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Applied nutritional investigation

Phase angle is associated with nutritional risk in subacute stroke patients at the beginning of rehabilitation

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ABSTRACT

Objectives: Malnutrition in stroke is associated with poor clinical outcomes. Bioelectrical impedance analysis–derived phase angle (PhA) is widely used for assessing nutritional status as an index of muscle quality. This study aimed to evaluate the associations between whole body and limb PhAs and nutritional risk in stroke patients. PhA predictors were also identified.

Methods: Consecutive subacute stroke patients aged ≥50 y at the beginning of rehabilitation participated in this retrospective analysis. Nutritional risk was assessed using the Geriatric Nutritional Risk Index, the Prognostic Nutritional Index, and the Controlling Nutritional Status score. PhAs at 50 kHz for both whole body and limbs were measured. The associations between PhA and nutritional risk were examined through univariate/multivariate analyses.

Results: Overall, 272 subacute stroke patients were studied (age, 70.1 ± 12.4 y, body mass index, 26.8 ± 3.9 kg/m^2). Both whole body and limb PhAs were associated with Geriatric Nutritional Risk Index, Prognostic Nutritional Index, and Controlling Nutritional Status score, and this was also true in patients aged ≥75 y ($P < 0.001$). Low PhA values were observed in patients at high nutritional risk. The general linear model identified age, female sex, hypertension, diabetes, dysphagia, and time from stroke onset as independent predictors of PhA ($R^2 = 0.468$, $P < 0.001$). Furthermore, PhA emerged as a significant predictor of high nutritional risk according to each screening tool. Finally, optimal cutoffs of whole body PhA for predicting high nutritional risk were around 4.08°.

Conclusions: In stroke patients, low PhA values were associated with high nutritional risk. PhA at the beginning of rehabilitation may serve as a reliable parameter to be considered in the evaluation of nutritional status.

Introduction

In order to ensure high-quality care, the clinical management of disease-related malnutrition (undernutrition) involves a sequence of well-defined procedures. This approach, commonly known as Nutrition Care Process [1], includes different steps. The first step, nutritional screening, aims to identify patients at risk of being malnourished (i.e., nutritional risk) and those who are at risk of becoming malnourished (possibly also those who are overweight/obese) [2]. This is crucial for preventing worsening of nutritional status independently of the formal diagnosis of malnutrition.

In this regard, it is worth noting that phase angle (PhA), a directly measured bioelectrical impedance analysis (BIA) variable, provides information on the inherent bioelectrical characteristics of fat-free mass (FFM) and muscle mass [3,4]. High PhA values suggest cellular integrity, greater cellularity (i.e., more body cell mass relative to FFM), and low ratio of extracellular to intracellular water [3,5]. PhA might therefore be considered an index of muscle quality [6,7]. Low PhA is associated with malnutrition and sarcopenia [3,8,9]. Additionally, it has emerged as a significant predictor of different outcomes, such as impaired muscle strength [4], poor physical function [7], and mortality [10] as well as reduced quality of life [11] and poor prognosis [12]. Overall, the current body of evidence encourages further research on the use of PhA in the nutritional management of patients.

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Stroke is a leading cause of death and disability worldwide [13], with the need for long-term care and a substantial burden on health care systems [14]. The prevalence of malnutrition in stroke patients ranges from 3% to 87%, possibly depending on diagnostic criteria, settings, or both, with higher rates in subacute compared with acute patients [14–16]. The negative impact of stroke on nutritional status may be due to several factors, including age, inflammation, comorbidities, dysphagia, hemiparesis, reduced nutrient intake, decreased mobility, depression, and dementia [14,17,18]. Stroke-related sarcopenia [19,20] is also often observed, being associated with early motor unit loss as well as muscle atrophy/remodeling.

Overall, it is strongly suggested that evaluation of nutritional risk (with standard screening tools) be part of the multidimensional clinical assessment in order to identify stroke patients at risk of being or becoming malnourished. Of note, nutritional risk, evaluated using various screening tools, such as the Geriatric Nutritional Risk Index (GNRI), the Prognostic Nutritional Index (PNI), and the Controlling Nutritional Status (CONUT) score [16], is associated with infection development, longer hospital stays, low physical function, and increased mortality [16,21].

As for the assessment of nutritional status, PhA values can be low in stroke because of illness-related changes in body cell mass, tissue hydration, and fluid distribution [22]. Thus far, a few studies have reported preliminary findings on the association between PhA and nutritional risk, body composition, and functional status in stroke patients [20,23–28], with very limited evidence on segmental PhA [29,30].

In light of this background and taking into consideration both whole body and segmental PhAs, the present study aimed to evaluate the association between PhA and nutritional risk, as assessed by different screening tools. In addition, in light of the lack of consistent evidence, we sought to identify patient characteristics that may predict PhA values.

Materials and methods

Study design and participants

This was a single-center retrospective cohort study conducted in a rehabilitation hospital (Santa Maria del Pozzo Hospital, Naples, Italy). Consecutive early subacute stroke patients (>15 d and <3 mo after stroke) [31] who started rehabilitation within 2 wk of stroke onset between January 2021 and December 2023 were enrolled. The inclusion criteria comprised the following: 1) evidence of stroke (ischemic, hemorrhagic, subarachnoid hemorrhage), as diagnosed by computed tomography or magnetic resonance imaging; 2) age ≥50 y; and 3) time from stroke onset >15 d. The exclusion criteria were inability to measure BIA owing to implantation and missing data.

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Campania Sud Ethics Committee (Italy) (n.147/2023). Informed consent, clinical data, and assessments/measurements were obtained within 48 h of admission. The study staff members underwent comprehensive training in accordance with the principles of good clinical practice guidelines.

Data collection

Clinical data were collected based on the hospital information or provided by the patients or their family members. Patients were assessed for comorbidities; laboratory data related to nutritional status; dysphagia/swallowing function using the Food Intake Level Scale [32]; pressure ulcers defined by the European Pressure Ulcer Advisory Panel guidelines [33]; and nutritional risk with GNRI, PNI, and CONUT score. As reported elsewhere [34], GNRI was calculated using the formula (14.89 × serum albumin [g/dL]) + (41.7 × [body weight/ideal body weight]). Ideal body weight was determined with the Lorentz formula [35]. The actual ratio of body weight to ideal body weight was considered 1 when the actual body weight exceeded the ideal body weight. Nutritional risk was normal (score >98), mild (score 97–92), moderate (score 91–82), or severe (score <82). PNI was calculated as (10 × serum albumin [g/dL]) + (0.005 × total lymphocyte count [n/mm^3]). Nutritional risk was considered normal (score >38), moderate (score 35–38), or severe (score <35). CONUT score was derived from serum albumin concentration, total peripheral lymphocyte count, and total cholesterol concentration according to the original formula [36]. Nutritional risk was defined as normal (score 0–1), light (score 2–4), moderate (score 5–8), or severe (score 9–12). On the whole, high (moderate plus severe) nutritional risk was defined as GNRI <92, PNI ≤38, or CONUT score ≥5.

Anthropometry and BIA

Anthropometric measurements were performed following standard procedures [29]. Weight and height were measured in duplicate to the nearest 0.1 kg. Weight was measured with a wheelchair platform scale (7708 platform scale; Soehnle Industrial Solutions GmbH, Backnang, Germany), whereas height was recorded in the supine position with the patient lying in bed with a portable stadiometer (seca 213; seca, Hamburg, Germany). Body mass index (BMI) was calculated as body weight (kg) divided by squared height (m). Underweight was defined as BMI <20 if <70 y or BMI <22 if ≥70 y [37].

BIA was performed using a Human im touch phase-sensitive multifrequency device (DS Medica S.r.l., Milan, Italy) with standardized conditions (i.e., early morning, room temperature of 23–25°C, fasting >3 h, supine position for at least 10 min before starting the measurement) [38] on both the affected body side and the unaffected body side. After cleaning the skin surface, subjects remained lying down with upper and lower limbs slightly abducted so there was no contact between the extremities and trunk. The segmental evaluation (upper and lower limbs separately) was conducted in accordance with Organ et al. [39]. For the right side, the injecting electrodes were always placed on the dorsal surface of the right hand and foot. The measuring electrodes were placed as follows: for the whole body, anterior surface of the right wrist and ankle; for the upper limbs, right and left wrists; and for the lower limbs, right and left ankles. Symmetrical placement of the electrodes was used for the left side. For statistical analyses, values of whole body and limb PhAs were calculated as mean values of affected and unaffected sides.

Impedance and PhA were measured at 50 kHz, injecting an alternating sinusoidal electrical current of 800 μA. 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 impedance (at each of the different frequencies considered) and 2% for PhA. Patients with very low PhAs were identified using PhA percentiles recently published for the Italian population [40].

Statistical analysis

Statistical analysis was carried out using SPSS Statistics 28.0 (IBM, Armonk, NY, USA). Results were reported as mean ± SD, median and interquartile range, or number and percentage of patients as appropriate. $P < 0.05$ was considered significant for all tests (two-tailed). Sample size analysis revealed that for correlation analysis, a total of 194 participants were required (statistical power 0.80, correlation coefficient 0.20, and alpha level 0.05).

The Kolmogorov–Smirnov test was used as a test of normality. Comparisons between groups were assessed using the Student's t test and one-way analysis of variance with post hoc Tukey's test for parametric variables, whereas the Mann–Whitney U test and the Wilcoxon rank sum test were applied for non-parametric variables. The χ^2 test was used for testing differences between categorical variables.

Partial correlation analysis was carried out to examine the relationship of PhA with variables of interest. A general linear model was used to determine predictors of whole body PhA based on age, sex, atrial fibrillation, hypertension, diabetes mellitus, coronary artery disease, hyperlipemia, previous stroke, dysphagia, pressure ulcers, and time from stroke onset.

Logistic regression analyses were performed to determine independent risk factors for high nutritional risk. The potential predictors were age, sex, atrial fibrillation, hypertension, diabetes mellitus, coronary artery disease, hyperlipemia, previous stroke, dysphagia, pressure ulcers, time from stroke onset, and PhA (whole body and limbs).

The receiver operating characteristic (ROC) method was used to assess the predictive power of both whole body and limb PhAs for high nutritional risk. The optimal cutoff value of each index was determined according to the greatest Youden's index.

Results

A total of 294 stroke patients were newly admitted to the rehabilitation hospital during the study period. Patients with missing data (n = 10), metal implants (n = 6), or pacemakers (n = 6) were excluded from the analysis. Finally, 272 patients with ischemic stroke (82% of total sample), hemorrhagic stroke (16% of total sample), or subarachnoid hemorrhage (2% of total sample) were included in the study.

The main characteristics of the participants (46.3% women) are shown in Table 1. Age ranged from 50 to 96 y (mean, 70.1 ± 12.4), with no difference between sexes. Compared with women, men had greater weight and height and slightly lower BMI. On the whole, 8% of patients were underweight, 50% were overweight, and 19% were obese. A high proportion of patients (both sexes) had hypertension, whereas atrial fibrillation and hypothyroidism were more prevalent in female than in male participants. The median time from stroke onset was 18 d (interquartile range, 12–27).

PhA values (for the whole body and upper and lower limbs) were slightly lower ($P < 0.001$) in the affected body side compared with the unaffected body side (data not shown) and were greater in male compared with female sex. For instance, whole body PhA varied between 2.25° and 7.00° in men and between 1.35° and 6.70° in women (Table 1). Lower PhA values were observed in stroke patients aged ≥75 y (n = 111), being 4.02 ± 0.97° in men and 3.26 ± 0.89° in women ($P < 0.001$). Compared with reference values from the general population [40], 71% of female patients and 67% of male patients had PhA values below the third percentile.

According to the general linear model (R^2 = 0.468, $P < 0.001$), age ($P < 0.001$), female sex ($P < 0.001$), hypertension ($P < 0.05$), diabetes ($P < 0.01$), dysphagia ($P < 0.02$), and time from stroke onset ($P < 0.001$) emerged as independent predictors of whole body PhA. Other variables (atrial fibrillation, coronary artery disease, hyperlipemia, previous stroke, and pressure ulcers) were not included in the model.

After adjusting for sex, PhA (whole body, upper and lower limbs) positively correlated with body weight, BMI, albumin, lymphocyte count, and hemoglobin but not with total cholesterol (Table 2). As for nutritional risk, both whole body and limb PhAs showed significant associations with GNRI, PNI, and CONUT score.

Table 2
Partial correlation between PhA and variables of interest in 272 subacute stroke patients

Variable	PhA, whole body		PhA, upper limbs		PhA, lower limbs	
	r	p value	r	p value	r	p value
Body weight	0.390	< 0.001	0.296	0.017	0.370	< 0.001
BMI	0.242	< 0.001	0.211	< 0.001	0.215	< 0.001
GNRI	0.369	< 0.001	0.298	< 0.001	0.311	< 0.001
PNI	0.388	< 0.001	0.346	< 0.001	0.332	< 0.001
CONUT score *	−0.360	< 0.001	−0.299	< 0.001	−0.275	< 0.001
Albumin	0.358	< 0.001	0.297	< 0.001	0.300	< 0.001
Cholesterol	0.087	0.157	0.041	0.534	0.006	0.927
Lymphocyte count	0.230	< 0.001	0.244	< 0.001	0.215	< 0.001
Neutrophil count	−0.023	0.707	−0.065	0.326	0.064	0.339
Hemoglobin	0.384	< 0.001	0.355	< 0.001	0.293	< 0.001
Platelet count	0.043	0.480	0.035	0.596	0.061	0.358

BMI, body mass index; CONUT, Controlling Nutritional Status; GNRI, Geriatric Nutritional Risk Index; PhA, phase angle; PNI, Prognostic Nutritional Index.
*Because CONUT score is an ordinal variable, Spearman's correlation analysis was used.

Similar results emerged when a separate analysis for male and female patients was performed (data not shown). When stroke patients aged ≥75 y were considered, the associations with nutritional risk persisted but only for the whole body and upper limbs (Supplementary Table 1).

Mean whole body PhA values (adjusted for sex) were lower ($P < 0.001$) in patients at high nutritional risk compared with those at low nutritional risk, being 3.86 ± 1.05° versus 4.48 ± 1.17° with GNRI, 3.58 ± 0.99° versus 4.46 ± 1.09° with PNI, and 3.78 ± 1.07° versus 4.41 ± 1.11° with CONUT score. These differences ($P < 0.001$) were similarly observed for upper and lower limbs and in stroke patients aged ≥75 y (data not shown). In addition, the prevalence of high nutritional risk increased similarly in both sexes

Table 1
Anthropometric and clinical characteristics of subacute stroke patients

Variable	Total N = 272	Women N = 126	Men N = 146	p value
Age, y	70.1 ± 12.4	71.7 ± 13.0	68.9 ± 11.7	0.065
Weight, kg	73.0 ± 13.7	68.9 ± 14.0	76.6 ± 12.3	< 0.001
Height, cm	163.9 ± 9.4	157.9 ± 7.7	169.1 ± 7.5	< 0.001
BMI, kg/m^2	26.8 ± 3.9	27.3 ± 4.6	26.4 ± 3.1	0.050
PhA, whole body, degrees	4.11 ± 1.14	3.68 ± 1.05	4.49 ± 1.08	< 0.001
PhA, upper limbs, degrees	3.64 ± 1.27	3.07 ± 1.11	4.11 ± 1.21	< 0.001
PhA, lower limbs, degrees	4.87 ± 1.46	4.54 ± 1.53	5.15 ± 1.33	< 0.001
Stroke risk factors				
Atrial fibrillation	47 (17.3)	29 (23.0)	18 (12.3)	0.015
Hypertension	209 (76.8)	101 (80.2)	108 (74.0)	0.144
Diabetes mellitus	95 (34.5)	44 (34.9)	50 (34.2)	0.504
Coronary artery disease	94 (34.5)	42 (33.3)	53 (36.3)	0.081
Hyperlipemia	111 (40.8)	55 (43.7)	56 (38.4)	0.223
Previous stroke	47 (17.3)	20 (15.9)	27 (18.5)	0.342
Hypothyroidism	36 (13.2)	23 (18.3)	13 (8.9)	0.018
Dysphagia	96 (35.3)	51 (40.5)	45 (30.8)	0.245
Pressure ulcers	52 (19.1)	28 (22.2)	24 (16.4)	0.137
Nutritional risk				
GNRI	90 (84–95)	89 (83–93)	91 (86–96)	0.009
PNI	40 (35–44)	39 (34–44)	41 (36–45)	0.119
CONUT score	4 (3–6)	4 (2–7)	4 (3–6)	0.409
Laboratory parameters				
Albumin, g/dL	3.23 ± 0.56	3.15 ± 0.61	3.30 ± 0.51	0.022
Cholesterol, mg/dL	147 ± 42	156 ± 42	140 ± 40	< 0.001
Lymphocyte count, mL	1400 (1000–1900)	1400 (1000–1900)	1400 (1100–1800)	0.562
Neutrophil count, mL	5500 (4100–7200)	5400 (4000–7200)	5500 (4225–6975)	0.587
Hemoglobin, g/dL	13.0 ± 2.0	12.5 ± 1.9	13.4 ± 1.9	< 0.001
Platelet count, mL × 1000	247 (202–309)	255 (211–310)	242 (193–306)	0.199

BMI, body mass index; CONUT, Controlling Nutritional Status; GNRI, Geriatric Nutritional Risk Index; PhA, phase angle; PNI, Prognostic Nutritional Index.
Data are expressed as mean ± SD, n (%), or median (interquartile range).

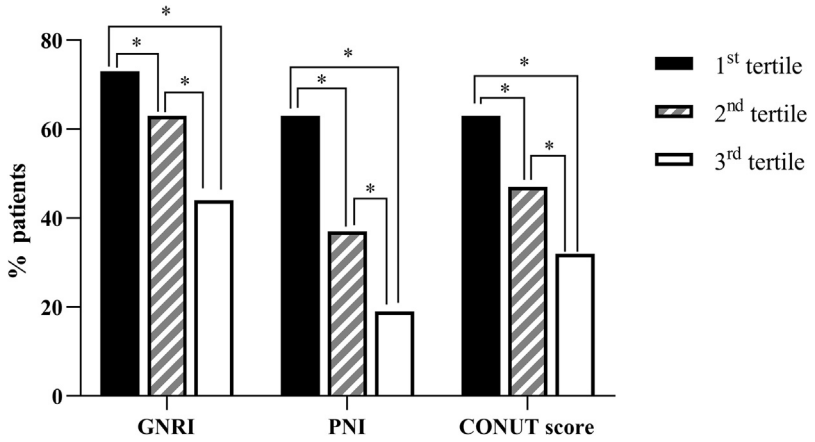

Fig. 1. Prevalence of high nutritional risk according to PhA tertiles in 272 stroke patients. First tertile 1.35° to 3.45°, second tertile 3.46° to 4.65°, third tertile 4.66° to 7.00°. No significant differences were noted between sexes. CONUT, Controlling Nutritional Status; GNRI, Geriatric Nutritional Risk Index; PhA, phase angle; PNI, Prognostic Nutritional Index. (*p<0.05)

along tertiles of PhA for each screening tool (Fig. 1). Stroke patients at high nutritional risk according to all three tools were 54% in the first tertile, 34% in the second tertile, and 18% in the third tertile.

When univariate logistic analysis was used, whole body PhA as well as age ≥75 y, male sex, dysphagia, pressure ulcers, and time from stroke onset was associated with having a high nutritional risk based on GNRI, PNI, or CONUT score (Supplementary Tables 2–4). In multivariate analysis, whole body PhA remained a significant predictor of high nutritional risk ($P < 0.001$) along with dysphagia and time from stroke onset (GNRI) (Supplementary Table 2), time from stroke onset (PNI) (Supplementary Table 3), and age ≥75 y (CONUT score) (Supplementary Table 4). Similar results were found for upper and lower limb PhAs (data not shown).

Finally, ROC analyses were performed to identify the PhA cutoff values for detecting high nutritional risk. With regard to PNI (Fig. 2A), the optimal PhA cutoff was 4.08° (sensitivity 62% and specificity 72%) for whole body, 3.88° (57% and 80%) for upper limbs, and 4.98° (59% and 76%) for lower limbs. For GNRI (Fig. 3), the optimal PhA cutoff was 4.13° (sensitivity 60% and specificity 61%) for whole body, 3.88° (54% and 66%) for upper limbs, and 4.98° (60% and 76%) for lower limbs. Finally, for CONUT score (Fig. 4), the optimal PhA cutoff was 4.13° (sensitivity 60% and

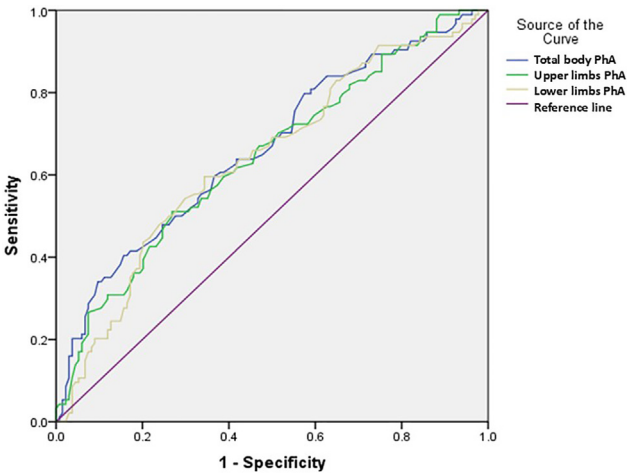

Fig. 3. Receiver operating characteristic (ROC) curves of whole-body, upper and lower limbs PhA for high nutritional risk with GNRI. PhA = phase angle; GNRI = geriatric nutritional risk index. Whole-body PhA: AUC 0.663, 95% CI 0.591-0.735, p<0.001; Upper limbs PhA: AUC 0.643, 95% CI 0.570-0.716, p<0.001; Lower limbs PhA: AUC 0.639, 95% CI 0.565-0.712, p<0.001.

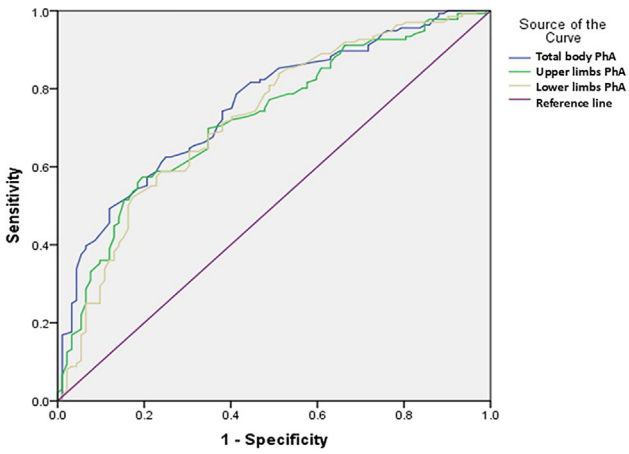

Fig. 2. Receiver operating characteristic (ROC) curves of whole-body, upper and lower limbs PhA for high nutritional risk with PNI. PhA = phase angle; PNI = prognostic nutritional index. Whole-body PhA: AUC 0.755, 95%CI 0.693-0.818, p<0.001; Upper limbs PhA: AUC 0.723, 95%CI 0.657-0.789, p<0.001; Lower limbs PhA: AUC 0.724, 95%CI 0.656-0.791, p<0.001.

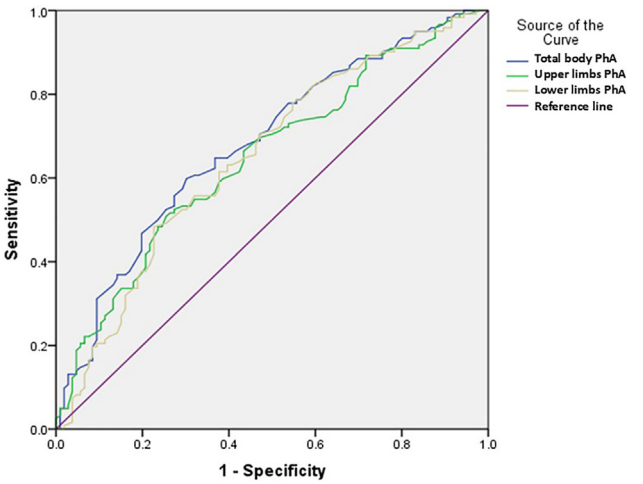

Fig. 4. Receiver operating characteristic (ROC) curves of whole-body, upper and lower limbs PhA for high nutritional risk with CONUT score. PhA = phase angle; CONUT = controlling nutritional status score. Whole-body PhA: AUC 0.680, 95%CI 0.611-0.750, p<0.001; Upper limbs PhA: AUC 0.649, 95%CI 0.578-0.720, p<0.001; Lower limbs PhA: AUC 0.651, 95%CI 0.579-0.722, p<0.001.

specificity 66%) for whole body, 3.93° (53% and 73%) for upper limbs, and 4.78° (62% and 62%) for lower limbs.

Discussion

This study examined the association between PhA and nutritional risk in subacute stroke patients admitted to a rehabilitation unit, with some novel findings: 1) both whole body and limb PhAs were significantly associated with nutritional risk, particularly with PNI, and this was also true in patients aged ≥75 y; 2) PhA was a significant predictor of high nutritional risk along with dysphagia (for GNRI), time from stroke onset (for GNRI and PNI), and age ≥75 y (for CONUT score); and 3) optimal PhA cutoffs for predicting high nutritional risk were proposed for whole body and upper and lower limb measures (with a slightly greater predictive ability for PNI). Stroke is often associated with malnutrition [14–16]. In addition, muscle loss, reduced muscle function, and compromised cell integrity [15] contribute to a condition known as stroke-related sarcopenia [19,20], which is associated with early motor unit loss and muscle atrophy/remodeling. Notably, the majority of patients included in this study were overweight or obese, making it more difficult to reach a diagnosis of malnutrition based on underweight or low FFM.

Based on these considerations, an evaluation of nutritional risk (using standard screening tools) should be included in the clinical assessment to identify stroke patients who may be malnourished or at risk of malnutrition [2]. This is crucial for preventing worsening of nutritional status independently of the formal diagnosis of malnutrition. Other parameters may be helpful for a more comprehensive evaluation of nutritional status (e.g., with regard to body composition). In this respect, PhA is a raw, directly measured BIA variable, reflecting both fluid distribution and body cell mass, which has been associated with the amount and quality of skeletal muscle mass as well as sarcopenia [3,4,41]. In a few studies concerning stroke patients undergoing rehabilitation, PhA has been associated with nutritional status, body composition, sarcopenia, sarcopenic obesity, and functional outcomes [20,24–27]. However, almost all of the evidence concerns only whole body PhA, with few data regarding segmental assessment [29,30].

In light of this, both whole body and segmental PhAs were determined in stroke patients admitted to a rehabilitation unit. Mean whole body PhAs of patients were clearly below the reference values reported in the literature for elderly individuals of either sex [40,42,43] but were similar to those shown in some previous reports on acute and subacute stroke patients [20,24,26], thus suggesting marked structural changes of FFM/muscle mass, as already observed in the elderly [4]. Significant differences in PhA were observed between the affected and unaffected sides, which was in agreement with findings in subacute patients [30] but in contrast to those in acute stroke patients [44], possibly because of the deterioration of nutritional status during hospitalization [14].

In the general population, PhA depends on sex, race, age, BMI, and FFM [5,43,45]. In the stroke patients studied, age, female sex, hypertension, diabetes, dysphagia, and time from stroke onset were independent predictors of whole body PhA. PhA was also greater in male than in female patients and lower in elderly patients, in line with previous findings [25,26,46–50]. Of note, dysphagia, hypertension, and diabetes are already known to be associated with malnutrition and sarcopenia in stroke patients [17,18].

Available studies have already shown a significant association of PhA with sarcopenia (fair predictive ability) in stroke patients [20,27], whereas inconsistent evidence is available regarding the association with body composition and malnutrition (as assessed using standard approaches) [24,48,49]. Along these lines, keeping in mind that nutritional screening aims to identify patients at risk of being malnourished and also those at risk of becoming malnourished, a major aim of this study was to investigate the relationship between PhA and nutritional risk in subacute stroke patients. Three different screening tools (GNRI, PNI, and CONUT score) were chosen for ease of application, consistency, and increasing use in stroke patients [16,51]. These tools are based on basic laboratory tests (and body weight for GNRI), making them suitable for retrospective analysis, and may reflect nutritional status and also disease-related metabolic alterations. It is worth noting that these three tools have indeed been associated with various clinical outcomes [2]. Our findings showed significant associations between PhA and the three tools, particularly with regard to PNI for the whole body, as first demonstrated by simple correlation analysis. This was true in both sexes separately and also confirmed in patients aged ≥75 y. These results are consistent with earlier preliminary findings in stroke patients with respect to GNRI [27,29,48]. Similar associations have been reported in conditions such as hip fractures [52], Crohn's disease [53], and COVID-19 [54]. As for segmental BIA, lower correlation coefficients were observed for limb PhA compared with whole body measures (also in elderly patients), suggesting similar but not closer associations [3,4].

Correspondingly, patients with lower PhA values (e.g., in the first tertile) were at higher risk of malnutrition compared with those with higher PhA values. According to ROC analysis, PhA emerged as a significant predictor of high nutritional risk, with optimal cutoff points of approximately 4.08° to 4.13° for whole body, 3.88° to 3.93° for upper limbs, and 4.78° to 4.98° for lower limbs. It should be noted that area under the curve values were around or slightly below 0.700, indicating fair/weak discriminatory ability (Fig. 2). Notably, so far only one study has reported PhA cutoff values for GNRI-derived high nutritional risk in stroke patients, reporting slightly greater values [49], whereas a recent article on patients with hip fractures proposed similar values [52].

To our knowledge, this is the first study to provide data on the relationship between PhA (both whole body and limbs) and various nutritional screening tools in a cohort of subacute stroke patients at rehabilitation admission. Nevertheless, this study has some limitations. It was conducted in a single center, which limits the generalizability of the results. Additionally, PhA may show different associations with other screening tools, which could not be evaluated in the present study. Finally, so far no data are available on the relationship between PhA and changes in nutritional risk during rehabilitation.

Conclusions

This study contributes novel findings to the nutritional assessment of subacute stroke patients admitted for rehabilitation. Both whole body and limb PhAs were significantly associated with nutritional risk, particularly with PNI, even in patients aged ≥75 y. The optimal PhA cutoff for predicting high nutritional risk indicated that patients with whole body PhA below 4.08° may have higher nutritional risk. Furthermore, PhA emerged as an independent predictor of high nutritional risk according to each screening tool used. These findings suggest that assessing both risk and specific parameters such as PhA is crucial in the clinical management of stroke patients for early and more comprehensive identification of poor nutritional status, for guiding targeted interventions, and for optimizing patient outcomes. Further studies are required to evaluate changes in PhA values and nutritional risk subsequent to rehabilitation as well as to assess the relationship of PhA with body composition and malnutrition, as assessed by international criteria.

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Declaration of competing interest

The authors 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

Olivia Di Vincenzo: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Ermenegilda Pagano:** Visualization, Validation, Resources, Project administration, Investigation. **Giada Ballarin:** Writing – review & editing, Validation, Software. **Fabrizio Pasanisi:** Writing – review & editing, Visualization, Validation, Supervision. **Luca Scalfi:** Writing – review & editing, Visualization, Validation, Software, Project administration, Methodology, Formal analysis, Data curation, Conceptualization.

Data sharing

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.nut.2024.112637.

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