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Phase Angle and Ultrasound Assessment of the Rectus Femoris for Predicting Malnutrition and Sarcopenia in Patients with Esophagogastric Cancer: A Cross-Sectional Study

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Abstract: Background: Disease-related malnutrition and sarcopenia are prevalent conditions in gastrointestinal cancer patients, whose early diagnosis is essential to establish a nutritional intervention that contributes to preventing adverse outcomes and improving the disease prognosis. Phase angle (PhA), rectus femoris cross-sectional area (RFCSA) and rectus femoris thickness (RF-Y-axis) are considered effort-independent markers of muscle mass, strength and functionality. These markers are influenced by the metabolic changes in cancer patients but have not been fully validated in this population. **Objective:** This study aimed to evaluate the potential utility of PhA, RFCSA and RF-Y-axis in predicting malnutrition and sarcopenia in patients with esophagogastric cancer (EGC). **Methods:** This was a cross-sectional study of patients diagnosed with EGC. PhA was obtained using bioelectrical impedance vector analysis (BIVA), along with ASMMI. RFCSA and RF-Y-axis were measured via nutritional ultrasound (NU®). Muscle capacity was assessed using handgrip strength (HGS), and functionality by applying the Short-Physical-Performance-Battery (SPPB). Malnutrition and sarcopenia were determined according to GLIM and EWGSOP2 criteria, respectively. **Results:** Out of the 35 patients evaluated, 82.8% had malnutrition and 51.4% sarcopenia. RFCSA(r=0.582) and RF-Y-axis(r=0.602) showed significant, moderate correlations with ASMMI, unlike PhA(r=0.439), which displayed a weak correlation with this parameter. However, PhA (OR=0.167,CI 95%:0.047-0.591,p=0.006), RFCSA (OR=0.212, CI 95%:0.074-0.605,p=0.004), and RF-Y-axis (OR=0.002,CI 95%:0.000-0.143,p=0.004) all showed good predicting ability for sarcopenia in the crude models, but only RF-Y-axis was able to explain malnutrition in the regression model (OR=0.002, CI 95%:0.000-0.418,p=0.023). **Conclusion:** RF-Y-axis emerged as the only independent predictor of both malnutrition and sarcopenia in this study, likely due to its stronger correlation with ASMMI compared to PhA and RFCSA.

Keywords: esophagogastric cancer; malnutrition; sarcopenia; nutritional ultrasound; phase angle; morphofunctional assessment

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1. Introduction

According to the latest data from the Global Cancer Observatory (GLOBOCAN) of 2022, gastrointestinal (GI) cancers are a major public health concern as they pose the highest lifetime risk of death, due to the invasive nature of the disease [1]. In Europe, esophageal and gastric cancers, two of the most lethal malignant GI tumors [2,3], accounted for 189.031 new cases and 142.508 deaths in 2020 [4], resulting in a sixth and third place in terms of mortality, respectively [1]

These patients commonly experience a high rate of nutritional impairment due to symptoms arising from systemic inflammation and local tumor effects, such as dysphagia, nausea, malabsorption, vomiting, diarrhea or fatigue [5–7]. This leads to inadequate nutritional intake [8–10], which causes involuntary weight loss and reduced muscle mass [11–14]. Therefore, disease-related malnutrition (DRM) and sarcopenia are the most common cancer-related conditions, affecting between 15% and 40% of patients at the time of diagnosis. Moreover, in advanced stages of esophagogastric cancer (EGC), DRM and sarcopenia may affect up to 75% of patients [15–18].

Currently, in cancer patients, DRM and sarcopenia have been associated with adverse outcomes, including higher likelihood of postoperative complications and reduced response and tolerance to treatment [19]. This results in increased length of hospital stay, disease burden and healthcare costs, further worsening patient prognosis and overall survival [20–22]. Hypercatabolic state and, consequently, muscle wasting are often exacerbated by most chemotherapeutic agents and surgery itself, underscoring the importance of evaluating muscle mass as a key component in morphofunctional assessment to identify malnutrition and sarcopenia [23], which can also occur in individuals with normal weight, overweight, or obesity.

The Global Leadership Initiative on Malnutrition (GLIM) has highlighted the role of reduced muscle mass as a phenotypic criterion for diagnosing malnutrition in clinical settings [24]. Similarly, in 2019, the European Working Group on Sarcopenia in Older People 2 (EWGSOP2) updated the definition of this condition, establishing that sarcopenia is probable when low muscle strength is detected; its diagnosis is confirmed by the presence of low muscle quantity or quality, and is considered severe when low physical performance is identified [25]. There are several techniques available to assess changes in body composition, such as bioelectrical impedance analysis (BIA) and ultrasound (US), which have the advantages of low cost, high portability and bedside use [26–28], unlike MRI and CT, currently considered as gold standards for assessing the nutritional status of patients [29,30].

On one hand, BIA is a non-invasive method based on the human's body ability to transmit an electrical current, providing the bioelectrical impedance vector analysis (BIVA) and phase angle (PhA), both of which elucidate insights into cell membrane integrity and vitality, and body hydration [31–35]. The BIVA approach and PhA are derived from raw measurements, specifically resistance (R) and reactance (Xc), rendering them independent of body weight and free from calculation-inherent errors, which makes them suitable for use in cancer patients [36,37].

On the other hand, US has proven to be a valuable tool, independent of hydration status. It has shown good validity for estimating muscle mass [38–41] through measurements of different body compartments [42]. Although various muscular structures can be evaluated, the rectus femoris (RF) is one of the most referenced since anterior thigh muscles are affected early in catabolic processes [43]. Like PhA, ultrasound-derived rectus femoris cross-sectional area (RFCSA) and muscle thickness or rectus femoris Y-axis (RF-Y-axis) have been proposed as attractive, effort-independent surrogate markers of malnutrition and sarcopenia. Recent studies have demonstrated that lower values of these parameters are linked to reduced muscle mass, strength and/or functionality [44–48].

However, contradictory findings have also been reported [49–52]. In addition, most studies yielding positive results have focused on contexts outside of oncology, including cardiovascular diseases, chronic obstructive pulmonary disease, Sars-CoV2 disease or even healthy patients [46,47,53]. Furthermore, research evaluating the effectiveness of PhA has predominantly examined its association with postoperative complications rates, length of hospital stay, quality of life and survival, rather than with malnutrition and sarcopenia [54–57].The same has occurred when

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considering ultrasound measurements, as studies have concentrated on establishing correlations between RFCSA, RF-Y-axis, and mortality [45].

Consequently, to date, there is a gap in the literature regarding the ability of certain bioelectrical and ultrasound parameters to reflect nutritional status, including muscle quantity and quality in EGC patients. Therefore, our aim was to evaluate the potential utility of PhA, RF-CSA and RF-MT in identifying malnutrition and sarcopenia according to the GLIM and EWGSOP2 criteria, respectively, in adult patients with EGC.

2. Materials and Methods

2.1. Study Design

Prospective cross-sectional study, single-center, developed in 35 patients diagnosed with esophagogastric cancer. The patients were recruited in the Endocrinology and Nutrition Service of the Hospital Universitario y Politécnico La Fe in Valencia between January 2024 and September 2024, after being referred from esophagogastric surgery or medical oncology department.

The inclusion criteria were patients between 18 and 80 years old with histologically confirmed diagnoses, regardless of tumor stage and route of feeding. The exclusion criteria were patients with concomitant non-esophagogastric malignant tumors and those undergoing palliative treatment and patients with ECOG (Eastern Cooperative Oncology Group) >2. Patients diagnosed with severe liver cirrhosis, chronic kidney disease stage 4 or 5 (glomerular filtration rate less than 30 ml/min/1.73 m^2, measured by the equation proposed by the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI)), heart failure, mental illness, or stroke were excluded. Additionally, patients without all clinical data such as weight or height and contraindications to BIA were also excluded. This ensured that, in total, 4 patients were excluded from the present study.

The study was approved by the Clinical Research Ethics Committee of the La Fe Health Research Institute (number *2023-1188-1*, approval date December 20th 2023) and informed consent was obtained from each patient to use their data anonymously.

1.2. Clinical and Sociodemographic Data

We collected data related to sex, age, comorbidities such as diabetes, hypertension, dyslipemia; tumor location, TNM (Tumor Nodes Metastasis) cancer staging system, oncology treatment and ECOG. Information was recruited by interview or medical record. The level of physical activity was assessed using the International Physical Activity Questionnaire (IPAQ) [58]. Based on the results, participants were classified into inactive or low physical activity, moderate activity, and high activity.

1.3. Anthropometric Measurements

A stadiometer was used to measure height, and weight was calculated using a calibrated weighing scale set (certified test weights ± 0.1 kg) (*SECA* ®, Hamburg, Germany). As part of anthropometry, patients were measured with the patient standing, dressed in light clothing, barefoot, and with the head oriented in the Frankfurt horizontal plane, using a mechanical column scale. The patient's body mass index (BMI) was determined and classified according to the World Health Organization (WHO). For older patients, the BMI was classified according to the recommendations of the Spanish Society of Geontology and Geriatry (SEGG) and the Spanish Society of Clinical Nutrition and Metabolism (SENPE) [59].

Calf (CC) and mid-arm circumferences (MAC) were measured according to recommendations and using a flexible, non-elastic measuring tape (SECA® 201) calibrated in centimeters with millimeter precision. The CC cut-off was <34 cm for men and <33 cm for women (BMI = 18.5–24.9 kg/m^2, for other BMIs, adjustment factors) [60].

1.4. Nutritional Screening and Diagnosis of Malnutrition

Nutritional risk was evaluated by the subjective global assessment (SGA) [61]. The SGA is the most studied, validated, and widely recognized method for accurately assessing the nutritional status of oncology patients [62,63]. It produces the following global ratings: well nourished (A), moderately malnourished(B), or severely malnourished (C).

The GLIM criteria were used to diagnose malnutrition [24], which stipulate that a minimum of one etiologic and one phenotypic criterion must be present at the same time. The phenotypic criteria included: (a) unintentional weight loss > 5% over the past six months or >10% beyond six months, (b) a body mass index (BMI) of <18.5 kg/m^2 for individuals under 70 years of age or <20 kg/m^2 for those aged 70 and older, and (c) reduction of muscle mass based on appendicular skeletal muscle mass index (ASMMI) (<7 kg/m^2 in males and <5.5 kg/m^2 in females) or fat free mass index (FFMI) (<17 kg/m^2 in males and <15 kg/m^2 in females).

We determined that all patients fulfilled the GLIM etiological criteria for chronic disease-related due to cancer. Dietary intake was estimated using a 24-hour dietary recall of 3 days conducted by a trained registered dietitian.

1.5. Morphofunctional Assessment

1.5.1. Bioelectrical Impedance Vector Analysis (BIVA)

The impedance measurements were conducted using a single-frequency and phase-sensitive impedance analyzer (NUTRILAB®, AKERN®, Pontassieve, Italy), which applies an alternating sinusoidal electric current of 400 μA at 50 kHz. We performed the measurements following the standard and validated technique [64], which are based on the placement of the electrodes (*BIATRODES™)* on the back of the right hand (center of the third proximal phalanx) and one electrode on the corresponding foot (proximal to the second and third metatarsophalangeal joints). The position of the patients was supine with the legs opened at a 45° angle relative to the body's midline, while the upper limbs were positioned 30° away from the trunk. To avoid disturbances, all patients waited five minutes in a supine position to balance the fluid distribution, and they were instructed to abstain from food and drink the 2 hours before the test [65]. Bioelectrical parameters were analyzed to estimate body composition, including PhA, total body water (TBW), extracellular body water (ECW), intracellular body water (ICW), fat-free mass (FFM), fat mass (FM), body cell mass (BMC) and appendicular skeletal muscle mass (ASMM). To assess the hydration status, ECW/TBW ratio and TBW/FFM % was used.

1.5.2. Nutritional Ultrasound (NU)®

The U PROBE-L6C® (manufacturer Léleman®, Valencia, Spain) (linear 7.5–10 KHz) ultrasound scanner was used, which allowed a depth of up to 100 mm. The patient was in a relaxed supine position with the knee fully extended. Ultrasound scans of the rectus femoris muscle were performed at a point two-thirds of the way between the superior pole of the patella and the anterior superior iliac spine, according to standardized technique [66]. The probe was covered with a suitable water-soluble transmission gel to ensure proper acoustic contact without compressing the dermal surface. It was aligned perpendicularly to both the longitudinal and transverse axes of the rectus femoris muscle to acquire the transverse image (Figure 1A). We measured in the transversal axis the cross-sectional area (RFCSA) in cm^2, muscle thickness (or RF-Y-axis), the RF-X-axis and leg subcutaneous fat (RF-AT) in cm.

The other component of NU® is the fat assessment at the level of abdominal wall. The measurement point was established at the midpoint between the xiphoid appendix and the umbilicus in the midline. In the cross-sectional view, the anatomical structures observed were arranged from the most superficial layer, which corresponds to the epidermis, followed by the superficial and deep adipose tissue layers. The two anterior rectus abdominis muscles, which converge at the central part of the *linea alba*, were identified. Lastly, the preperitoneal fat layer located between the lower border of the *linea alba* and the parietal peritoneum was visualized (Figure 1B). The images were taken during unforced expiration, in a transverse axis, and aligned perpendicularly to the skin. In this case, we measured the total subcutaneous abdominal adipose tissue (T-SAT), superficial subcutaneous abdominal fat (S-SAT), and total visceral adipose tissue (VAT), all in cm. The procedure was performed by one experienced professional, to avoid interobserver variability.

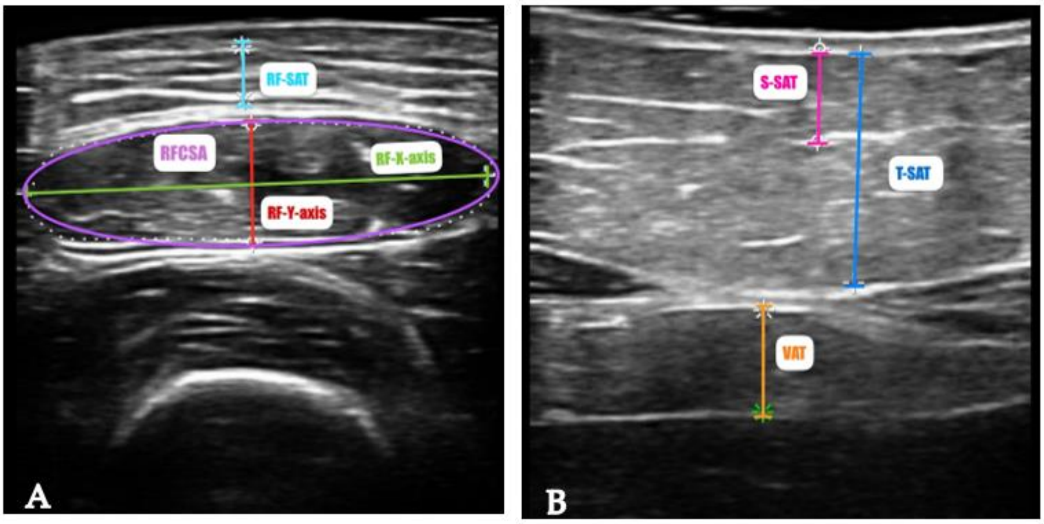

Figure 1. Measurement of rectus femoris (A) and abdominal adipose tissue (B) by ultrasound of a patient of our sample. Abbreviations - RFCSA: rectus femoris cross sectional area; RF-Y-axis: rectus femoris Y axis or muscle thickness; RF-X-axis: rectus femoris X axis; RF-SAT: rectus femoris superficial adipose tissue; VAT: visceral adipose tissue; T-SAT: total subcutaneous adipose tissue and S-SAT: superficial subcutaneous adipose tissue.

1.5.3. Functional and Muscle Strength Assessment

The measurement of hand grip strength (HGS) in the dominant hand was assessed using a Jamar dynamometer (Asimow Engineering Co., Los Angeles, CA, USA). The patients were instructed to sit in a chair with a backrest, with both feet on the floor, with the shoulders close to the body in a neutral position and the forearm flexed at 90º without rotation [67,68]. The correct grip was then explained to them and initiated when they were in a comfortable position. They were asked to squeeze as hard as they could after receiving a verbal command, they were encouraged with words of effort to achieve a better result. Three measurements were recorded with the dominant hand, with 1 minute of rest between each measurement, and then averaged.

To assess the physical performance, the Short Physical Performance Battery (SPPB) test was used, which consists of three tests: balance (feet together, semi tandem, and tandem), walking speed (over 4 m), and the chair rising test. With it, patients were divided into dependent/disabled (0-3 points), frail (4–6 points), pre-fragile (7–9 points), or autonomous/ robust (10-12 points) [69].

1.6. Assessment and Diagnosis of Sarcopenia

Sarcopenia risk was performed using the validated Spanish version of the SARC- F) [70], a five-item self-report questionnaire based on patient's perceptions of their own limitations in Strength, Assistance in walking, Rise from a chair, Climb stairs and experiences with Falls. The final score was used to classify patients into low probability of sarcopenia (<4 points) or high probability of sarcopenia (≥ 4 points) [71].

To diagnose sarcopenia, EWGSOP2 (European Working Group on Sarcopenia in Older People) criteria was used [25]. The patients were classified according to the EWGSOP2 algorithm: (1) probable sarcopenia if they presented low muscle strength in dynamometry (<27 kg in men and <16 kg in women); (2) confirmed sarcopenia, if there is coexistence of low muscle strength with the previously described criteria and low muscle quantity or quality defined as ASMMI (<7 kg/m^2 in males and <5.5 kg/m^2 in females); and (3) severe sarcopenia if, in addition to low strength and low muscle quantity/quality, there is low physical performance (SPPB test ≤ 8 points).

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1.7. Statistical Analysis

Continuous variables are described as mean and standard deviation (SD) or median and interquartile range (IQR). Categorical variables are described as proportions (%). Previously, the Shapiro-Wilk test was performed to check the normality of the data. Comparisons between groups were made with different tests, depending on the nature of the variables, including the Mann-Whitney U test, Fisher's exact test, one-way ANOVA and the Kruskal-Wallis test, followed by the Bonferroni post-hoc, as appropriate. Inferential statistics were performed with bivariate correlations with the Pearson and Spearman correlation test, according to normal distribution. To confirm whether different variables are factors that can predict malnutrition and sarcopenia, we conducted binary logistic regression analysis using a crude model in the presence or absence of malnutrition and sarcopenia as dependent variables. Statistical significance was set at $p < 0.05$. All statistical analyses were performed with SPSS 30.0 (SPSS Inc., Chicago, IL, USA) software package.

3. Results

Participants Characteristics

The study included 35 patients, 26 of whom were male (74.3%) with a mean age of 62.8 ± 8.8 years. A total of 25 (71.4%) patients had esophagus cancer and 14 (40%) were in stage III. The combination of surgery and chemotherapy (CTx) was the most used therapy (54.3%). Most patients were inactive or considered with low physical activity (74.3%). An overview of the characteristics of the population study, including demographic and clinical variables, screening methods and anthropometric measurements are summarized in Table 1.

Table 1. Baseline demographic and disease characteristics of the participants.

Variables	All Patients (n=35)	Male (n=26)	Female (n=9)
Age (years)	62.8 ± 8.8	62.2 ± 9.5	64.8 ± 6.4
Primary site tumor			
Esophagus	25 (71.4%)	21 (80.8%)	4 (44.4%)
Gastric	10 (28.6%)	5 (19.2%)	5 (55.6%)
Tumor stage			
I	3 (8.6%)	0 (0%)	3 (33.3%)
II	10 (28.6)	8 (30.8%)	2 (22.2%)
III	14 (40%)	11 (42.3%)	3 (33.3%)
IV	8 (22.9%)	7 (26.9%)	1 (11.1%)
Comorbidities			
0	7 (20%)	6 (23.1%)	1 (11.1%)
1	8 (22.9%)	6 (23.1%)	2 (22.2%)
≥2	20 (57.1%)	14 (53.8%)	6 (66.7%)
Physical Activity			
Low or inactive	26 (74.3%)	19 (73.1%)	7 (77.8%)
Medium	5 (14.3%)	3 (11.5%)	2 (22.2%)
High	4 (11.4%)	4 (15.4%)	0 (0%)
Treatment			
Only CTx	8 (22.9%)	8 (30.8%)	0 (0%)
CTx and RTx	4 (11.4%)	2 (7.7%)	2 (22.2%)
Surgery and CTx	10 (54.3%)	13 (50%)	6 (66.7%)
Surgery, CTx and RTx	4 (11.4%)	3 (11.5%)	1 (11.1%)

Data are expressed as mean ± standard deviations or percentage. Groups were divided by sex variable. Abbreviations – CTx: chemotherapy; RTx: radiotherapy.

Classical and advanced parameters of nutritional status assessment in the study sample, stratified by sex, are shown in Table 2.

Table 2. Morphofunctional assessment parameters stratified by sex.

Variables	All Patients (n=35)	Male (n=26)	Female (n=9)
BMI (kg/m^2)	23.3 ± 5.7	23.5 ± 5.3	22.6 ± 6.9
Underweight	13 (37.1%)	9 (34.6%)	4 (44.4%)
Normal	12 (34.3%)	10 (38.5%)	2 (22.2%)
Overweight	4 (11.4%)	3 (11.5%)	1 (11.1%)
Obesity	6 (17.1%)	4 (15.4%)	2 (22.2%)
Weight loss within past 6 months (%)	14.3 ± 7.9	14.9 ± 8.3	12.3 ± 6.5
<5%	4 (11.4%)	3 (11.5%)	1 (11.1%)
5-10%	5 (14.3%)	2 (7.7%)	3 (33.3%)
>10%	26 (74.3%)	21 (80.8%)	5 (55.6%)
MAC (cm)	26.1 ± 5.3	23.5 ± 5.3	25.2 ± 6.9
CC (cm)	32.9 ± 4.4	33.3 ± 4.5	31.9 ± 4.1
Normal	8 (22.9%)	6 (23.1%)	2 (22.2%)
Low	27 (77.1%)	20 (66.9%)	7 (77.8%)
BIVA-derived parameters			
PhA (º)	4.7 ± 0.9	4.9 ± 0.9	4.3 ± 0.8
ECW/TBW ratio	0.5 ± 0.07	0.48 ± 0.06	0.51 ± 0.08
TBW/FFM (%)	69.7 ± 17.6	71.1 ± 14.7	66.0 ± 24.6
FM (%)	19.6 ± 12	18.7 ± 10.2	22.2 ± 16.6
ASMMI (kg/m^2)	6.8 ± 1.2	7.2 ± 1.06	5.6 ± 0.86
BCM (kg)	24.9 ± 6.1	27.1 ± 5.2	18.8 ± 3.9
Nutritional ultrasound ®: rectus femoris muscle			
RFCSA (cm^2)	2.8 ± 1.0	2.9 ± 1.02	2.2 ± 0.8
RF-Y-axis (cm)	0.8 ± 0.3	0.87 ± 0.27	0.77 ± 0.22
RF-X-axis	3.65 ± 0.50	3.76 ± 0.44	3.31 ± 0.55
RF-AT (cm)	0.41 (0.23 – 0.74)	0.35 (0.24-0.55)	0.78 (0.22-1.42)
Nutritional ultrasound ®: abdominal adipose tissue			
T-SAT (cm	1.4 (0.5-1.9)	1.35 (0.47-1.85)	1.41 (0.82-2.43)
S-SAT (cm)	0.52 (0.28-0.87)	0.47 (0.26-0.79)	0.68 (0.35-1.06)
VAT (cm)	0.55 (0.31-0.73)	0.52 (0.30-0.65)	0.58 (0.33-0.95)
Hand Grip Strength			
HGS (kg)	27.5 ± 8.4	31.1 ± 6.5	17.3 ± 2.5
Functional test			
SPPB	10 (7-11)	10 (7.7-11.2)	10 (6.5-10.5)

Data are expressed as mean ± standard deviation or median (interquartile range). Abbreviations – BMI: Body mass index; MAC: mid-arm circumference; CC: calf circumference; SGA: subjective global assessment ; BIVA: bioelectrical impedance vector analysis; PhA: phase angle; ECW: extracellular water; TBW: total body water; FFM: fat free mass; FM: fat mass; ASMMI: appendicular skeletal muscle mass index; BCM: body cellular mass; RFCSA: rectus femoris cross sectional area; RF-Y-axis: rectus femoris Y axis; RF-X-axis: rectus femoris X axis; RF-AT: rectus femoris adipose tissue; T-SAT: total subcutaneous adipose tissue; S-SAT: superficial subcutaneous adipose tissue; VAT: visceral adipose tissue; HGS: hand grip strength; SPPB: Short Physical Performance Battery.

According to SGA, 3 (8.6%) patients were classified as well nourished, 14 (40.0%) as mild to moderately malnourished and 18 (51.4%) as severely malnourished. Considering an average weight loss of 14.3 ± 7.9 within the past six months, malnutrition was prevalent in 82.8% of patients according to GLIM criteria, with 31.4% categorized as stage 1 (moderate) and 51.4% as stage 2 (severe) . The diagnosis of malnutrition was more prevalent in men than women (84.6% and 77.6% respectively), but severe malnutrition was higher in women (55.6%).

Following the EWGSOP2 criteria, the prevalence of sarcopenia was 18 patients (51.4%), with 8 (22.8%) classified as having confirmed sarcopenia and 10 (28.6%) as having severe sarcopenia, despite only 8 (22.8%) participants being identified as at risk for this condition based on SARC-F findings.

As shown in Table 3, weight loss was the only variable that showed a statistically significant difference between non-malnutrition and stages 1 ($p = 0.010$) and 2 ($p < 0.001$) of this condition. When analyzing BIVA-derived parameters by group pairs, the PhA values associated with severe malnutrition (4.3 ± 0.7) were significantly lower than those corresponding to non-malnourished individuals (5.3 ± 0.7; $p = 0.001$). The data for BMI ($p < 0.001$), ASMMI ($p = 0.003$) and BCM ($p = 0.017$) exhibited the same trend.

Regarding US measurements, both RF-CSA ($p < 0.001$) and RF-Y-axis ($p < 0.001$) showed significant differences between the non-malnutrition and severe malnutrition groups. Although the %FM measured by BIVA did not reveal noteworthy variations among any of the groups, significant differences were observed between the RF-adipose tissue values of the two groups ($p = 0.020$).

Differences between malnutrition groups and sociodemographic and clinical variables such as physical activity, primary site tumor, comorbidities, tumor stage and treatment were not founded.

Table 3. Differences in demographic, clinical, BIVA-derived, and ultrasound data according to the GLIM criteria.

Variables	No malnutrition (n=6)	Moderate malnutrition (n=11)	Severe malnutrition (n=18)	p-value
Sex				0.773
Male	4 (66.7%)	9 (81.8%)	13 (72.2%)	
Female	2 (33.3%)	2 (18.2%)	5 (27.8%)	
Age (years)	60.5 ± 4.8	63.3 ± 10.9	63.3 ± 8.7	0.786
BMI (kg/m^2)	29.3 ± 5.6	25.9 ± 4.8	19.6 ± 3.0	<0.001***
Weight loss within past 6 months (%)	4.2 ± 4.3	14.9 ± 5.5	17.3 ± 7.4	<0.001***
MAC (cm)	31.0 ± 4.6	29.4 ± 4.3	22.4 ± 3.0	<0.001***
CC (cm)	36.8 ± 5.3	34.9 ± 3.5	30.3 ± 2.8	<0.001***
SGA				
Well nourished (A)	3 (50%)	0 (0%)	0 (0%)	<0.001***
Mild to moderately malnourished (B)	2 (33.3%	8 (72.7%)	4 (22.2%)	
Severely malnourished (C)	1 (16.7%)	3 (27.3%)	14 (77.8%)	
BIVA-derived parameters				
PhA (º)	5.3 ± 0.7	5.1 ± 1.02	4.3 ± 0.7	0.016*
ECW/TBW ratio	0.46 ± 0.04	0.47 ± 0.07	0.50 ± 0.07	0.405
TBW/FFM (%)	62.3 ± 30.3	74.3 ± 2.1	69.7 ± 17.2	0.430
FM (%)	25.7 ± 13.9	21.0 ± 13.6	16.7 ± 9.8	0.255
ASMMI (kg/m^2)	7.7 ± 1.5	7.6 ± 0.8	6.0 ± 0.8	<0.001***
BCM (kg)	29.9 ± 4.7	27.6 ± 5.6	21.7 ± 4.9	<0.001***
Nutritional ultrasound ®: rectus femoris muscle				
RFCSA (cm^2)	3.5 ± 0.9	3.5 ± 0.9	2.1 ± 0.6	<0.001***
RF-Y-axis (cm)	1.1 ± 0.3	0.97 ± 0.19	0.68 ± 0.18	<0.001***
RF-X-axis (cm)	3.64 ± 0.22	3.96 ± 0.12	3.46 ± 0.11	0.030*
RF-Adipose tissue (cm)	0.82 (0.4-1.16)	0.44 (0.34-1.01)	0.30 (0.18-0.50)	0.037*
Nutritional ultrasound ®:				

abdominal adipose tissue				
T-SAT (cm	2.08 (1.72-2.59)	1.30 (0.55-2.62)	1.0 (0.36-1.56)	0.012*
S-SAT (cm)	1.07 (0.73-1.26)	0.62 (0.34-0.95)	0.44 (0.19-0.65)	0.011*
VAT (cm)	0.63 (0.56-0.97)	0.62 (0.55-0.93)	0.34 (0.24-0.48)	0.004**

Data are expressed as mean ± standard deviation or median (interquartile range) or percentage. Asterisk indicates significant difference between groups, according to the Mann–Whitney test or Fisher's exact test (*** p < 0.001, ** p < 0.01, * p < 0.05) Abbreviations – BMI: Body mass index; MAC: mid-arm circumference; CC: calf circumference; SGA: subjective global assessment ; BIVA: bioelectrical impedance vector analysis; PhA: phase angle; ECW: extracellular water; TBW: total body water; FFM: fat free mass; FM: fat mass; ASMMI: appendicular skeletal muscle mass index; BCM: body cellular mass; RFCSA: rectus femoris cross sectional area; RF-Y-axis: rectus femoris Y axis; RF-X-axis: rectus femoris X axis; RF-AT: rectus femoris adipose tissue; T-SAT: total subcutaneous adipose tissue; S-SAT: superficial subcutaneous adipose tissue; VAT: visceral adipose tissue; HGS: hand grip strength; SPPB: Short Physical Performance Battery.

In relation to sarcopenia diagnosis, significant differences were observed in sex (p = 0.003) and age (p= 0.021) across the four groups, as well as in the SARC-F score. All patients without sarcopenia were men. Table 4 shows that the PhA values for individuals with confirmed (4.5 ± 0.8; p = 0.009) and severe sarcopenia (4.1 ± 0.5, p < 0.001) were significantly lower than those for patients without this condition (5.6 ± 0.7). This finding was also evident in the values obtained for BCM (p = 0.011, p < 0.001) and ASMMI (p < 0.001, p < 0.001). Like BCM and ASMMI, both RF-CSA and RF-y-axis showed significant differences between the non-sarcopenia group and the confirmed (p < 0.001) and severe sarcopenia groups (p = 0.027, p = 0.039).

Significant differences were also observed between the non-sarcopenia and sarcopenia probable groups when comparing the data for PhA (p = 0.044). The same pattern was noted for the other two diagnostic components of sarcopenia, showing significantly higher HGS values in patients without sarcopenia compared to those with probable (p = 0.037), confirmed (p = 0.002), and severe sarcopenia (p < 0.001). SPPB values in patients with severe sarcopenia were also significantly lower than those in the other groups (p < 0.001).

As presented with malnutrition, we did not find differences between sarcopenia groups and other sociodemographic and clinical variables.

Table 4. Differences in demographic, clinical, BIVA-derived, and ultrasound data according to the EWGSOP2 criteria.

Variables	No sarcopenia (n=12)	Probable sarcopenia (n=5)	Confirmed sarcopenia (n=8)	Severe sarcopenia (n=10)	*p* value
Sex					0.003**
Male	12 (100%)	1 (20%)	5 (62.5%)	8 (80%)	
Female	0 (0%)	4 (80%)	3 (37.5%)	2 (20%)	
Age (years)	57.7 ± 9.4	68.8 ± 6.5	61.2 ± 6.9	67.2 ± 7.1	0.021*
BMI (kg/m^2)	27.3 ± 5.2	26.9 ± 5.5	18.5 ± 3.2	20.3 ± 2.6	<0.001***
MAC (cm)	30.4 ± 3.8	29.2 ± 5.5	20.4 ± 2.3	23.9 ± 2.4	<0.001***
CC (cm)	36.7 ± 4.2	33.3 ± 3.4	30.3 ± 3.1	30.3 ± 2.5	<0.001***
SARC-F					<0.001***
No risk	12 (100%)	2 (40%)	8 (100%)	5 (50%)	
Sarcopenia risk	0 (0%)	3 (60%)	0 (0%)	5 (50%)	
BIA-derived parameters					
PhA (º)	5.6 ± 0.7	4.5 ± 0.9	4.5 ± 0.8	4.1 ± 0.5	<0.001***
ECW/TBW ratio	0.47 ± 0.04	0.48 ± 0.09	0.48 ± 0.07	0.51 ± 0.07	0.550
TBW/FFM (%)	74.15 ± 1.97	60.13 ± 33.3	73.4 ± 0.29	66.0 ± 24.5	0.407
FM (%)	19.4 ± 12.7	25.2 ± 19.1	14.2 ± 8.9	21.4 ± 8.4	0.408
ASMMI (kg/m^2)	7.98 ± 0.95	6.73 ± 0.57	5.92 ± 0.96	6.08 ± 0.69	<0.001***

BCM (kg)	30.2 ± 3.6	23.5 ± 6.3	22.7 ± 6.3	21.1 ± 3.9	<0.001***
Nutritional ultrasound ®: rectus femoris muscle					
RFCSA (cm^2)	3.56 ± 0.76	2.80 ± 0.60	1.82 ± 0.49	2.53 ± 1.05	<0.001***
RF-Y-axis (cm)	1.05 ± 0.22	0.86 ± 0.13	0.58 ± 0.18	0.80 ± 0.21	<0.001***
RF-AT (cm)	0.48 (0.36-0.85)	1.10 (0.28-1.84)	0.26 (0.15-0.48)	0.30 (0.18-0.49)	0.072
RF-X-axis (cm)	3.79 ± 0.11	3.75 ± 0.20	3.49 ± 0.99	3.55 ± 0.23	0.520
Hand Grip Strength					
HGS (kg)	35.9 ± 4.9	19.5 ± 7.1	25.4 ± 5.2	23.3 ± 6.2	<0.001***
Functional test					
SPPB	11.5 (10-12)	10 (7.5-10.5)	10 (9-10.75)	6 (5-7.25)	<0.001***

Data are expressed as mean ± standard deviation or median (interquartile range) or percentage. Asterisk indicates significant difference between groups, according to the Mann–Whitney test or Fisher's exact test (*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$) Abbreviations – BMI: Body mass index; MAC: mid-arm circumference; CC: calf circumference; BIVA: bioelectrical impedance vector analysis; PhA: phase angle; ECW: extracellular water; TBW: total body water; FFM: fat free mass; FM: fat mass; ASMMI: appendicular skeletal muscle mass index; BCM: body cellular mass; RFCSA: rectus femoris cross sectional area; RF-Y-axis: rectus femoris Y axis; RF-X-axis: rectus femoris X axis; RF-AT: rectus femoris adipose tissue; T-SAT: total subcutaneous adipose tissue; S-SAT: superficial subcutaneous adipose tissue; VAT: visceral adipose tissue; HGS: hand grip strength; SPPB: Short Physical Performance Battery.

PhA showed a weak but significant direct correlation with ASMMI ($r = 0.439$, $p = 0.008$), whereas RFCSA ($r = 0.582$, $p < 0.001$) and RF-Y-axis ($r = 0.602$, $p < 0.001$) were significantly and moderately correlated with ASMMI. As shown in Table 5, although BCM ($r = 0.397$, $p = 0.018$) displayed a statistically significant correlation with BMI, PhA did not; therefore, it was also not correlated with weight loss, similar to RFCSA. RF-Y-axis was the only muscle mass-related measure significantly correlated with all three diagnostic components of malnutrition, namely weight loss ($r = -0.386$, $p = 0.022$), BMI ($r = 0.599$, $p < 0.001$), and ASMMI.

In contrast, adipose tissue markers such as RF-AT, T-SAT and S-SAT were also ultrasound measurements associated with weight loss and BMI. All three—RF-AT ($r = 0.742$, $p < 0.001$), total subcutaneous ($r = 0.826$, $p < 0.001$), and superficial subcutaneous abdominal fat ($r = 0.799$, $p < 0.001$)—showed high correlations with BMI, as well as FM ($r = 0.543$, $p < 0.001$), but insignificant correlations with weight loss. These findings suggest that RF-Y-axis may perform better than the other parameters as a predictor of malnutrition.

Table 5. Correlations between BIVA-derived parameters, ultrasound measurements, and components of malnutrition diagnosis according to GLIM criteria (%weight loss, BMI and ASMMI).

Variables	**% weight loss**		**BMI (kg/m^2)**		**ASMMI (kg/m^2)**	
	r	***p* value**	**r**	***p* value**	**r**	***p* value**
BIA-derived parameters						
PhA (º)	-0.093	0.596	0.288	0.094	0.439	0.008**
ECW/TBW ratio	0.244	0.157	0.244	0.158	-0.246	0.154
TBW/FFM (%)	0.156	0.378	0.261	0.136	0.169	0.338
FM (%)	-0.232	0.181	0.543	<0.001*	0.204	0.240
BCM (kg)	-0.313	0.067	0.397	0.018*	0.837	<0.001***
Nutritional ultrasound ®: rectus femoris muscle						
RFCSA (cm^2)	-0.311	0.069	0.531	0.001*	0.582	<0.001***
RF-Y-axis (cm)	-0.386	0.022*	0.599	<0.001*	0.602	<0.001***

RF-AT (cm)	-0.420	0.012*	0.742	<0.001*	0.245	0.156
Nutritional ultrasound ®: abdominal adipose tissue						
T-SAT (cm	-0.491	0.005*	0.826	<0.001*	0.399	0.026*
S-SAT (cm)	-0.459	0.009*	0.799	<0.001*	0.416	0.020*
VAT (cm)	-0.092	0.112	0.607	<0.001*	0.278	0.130

Asterisk indicates significant correlation (*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$). Abbreviations - BMI: Body mass index; ASMMI: appendicular skeletal muscle mass index; PhA: phase angle; ECW: extracellular water; TBW: total body water; FFM: fat free mass; FM: fat mass; BCM: body cellular mass; RFCSA: rectus femoris cross sectional area; RF-Y-axis: rectus femoris Y axis; RF-AT: rectus femoris adipose tissue; T-SAT: total subcutaneous adipose tissue; S-SAT: superficial subcutaneous adipose tissue; VAT: visceral adipose tissue.

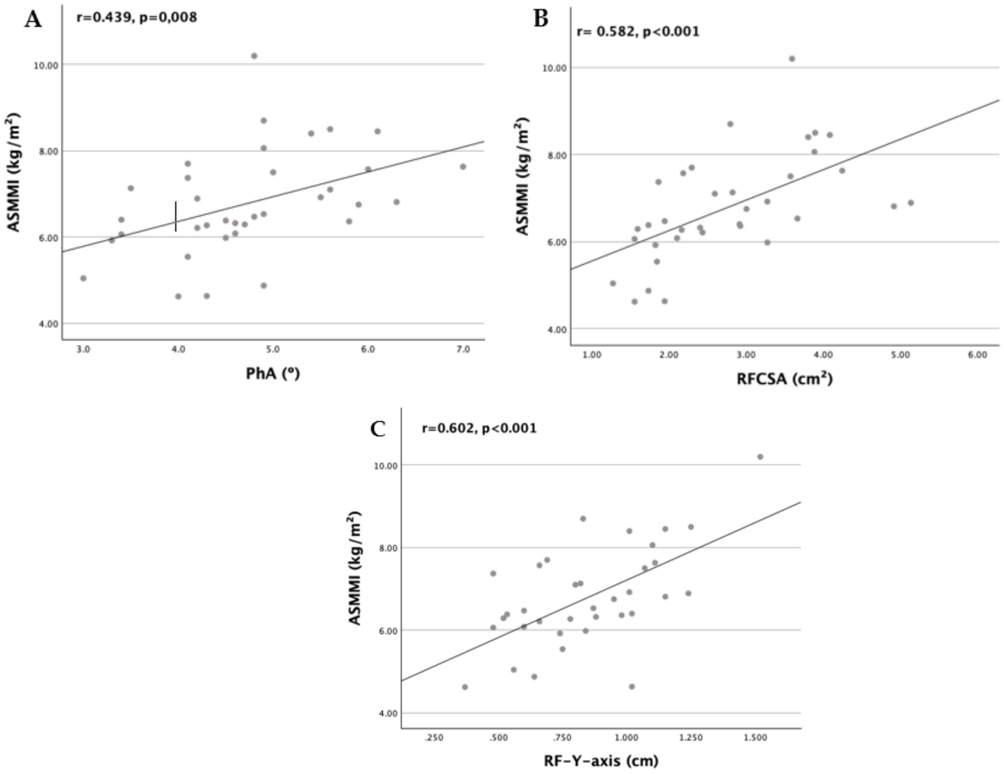

Figure 2. Scatter plot graphs of correlation between ASMMI and (A) PhA, (B) RFCSA, (C) RF-Y-axis.

As detailed in Table 6, regarding the diagnostic components of sarcopenia, PhA exhibited statistically significant direct correlations with HGS ($r = 0.556$, $p < 0.001$), ASMMI ($r = 0.439$, $p = 0.008$), and SPPB ($r = 0.475$, $p = 0.004$), similar to BCM; however, the correlations with PhA were weaker, as previously mentioned. Although both RFCSA and RF-Y-axis showed significant and moderate correlations with ASMMI, RF-Y-axis ($r = 0.602$, $p < 0.001$) demonstrated the strongest association. Only RFCSA was statistically significantly correlated with HGS ($r = 0.447$, $p = 0.007$). Neither ultrasound measure was correlated with SPPB.

These results suggest that PhA may provide a better prediction of sarcopenia than either RFCSA or RF-Y-axis.

Table 6. Correlations between BIVA-derived parameters, ultrasound measurements, and components of sarcopenia diagnosis according the EWGSOP2 (HGS, ASMMI, SPPB).

Variables	**HGS (kg)**		**ASMMI (kg/m²)**		**SPPB**	
	r	***p* value**	**R**	***p* value**	**R**	***p* value**

BIA-derived parameters						
PhA (º)	0.556	<0.001*	0.439	0.008*	0.475	0.004**
ECW/TBW ratio	-0.257	0.135	-0.246	0.154	-0.376	0.026
TBW/FFM (%)	0.223	0.204	0.169	0.338	0.124	0.483
BCM (kg)	0.751	<0.001*	0.837	<0.001*	0.461	0.005**
Nutritional ultrasound ®: rectus femoris muscle						
RFCSA (cm^2)	0.447	0.007*	0.582	<0.001*	0.233	0.178
RF-Y-axis (cm)	0.315	0.065	0.602	<0.001*	0.151	0.388

Asterisk indicates significant correlation (*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$). Abbreviations - HGS: hand grip strength; ASMMI: appendicular skeletal muscle mass index; SPPB: Short Physical Performance Battery; PhA: phase angle; ECW: extracellular water; TBW: total body water; FFM: fat free mass; FM: fat mass; BCM: body cellular mass; RFCSA: rectus femoris cross sectional area; RF-Y-axis: rectus femoris Y axis. .

As shown in Figure 3, a positive correlation was found between RF ultrasound measurements and BIVA-derived parameters as shown in figure 2. RFCSA showed a moderate positive correlation with PhA (r=0.564, p<0.001) and BCM (r=0.533, p<0.001). RF-Y-axis revealed a weak positive correlation with PhA (r=0.457, p=0.006) and BCM (r=0.445, p=0.007).

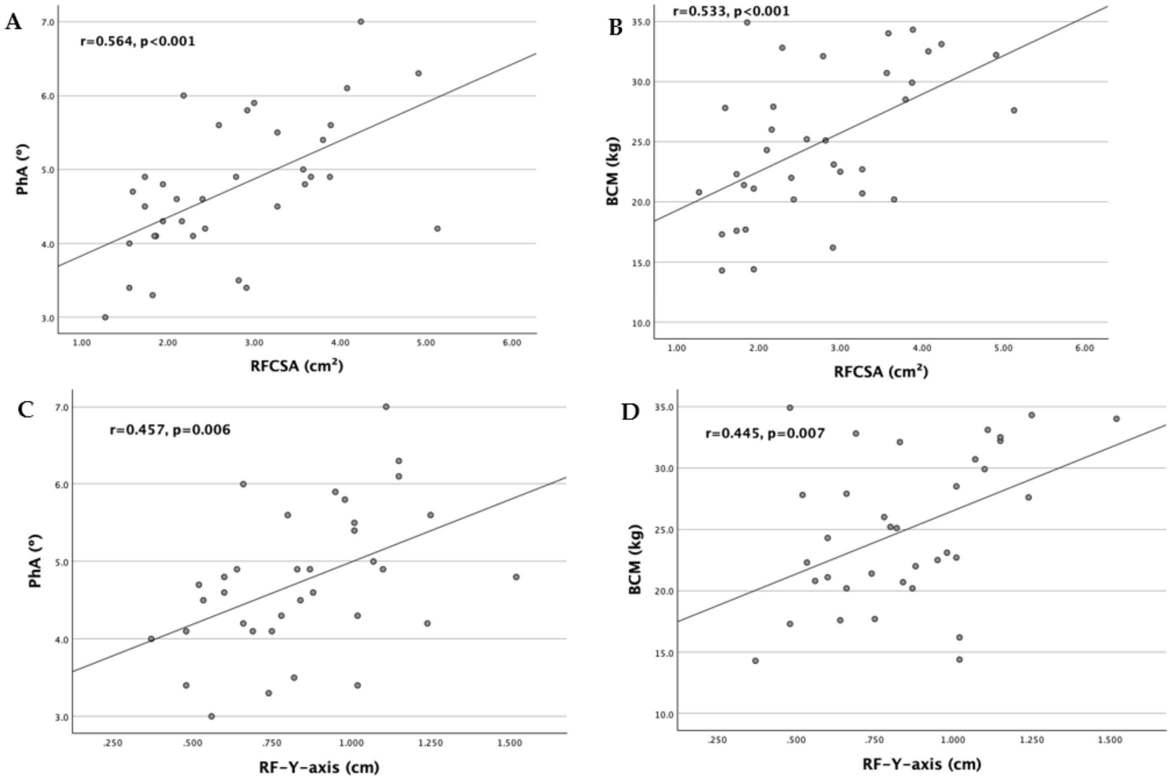

Figure 3. Scatter plot graphs of correlation between RF ultrasound measurements and BIVA-derived parameters: (A) RFCSA with PhA, (B) RFCSA with BCM, (C) RF-Y-axis with PhA and (D) RF-Y-axis with BCM.

The unadjusted binary logistic regression models aimed at predicting the presence of malnutrition demonstrated that higher values of the RF-Y-axis (OR = 0.002, IC 95%: 0.000-0.418, p = 0.023), total subcutaneous abdominal fat (OR = 0.192, IC 95%: 0.043-0.851, p = 0.030), and superficial subcutaneous abdominal fat (OR = 0.019, IC 95%: 0.001-0.448, p = 0.014) are protective factors against this condition. As shown in Table 7, it was revealed that for each one-cm increase in RF-Y-axis, total subcutaneous abdominal fat, and superficial subcutaneous abdominal fat, the likelihood of not having malnutrition is 500, 5.2, and 52.6 times higher, respectively.

Table 7. Crude logistic regression analysis evaluating PhA, RFCSA, RFT, T-SAT and S-SAT with GLIM malnutrition and EWGSOP2 sarcopenia.

	Malnutrition		Sarcopenia	
Variables	**OR**	***p* value**	**OR**	***p* value**
PhA (º)	0.430 (0.152-1.217)	0.112	0.167 (0.047-0.591)	0.006**
BCM (kg)	0.817 (0.673-0.993)	0.042*	0.797 (0.682-0.932)	0.005**
Nutritional ultrasound ®: rectus femoris muscle				
RFCSA (cm^2)	0.401 (0.155-1.037)	0.060	0.212 (0.074-0.605)	0.004**
RF-Y-axis (cm)	0.002 (0.000-0.418)	0.023*	0.002 (0.000-0.143)	0.004**
RF-AT (cm)	0.220 (0.035-1.369)	0.105		
Nutritional ultrasound ®: abdominal adipose tissue				
T-SAT (cm	0.192 (0.043-0.851)	0.030*		
S-SAT (cm)	0.019 (0.001-0.448)	0.014*		

Asterisk indicates statical significance (*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$). Abbreviations - PhA: phase angle; BCM: body cellular mass; RFCSA: rectus femoris cross sectional area; RF-Y-axis: rectus femoris Y axis; RF-AT: rectus femoris adipose tissue; T-SAT: total subcutaneous adipose tissue; S-SAT: superficial subcutaneous adipose tissue.

Then, the crude analyses for predicting sarcopenia indicated that higher values of PhA (OR = 0.167, IC 95%: 0.047-0.591, p = 0.006) and ultrasound measurements of the rectus femoris, namely RFCSA (OR = 0.212, IC 95%: 0.074-0.605, p = 0.004) and RF-Y-axis (OR = 0.002, IC 95%: 0.000-0.143, p = 0.004) are protective against this condition. Specifically, the likelihood of being free from sarcopenia increases by 5.99 times with each one-degree increase in PhA. Similarly, for every one-cm increase in RFCSA and RF-Y-axis, the probability of not having sarcopenia rises by 4.72 and 500 times, respectively.

It is worth noting that BCM, like the RF-Y-axis, showed good predictive ability in both crude models for malnutrition and sarcopenia. However, the estimation of this parameter relies on predictive BIA equations, which require data such as weight and height that are not always available. For this reason, attention has been focused on the results corresponding to PhA, RFCSA, and the RF-Y-axis. Multivariable logistic regression models were not conducted due to the limited sample size.

4. Discussion

To the best of our knowledge, this is the first study to investigate the potential usefulness of phase angle and nutritional ultrasound in identifying the presence of malnutrition and sarcopenia in European patients with EGC, using the most recent diagnostic criteria (GLIM and EWGSOP2). Only two studies have assessed the predictive value of the PhA in patients with gastrointestinal cancer, one focusing solely on malnutrition [72] and the other including sarcopenia [73]. In fact, when considering ultrasound, only one study has utilized RF-CSA and RF-Y-axis to predict these two deleterious conditions in head and neck cancer patients [74], while another one to anticipate 12-month mortality in a similar sample [45].

Our investigation identified that malnutrition was highly prevalent in esophagus and gastric cancer patients (82.8%), with 31.4% of patients in moderate malnutrition and 51.4% in severe malnutrition. These values are higher than those found in most studies with the same population and similar methodology [73,75–77]. Moreover, these investigations have emphasized that those patients who are candidates for oncologic surgery, such as most of those included in our study, are twice as likely to present malnutrition. A study recorded 72.2% of malnutrition in patients after esophagogastric cancer surgery [78].

Moreover, this research shows that sarcopenia was highly prevalent in the patients with EGC analyzed, representing 51.5% of them. As with undernutrition, these results are significantly higher compared to other studies [79,80].The discrepancies observed can primarily be attributed to differences in methodology, as most studies have used different diagnostic criteria or another technique to assess body composition, like CT scans. Only one study included the EWGSOP2 diagnostic algorithm for sarcopenia, which found a 43.3% of sarcopenic patients [81].However, in studies that included patients who underwent esophagectomy or gastrectomy [82,83], the prevalence of sarcopenia increased considerably (57.4% and 57.7% respectively), more closely resembling our results. In fact, most of our patients classified in confirmed sarcopenia or severe sarcopenia were submitted to surgical management.

Clinical characteristics, such as tumor site, tumor stage, and type of treatment, did not show significant differences between the malnutrition and sarcopenia groups, likely due to sample heterogeneity, which resulted in very small frequencies in each subgroup. However, statistically significant differences were observed in some BIVA-derived parameters, such as PhA, ASMMI, and BCM. This trend has also been recorded by multiple studies carried out in oncology patients [34,84,85]. PhA was positively correlated with all the components of sarcopenia diagnosis (ASMMI, HGS and SPPB). Zuo et al. previously reported a similar correlation in gastric cancer patients [73]. Unlike the results observed in our study, they also found a positive correlation between PhA and all the nutritional indices used to diagnose malnutrition according to GLIM criteria.

Interestingly, BCM was the parameter most strongly correlated with the diagnostic components of malnutrition and sarcopenia. Also, the crude analyses for predicting these two conditions demonstrated that a higher value of BCM is a protective factor against malnutrition and sarcopenia. These results are consistent with those reported by Herrera-Martínez et al. in a large cohort of patients with head and neck cancer [86]. Their results demonstrated that BCM was more strongly associated with malnutrition (OR = 0.88, 95% CI = 0.84–0.93, $P < 0.001$) and sarcopenia (OR = 0.81, 95% CI = 0.76–0.87, $P < 0.001$) compared to PhA (OR = 0.54, 95% CI = 0.40–0.71, $P < 0.001$) (OR = 0.47, 95% CI = 0.33–0.66, $P < 0.001$).

However, the aim of the present study focused on parameters such as PhA due to its clinical significance, but in our study, phase angle was not able to predict malnutrition, although it could predict sarcopenia. Conversely, the study by Yang et al. using logistic regression models, confirmed PhA as a valuable indicator of malnutrition in patients with gastrointestinal cancer (OR = 0.548, 95% CI = 0.385–0.780, $P < 0.001$) [72]. A potential explanation for the discrepancies could be the altered hydration status and the small size of our study sample. The mean ECW/TBW index found that we found exceeded the reference value established by Ge et al. [87] for the oncologic population with sarcopenia, evidencing a state of overhydration (ECW/TBW ≥ 0.385), which may interfere with correlations involving PhA.

The use of NU® derived parameters based on muscle area and thickness (RFCSA and RF-Y-axis respectively) may contribute to the assessment of malnutrition and sarcopenia. We found a moderate positive correlation between RFCSA and R-Y-axis with ASMMI, as previously described by Hida et al. [88]. We also detected a weak correlation between RFCSA and HGS as Lopez-Gómez et al. [89], which indicates that RF ultrasound measurements could be related not only with the muscle quantity, but also with the muscle strength. This is supported by previous research of the role of ultrasound in the prediction of sarcopenia in elderly patients. It was revealed that RFCSA and RF-Y-axis were the best indicators for detecting loss of muscle mass and strength [90].

RF-Y-axis was the only marker capable of predicting both sarcopenia and malnutrition. Furthermore, it exhibited the strongest correlation with ASMMI when considering PhA and RFCSA. Ozturk et al. also disclosed that RF-Y-axis had a slightly greater positive correlation with the skeletal muscle mass for the diagnosis of malnutrition using GLIM criteria, in hospitalized internal medicine patients [91].

Due to the limited literature using these ultrasound measurements as markers of malnutrition and sarcopenia, making direct comparisons was challenging. In cancer patients we only have the data reported by two Spanish studies [74,89]. In one hand, Fernández-Jiménez et al. described that high levels of the RF-CSA (OR = 0.81 (0.68–0.98), $p < 0.05$) and RF-Y-axis (OR = 0.31 (0.15–0.61), $p < 0.001$) were associated with a decreased risk of malnutrition, as defined with GLIM criteria. Sarcopenia showed the same trend (OR = 0.64 (0.49–0.82), $p < 0.001$) for RFCSA and (OR = 0.27 (0.11–0.68), $p < 0.01$) for RF-Y-axis. In the other hand, Lopez-Gómez did only find statically differences of the RFCSA with sarcopenia diagnosis (sarcopenia: 2.47 cm^2 (±0.54 cm^2); no sarcopenia: 3.65 cm^2 (±1.34 cm^2); $p = 0.02$), but no differences with malnutrition.

Concerning adipose tissue, assessed by NU®, we found that all abdominal measurements (T-SAT, S-SAT and VAT) and RF-adipose tissue were significantly different between malnutrition groups. Additionally, T-SAT and S-SAT were correlated with all the components of malnutrition diagnosis, and they could predict the malnutrition in the crude logistic regression analysis. As expected and described by other studies [74], the US adipose tissue measurements did not show any relation with sarcopenia parameters, since they are highly associated with methods of assessing fat deposition and distribution.

Furthermore, we found a significant correlation between RFCSA and R-Y-axis with PhA, BCM and ASMMI which is consistent with a previous study in a longitudinal cohort of patients with cancer [45] and with the DRECO (Disease-Related caloric-protein malnutrition EChOgraphy) study [92]. These findings could inform the combined use of BIVA and NU®, which are readily available in routine clinical practice, to monitor the nutritional status of cancer patients.

There were several limitations to the current study. The first is the heterogeneity of the population under analysis regarding tumor stage, type of treatment and BMI, which weaken the results. The second is the small sample size of patients evaluated, which limited the ability to create multivariate logistic regression models. In addition, given the predominance of men in GI cancer studies, as is the case in the present cohort, drawing conclusions by gender in body composition is difficult. Therefore, multicenter trials with larger sample sizes are essential for further validation. Third, the cross-sectional nature of the study precluded the evaluation of cause-effect relationships derived from nutritional intervention, as well as the analysis of complications and survival outcomes.

5. Conclusions

In conclusion, RF-Y-axis is the only parameter that appears to be a promising and useful independent predictor of both malnutrition and sarcopenia in this sample of EGC patients. These results reinforce the implementation of RF-Y-axis in routine clinical practice and its use as a potential low muscle quantity or quality criterion into the EWGSOP2 criteria and as a potential phenotypic criterion for muscle mass loss into the GLIM criteria. Nevertheless, PhA and RFCSA had good performance in predicting sarcopenia, but not malnutrition in the same population. This suggests the need for a larger sample to demonstrate stronger correlations between these two markers and ASMMI, in order to effectively determine their usefulness as predictors not only of the presence but also of the severity of malnutrition and sarcopenia.

This study represents the initial exploration of an ongoing prospective nutritional follow-up project aimed at improving the process of identifying patients who require multimodal interventions, as well as assessing the outcomes of these interventions in terms of body composition and function. In this way, the research conducted would allow the results obtained to be translated into a more practical, effective, and objective morphofunctional assessment, thereby supporting the work of health professionals.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by Clinical Research Ethics Committee of the La Fe Health Research Institute (number *2023-1188-1*, approval date December 20th 2023).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data are contained within the article.

Conflicts of Interest: The authors declare no conflicts of interest.

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