.5] (supplementary Table 1). Correlations were performed on all other impedance measurements and only PA significantly correlated with the MNA-SF 1 to 14 score (group PA: R = 0.29, P = 0.05; women: R = 0.7, P < 0.0001; and men: R = 0.053, P = 0.74), whereas impedance (Z), R, R/H, xC, and xC/H did not. Although no correlation was found for men, inspection of spread of data points in Figure 2 shows that there were observations of high PA measurements that have been found to potentially indicate abnormal status, as cited using data from a previous study [20], and may also potentially skew statistical correlation. Grouping by MNA-SF malnutrition scoring (supplementary Table 2), PA for men was normal 4.7° [4.7] (n = 3); at risk 4.7° [4.5] (n = 22); and malnourished 4.7° [4.4] (n = 19). For women normal 5.1° [5.1] (n = 3); at risk 4.7° [4.7] (n = 10); and malnourished 4.1° [3.9] (n = 12). Full PA for patients categorizing by MUST scores were as follows: low risk 4.8 [4.5] (n = 32); medium risk 4.0 [4.2] (n = 4); and high risk 5.0 [4.7] (n = 8); for women low risk 4.5° [4.5] (n = 22); medium risk 5.1 (n = 1); and high risk: 3.9 [3.9] (n = 2).

Discussion

BIVA and PA assessments have been previously shown to have potential value in the assessment of nutritional and prognostic status in patients. This study aimed to investigate BIVA and PA assessment in a group of frail older hospital patients, compared with reference values and with malnutrition risk screening (by MUST and MNA-SF). This was considered especially important, as there have only been a small handful of studies performed similarly globally and none from the United Kingdom.

BIVA was performed in accordance with a previously derived method [15] and [16]. Comparing the male and female group data sets using confidence ellipses, and Mahalanobis distances from reference population groups, highly significant differences (P < 0.0001) were observed (Fig. 1). The areas of the ellipses are large, however, potentially indicating variability in R and xC impedance components, and are overlapping for male and female groups. The reason for these observations are most likely due to the lower patient numbers and general variability in patients including age, BMI, hydration status, disease-specific factors, and possibly medications. The study groups were also categorized by BMI (18.5–24.9, 25–29.9, and ≥30 kg/m², with two men omitted due to BMI <18.5) for patients ≥70 y (3 men and 1 women ages 60–69 y were omitted). These categories were chosen based on previous studies that have performed similar categorization (e.g., large studies have used the ≥70 age as a cut point [21] and [23]). BIVA showed a significant difference in two of the female groups (BMI 18.5–24.9 versus 25–29.9 kg/m² and 18.5–24.9 versus ≥30 kg/m²; supplementary Table 1 and Fig. 1). For both men and women, the visible observation is a relative shortening of the vector with increasing BMI. Furthermore, the most apparent observation from the overall group data compared with reference populations (Fig. 1) was also a relative shortening of the vector length, with a noticeable lowering in the xC/H component. A relative decrease in the xC/H component is understood to indicate a decrease in soft tissue mass/BCM, whereas a change in the R/H component

indicates alterations in hydration status [14], [15] and [16]. Data from healthy white men, ages 50 to 80 y, and a BMI range from normal weight to obese [22] showed a relative reduction in xC/H and increase in R/H in aging, indicating reductions in BCM and fat-free mass (FFM). An increase in the R/H component indicates a reduction in hydration status and was also found in groups of healthy older people in an earlier study [26]. However, after correction for body size and circumferences, there was no longer any significant effect of age on R; however, the downward reduction in xC remained. Data from this study shows in particular that the group of frail older hospitalized patients have significantly reduced mean xC/H values (e.g., Table 1, ~24–26 ohm/m for the groups), compared with ~28 to 35 previously observed [22], although note the individual differences in groups in Supplementary Table 1.

Separating the groups of data into MNA-SF malnutrition risk category, there was a trend toward significance ($P = 0.07$) for women and distinctly visible shifting toward the right (increasing R/H) with malnutrition categorization from at risk to malnourished (Supplementary Fig. 2). There were no significant differences between the groups or by statistically comparing the individual R, R/H, xC, or xC/H variables. Age was numerically higher with a trend toward significance ($P = 0.09$) in the female malnourished group compared with the at-risk group. Other studies have found distinct differences in group comparisons by MNA categorization, with a shifting of the vector along the R/H axis and decrease in xC/H with increasing risk for malnutrition [27] and [28]. It should be noted that the variation in MNA scoring was perhaps not considerably widely spread for the patient group studied here, with only small numbers <5 and >11 (Table 1 and Fig. 2); although with more study participants the distribution may have altered and possibly led to more significant variation. Separating by MUST scores, BIVA was only possible for the male low-versus high-risk groups due to low patient numbers (Supplementary Fig. 3) A similar trend and shift to the right of the R/H axis was observed ($P = 0.03$).

The analyses of the groups from this study are important as they suggest that despite the variability in age and BMI, many of the patients most likely have significantly reduced soft tissue masses (e.g., BCM.), which is consistent in aging and probably in frailty syndrome. However, distinct variability in the R/H component may indicate variability in the patient status, that is, some may have uncomplicated forms of undernutrition and loss of body mass (reduction in xC and increase in R/H); whereas other patients may have higher body mass/BMI, obesity, diabetes, and other chronic disease complications such as chronic heart failure, which may lead to a shortening of the vector and reduction in the R/H component (e.g., due to hyperhydration/edema). These possible alterations may be consistent here (e.g., note the normal-high BMI range of patients, especially women [Table 1] and the shortening of the R/H component). These complicated body composition alterations in frailty also may be a basis behind the potential BMI paradox in groups of older adults [29]. There are still many aspects that require further investigation with regard to BIVA accuracy, and it is known that potentially more accurate methods including specific BIVA are currently being developed [17].

The PA measurement relates to the xC/H ratio ($\text{arc-tangent } xC/R \times 180^\circ/\pi$) and its clinical relevance has been well documented, and recently discussed in detail [14]. PA has been suggested to be a superior prognostic marker and an indicator of nutritional and functional status. In aging, PA reduces due to the characteristic drop in the xC component. The mean PA values were lower here (Table 1 and Supplementary Table 1) than reference values for healthy white Swiss adults [21] (men ≥ 70 y, BMI 18.5–50 kg/m², mean PA range 5.03°–5.50°; and women, ≥ 70 y, mean PA range 5.07°–5.27°); and lower than values for healthy white Italian men, 70 to 80 y (BMI 18.5 to ≥ 30 kg/m², PA 5.8°–6.0°) [22]. In an American population of healthy adults, reference PA values for those ≥ 70 y were $6.19^\circ \pm 0.97^\circ$ for men (BMI 25.6 ± 4.2 kg/m²), and $5.64^\circ \pm 1.02^\circ$ for women (BMI 26 ± 6.4 kg/m²) [23]. It should be noted that the variation between PA reference measurements might be potentially due to differences in individual population groups and BIA analyzer differences [21], [22] and [23]. The mean/median PA values were lower in this study, which also might indicate the effects of disease and frailty (Table 1 and Supplementary Table 1). One study categorized older people by PA and MNA score (men [n = 77]: $5.2^\circ \pm 1.3^\circ$ [malnourished] versus $5.7^\circ \pm 1.0^\circ$ [normal]; and women [n = 93]: $5.0^\circ \pm 1.0^\circ$ [malnourished] versus $5.4^\circ \pm 0.9^\circ$ [normal]) [28]. Another study summarized a number of studies and range of disease conditions whereby specific PA cutoff points increased poor outcomes—tending to be between $\sim 4^\circ$ to 6° (although noting there is generally high variability from study to study [14]. It has been shown that a lower PA is associated with nutritional risk and malnutrition in middle-aged adults at hospital admission [18]. And another recent study determined the best PA cutoffs for predicting nutritional risk using area under the receiver operating characteristic curve analysis comparing healthy adults with hospitalized patients ($< 5.0^\circ$ in men and $< 4.6^\circ$ in women) [19]. In data presented here, the men had a lower PA (mean 4.7° /median 4.5°), MNA-SF at risk: $4.7^\circ/4.5^\circ$ [n = 22], and malnourished $4.7^\circ/4.4^\circ$ [n = 19]), but also, in particular, four patients had very high PA values (7.55° – 9.24°). A U-shaped distribution has also been observed in older patients whereby those at the lowest ($< 3.5^\circ$ – 4°) and highest ($> 6.4^\circ$) values had increased hospital mortality rates [20].

Further to the BIVA and PA data presented, there was an apparent discordant trend observed between the MUST and MNA categorization, which is consistent with other analyses previously performed [30]. It could be suggested from the BIA BIVA and PA assessment that a majority of patients are within categories of a higher risk for malnutrition, as the data may indicate reduced nutritional and functional status. The MUST scoring patterns do not seem to corroborate this data as a patient group, whereas the MNA-SF scoring appears to be more in to line; but this would require clarification in larger cohort numbers. Although beyond the scope of this article, this possible discordance may be a serious clinical issue as frail comorbid older patients at high nutritional risk may go unreported, since the MUST is the current gold standard for assessing malnutrition risk in the United Kingdom. Data from this study also supports the notion of possible increased malnutrition risk despite being within normal BMI ranges (BMI paradox in older people) [29].

Limitations of the study included study group size and participant grouping. Furthermore, there is a total lack of comparison data from the United Kingdom, and hence appropriate reference studies have been compared against an older European white population. Finally, cross-validation of bioelectrical impedance analyzers is another possible source of variability.

Conclusion

This study provides important BIVA and PA data from a frail older hospitalized patient group in the United Kingdom, indicating a high prevalence of reduced nutritional status consistent with at-risk and malnourished patient groups. Taken as a whole group, MNA-SF screening appeared more in line with BIA data, whereas MUST categorized patients predominantly at low risk; however there was no clear statistical significant differentiation in BIVA patterns between screening score categories. Further studies in larger cohort groups are clearly necessary as there are implications for care of frail older people.

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