Nutrition 135 (2025) 112763

Contents lists available at ScienceDirect

Nutrition

journal homepage: www.nutritionjrnl.com

Applied nutritional investigation

Association between muscle mass assessed by an artificial intelligence–based ultrasound imaging system and quality of life in patients with cancer-related malnutrition

Daniel de Luis M.D. [a,*], Angela Cebria M.D. [b,c], David Primo M.D. [a], Olatz Izaola M.D. [a], Eduardo Jorge Godoy Ph.D. [b,c], Juan Jose Lopez Gomez M.D. [a]

[a] Centro de Investigación of Endocrinología and Nutrición Facultad de medicina Universidad de Valladolid. Depto. Endocrinología Nutrición Hospital Clínico Universitario de Valladolid, Valladolid, Spain
[b] DAWAKO Medtech S.L., Parc Cientìfic de la Universitat de Valencia, Valencia, Spain
[c] Departamento de Informática, Universitat de Valencia, Técnicas Avanzadas de Desarrollo de Software centrado en la Persona, Valencia. Spain

A R T I C L E   I N F O

Article History:
Received 10 December 2024
Received in revised form 5 March 2025
Accepted 10 March 2025

Keywords:
Artificial intelligence
Cancer
Malnutrition
Muscle ultrasound
Health-related quality of life

A B S T R A C T

Introduction: Emerging evidence suggests that diminished skeletal muscle mass is associated with lower health-related quality of life (HRQOL) in individuals with cancer. There are no studies that we know of in the literature that use ultrasound system to evaluate muscle mass and its relationship with HRQOL.
Objective: The aim of our study was to evaluate the relationship between HRQOL determined by the EuroQol-5D tool and muscle mass determined by an artificial intelligence–based ultrasound system at the rectus femoris (RF) level in outpatients with cancer.
Material and methods: Anthropometric data by bioimpedance (BIA), muscle mass by ultrasound by an artificial intelligence–based at the RF level, biochemistry determination, dynamometry and HRQOL were measured.
Results: A total of 158 patients with cancer were included with a mean age of 70.6 ±9.8 years. The mean body mass index was 24.4 ± 4.1 kg/m^2 with a mean body weight of 63.9 ± 11.7 kg (38% females and 62% males). A total of 57 patients had a severe degree of malnutrition (36.1%). The distribution of the location of the tumors was 66 colon-rectum cancer (41.7%), 56 esophageal-stomach cancer (35.4%), 16 pancreatic cancer (10.1%), and 20.2% other locations. A positive correlation cross-sectional area (CSA), muscle thickness (MT), pennation angle, (BIA) parameters, and muscle strength was detected. Patients in the groups below the median for the visual scale and the EuroQol-5D index had lower CSA and MT, BIA, and muscle strength values. CSA (beta 4.25, 95% CI 2.03–6.47) remained in the multivariate model as dependent variable (visual scale) and muscle strength (beta 0.008, 95% CI 0.003–0.14) with EuroQol-5D index. Muscle strength and pennation angle by US were associated with better score in dimensions of mobility, self-care, and daily activities.
Conclusion: CSA, MT, and pennation angle of RF determined by an artificial intelligence–based muscle ultrasound system in outpatients with cancer were related to HRQOL determined by EuroQol-5D.

Introduction

Malnutrition frequently appears in patients with cancer due to their oncological process and the treatments received, such as surgery, radiotherapy, or chemotherapy [1]. This malnutrition is associated with an excess of morbidity and mortality [2], a higher risk of complications [3], prolonged hospital stays [4], poorer responses to the aforementioned adjuvant treatments [4], and a decrease in health-related quality of life (HRQOL) [5]. Suboptimal levels of certain body composition parameters, particularly reductions in skeletal muscle mass (SMM), have been identified as prognostic indicators of adverse oncological outcomes. These include diminished overall survival rates, as demonstrated in multiple studies [6,7], reduced disease-free survival durations [8,9], heightened incidence of postoperative complications [10,11], and exacerbated chemotherapy-related toxicity [12,13]. Consequently, the assessment of body composition has emerged

*Corresponding author.
E-mail address: dluisro@saludcastillayleon.es (D. de Luis).

https://doi.org/10.1016/j.nut.2025.112763
0899-9007/

as a critical methodological approach in contemporary oncology research.

Conventional endpoints such as morbidity and mortality are now being augmented by alternative outcome measures in patients with cancer, as advancements in life-prolonging cancer therapies have led to significant improvements in survival rates [14,15]. This shift has elevated the importance of evaluating HRQOL as a critical component for assessing the impact of healthcare interventions [16]. HRQOL is a subjective and multidimensional construct that encompasses key domains of physical health, psychological well-being, social interactions, and functional capacity [17]. Both the diagnosis and treatment of cancer can disrupt these interconnected domains, leading to profound effects on overall HRQOL [18]. Emerging evidence suggests that diminished SMM, as assessed through computed tomography (CT) imaging analysis, is associated with lower HRQOL in individuals with cancer [19]. This association is hypothesized to arise from the interrelationship between reduced muscular strength, compromised physical functionality, and their subsequent impact on independence and emotional well-being [20]. Moreover, muscle ultrasound, a novel technique for assessing muscle mass, is gaining recognition as a valuable tool for quantifying muscle status in the context of malnutrition [21]. Compared to methods such as CT, ultrasound offers distinct advantages, including cost-effectiveness, portability, and non-invasive application [22]. A significant limitation of muscle ultrasound lies in the substantial interobserver variability observed during its application. To address this challenge, automated interpretation systems leveraging artificial intelligence algorithms have the potential to standardize the results obtained through muscle ultrasound. These systems can facilitate consistency and ensure that the results align accurately with the interpretations made by radiologists from the original imaging data [23]. As far as we can know, there are no studies in the literature on outpatient patients with cancer that use an artificial intelligence–based muscle ultrasound system to evaluate muscle mass and its relationship with HRQOL.

The aim of our study was to evaluate the relationship between HRQOL determined by EuroQol-5D tool and muscle mass determined by an artificial intelligence–based muscle ultrasound system in outpatients with cancer and also other conventional parameters for assessing nutritional status.

Material and methods

Population

Data were collected prospectively, and the study was conducted in a single hospital with outpatient oncology patients previous to surgery treatment. A total of 158 outpatients of both sexes between the ages of 30 and 70 years with cancer and malnutrition were included. Malnutrition was evaluated with (Global Leadership Initiative on Malnutrition) (GLIM) criteria. Before collecting all clinical, biochemical, and quality of life data from the patients, inclusion criteria were verified, and exclusion criteria were ruled out. Patients were excluded if they had a formal contraindication for oral nutrition, a life expectancy of less than 6 months, a surgical intervention in the 3 months prior to the visit, any other unspecified pathology or condition that the investigator deemed likely to interfere with the implementation of the protocol. The HCUV Clinical Trials Committee (pi17-491) approved the study, and patients signed an informed consent form before beginning the study protocol.

Procedures

At the beginning of recruitment in the study, the following variables were collected: body weight, height, body mass index (BMI), GLIM stage, nutritional biochemistry, bioimpedance (BIA), ultrasound parameters of rectus femoris (RF) muscle, dynamometry and quality of life using the EuroQol-5D test [24].

Biochemical procedures

At baseline, fasting blood samples were drawn to measure C-reactive protein (CRP), albumin, prealbumin, and transferrin (Hitachi, ATM, Manheim, Germany). The ratio of active protein/prealbumin was calculated in order to assess inflammatory status.

Anthropometry, BIA, and dynamometry

Body height (in cm) was assessed utilizing a calibrated stadiometer (Omron, LA, CA, USA), and body weight was obtained using a digital scale (Omron, LA, CA, USA). BMI was derived by dividing body weight in kilograms by the square of height in meters. Total body fat mass was quantified through bioelectrical impedance analysis (accuracy $\pm$ 5 g) [24] using the EFG BIA 101 Anniversary device (Akern, Italy). Bioimpedance (BIA) assessed the components of impedance, including resistance (Rz), reactance (Xc), and phase angle (PhA), with PhA calculated as ($[Xc/Rz] \times (180°/\pi)$). The BIA provided data regarding fat mass, fat-free mass, SMM, appendicular muscle mass (aSMM), and aSMM index (aSMMI) as SMMI divided by squared height [25]. The diagnostic thresholds for low muscle mass were defined in accordance with the European Working Group on Sarcopenia in Older People (EWGSOP2) criteria, specifying ASMI < 7 kg/m^2 for men and ASMI < 5.5 kg/m^2 for women [26].

Muscle functionality was evaluated through handgrip strength measurements using a JAMAR dynamometer (Basel, Switzerland). For the assessment, participants were seated with their arms positioned at a 90-degree angle relative to the forearm and conducted the dynamometry test using their dominant hand.

Ultrasound procedure

Ultrasound assessments were performed on the dominant leg, specifically targeting the right RF, using a portable ultrasound device equipped with a 4- to 10-cm linear probe (Mindray Z60, Madrid, Spain). Measurements were taken from the anterior thigh while the patient lay supine with knees fully extended and relaxed. The imaging site was standardized to two-thirds of the femur's length, measured from the anterior superior iliac spine to the upper border of the patella. The acquired ultrasound images were processed using an artificial intelligence–driven system (PIIXMED) developed by DAWAKO Medtech S.L. (Valencia, Spain) (Fig. 1). These cloud-based application advantages convolutional neural networks with a U-Net architecture for automatic segmentation of regions of interest (ROIs), visually marked in green. Yellow lines represent three distinct muscle thickness (MT) measurements, which are averaged to calculate the final thickness. The contraction phase applies repeated 3×3 convolutions with rectified linear unit activations, followed by 2×2 max pooling with a stride of 2 to progressively reduce resolution. The software provides MT values along with quality indices derived from echo-intensity histograms, offering detailed structural and compositional muscle data. The following parameters were measured in the dominant leg; the cross-sectional area (CSA) in cm2, the Y-axis (Transverse MT) in millimeters (mm), muscle circumference, and the pennation angle in degrees was determined as the angle between the muscle fibers and the lower aponeurosis. Muscle quality indices were derived using a multithresholding algorithm, which relies on histogram echogenicity and grey intensity to establish thresholds that classify the pixels in an ultrasound image into distinct categories. This algorithm identifies threshold values for three specific classes: muscle (Mi index), fat (FATi index), and other complex structures such as collagen, connective tissue, and fibrosis (NMNFi index) [27,28]. This AI system has been validated with an intraclass correlation coefficient for reliability and consistency analysis of 0.960 and 95% CI [0.941–0.973] for MT, and 0.995 and 95% CI [0.993–0.997] for CSA [23].

Health-related quality of life EuroQol-5D test

EuroQol-5D test is validated and standardized for describing and evaluating HRQOL, it is a very useful and quick tool to perform in routine clinical practice with five questions. The questionnaire describes health status in terms of five dimensions: mobility, self-care, daily activities, pain or discomfort, and anxiety or depression. Each of these dimensions is divided into three levels of severity (no problems, some problems, and extreme problems). These data are later converted into a single general score (EQ-5D index) using a predefined value table [24]. The index ranges from 1 (best health status) to 0 (worst health status). The test also has a visual scale that goes from 0 (worst quality) to 100 (best quality).

Statistical analysis

A sample size calculation was conducted considering an improvement a positive correlation of EuroQol-5D test with CSA of RF, yielding a sample size of (n = 150), with a type I error < 0.05 and a statistical power of 80%. Categorical variables were expressed as percentages (%). The normality of continuous variables was evaluated using the Kolmogorov–Smirnov test. Continuous variables were presented as means $\pm$ standard deviation. Parametric variables were compared using the Student's t test for both paired and unpaired data, while non-parametric

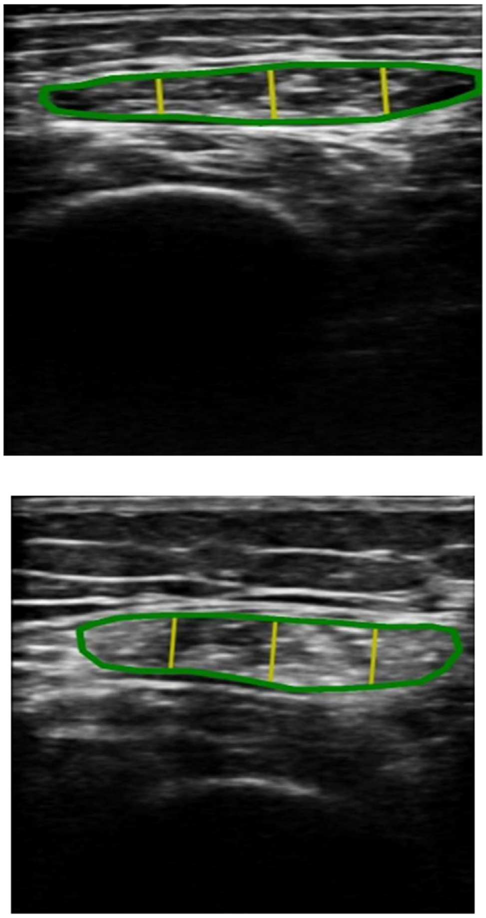

Fig. 1. The figure presents an example of two patients with cancer with ultrasound images of the Rectus Femoris muscle captured in the transverse plane. The muscle belly's automatically segmented ROI is highlighted in green, while yellow lines represent the three measurements of muscle thickness used to calculate the average thickness value.

variables were analyzed using the Kruskal−Wallis test and the Mann−Whitney *U*-test. Differences in categorical variables were assessed using the chi-square test. We performed a linear regression multivariate stepwise for the effect of the different variables that were statistically related to quality of life, adjusted for age, sex, tumor location and body weight. A P value <0.05 was considered statistically significant. Data analysis was conducted using SPSS software version 23.0 (SPSS Inc., Chicago, IL, USA).

Results

In total, 158 patients with cancer were included with a mean age of 70.6 ±9.8 years. The mean BMI was 24.4 ± 4.1 kg/m^2 with a mean body weight of 63.9 ± 11.7 kg. The distribution by sex was: 60 women (38%) and 98 men (62%). A total of 57 patients had a severe degree of malnutrition according to GLIM criteria (36.1%) and 101 (63.9%) a moderate degree of malnutrition. The distribution of the location of the tumors was 66 colon-rectum cancer (41.7%), 56 esophageal-stomach cancer (35.4%), 16 pancreatic cancer (10.1%), and 20 in other locations such as (bladder, lung, breast, etc.) (20.2%). At the time of the nutritional evaluation, none of the patients had received surgical treatment for their oncological process, 33 (10.4%) had received radiotherapy at least 3 months before the evaluation, and 92 (58.2%) chemotherapy in the same period.

Table 1 shows the ultrasound parameters of the quadriceps RF and BIA variables. According to the EWGSOP2 criteria, 43 patients presented sarcopenia (27.2%). Table 2 shows the biochemical variables, showing normal albumin levels above 3 g/dL, but elevated CRP levels above 3 mg/dL, indicating an inflammatory status, typical of the cancer patient.

Table 1
Ultrasound and BIA parameters of patients with cancer (mean ± SD)

Parameters	Mean ± SD
Phase angle (°)	5.1 ± 0.9
Resistance ohms	568.2 ± 99.7
Reactance ohms	50.2 ± 12.1
Fat mass (kg)	17.7 ± 3.5
Fat free mass (kg)	46.2 ± 8.9
SMM (kg)	22.9 ± 6.1
aSMM (kg)	16.7 ± 4.3
aSMMI (kg/m^2)	8.9 ± 0.9
CSA RF (cm^2/m^2)	2.95 ± 1.1
MT RF (cm)	1.62 ± 0.6
MC RF (cm)	7.6 ± 1.2
Pennation angle (°)	6.8 ± 2.1
Mi	0.44 ± 0.1
FATi	0.41 ± 0.1
NMNFi	0.15 ± 0.1

CSA, cross-sectional area; FATi, fat index; MT, muscle thickness; MC, muscle circumference; Mi, muscular index; NMNFi, no muscular no at index; RF, rectus femoris.

After performing the EuroQol-5D test, the visual scale gave an average of 65.3 ± 14.5 points (100 points is the best), and the EQ5D index of 0.82 ± 0.09 points (1.0 is full health). The questionnaire showed health status in terms of five dimensions: mobility (no problems 88.2%, some problems 10.4%, and extreme problems 1.4%), self-care (no problems 91%, some problems 8.3%, and extreme problems 0.7%), daily activities (no problems 88.9%, some problems 9.0%, and extreme problems 2.1%), pain or discomfort (no problems 79.9%, some problems 19.4%, and extreme problems 0.7%), and anxiety or depression (no problems 64.6%, some problems 30.6%, and extreme problems 4.9%). In each of the 5 areas of the EQ we dichotomize the patients into (no problems) vs. (some problems plus extreme problems). The analysis in terms of each five dimensions reported differences in the following parameters: mobility (dynamometry (25.7 ± 4.3 kg vs. 20.2 ± 4.5 kg;P = 0.001) and pennation angle by US (7.01 ± 1.1° vs. 5.42 ± 1.4°; P = 0.001)), self-care (dynamometry (25.5 ± 8.3 kg vs. 20.0 ± 6.5 kg; P = 0.001) and pennation angle by US (6.98 ± 2.1° vs. 5.11 ± 1.3 °; P = 0.001)), daily activities (dynamometry (25.7 ± 5.2 kg vs. 19.4 ± 4.52 kg; P = 0.001) and pennation angle by US (7.04 ± 1.0° vs. 5.07 ± 2.0 °; P = 0.001)), and anxiety or depression (CSA RF (3.2 ± 0.9 cm vs. 2.6 ± 0.4 cm; P = 0.01) and MT RF (1.00 ± 0.1 cm vs. 0.89 ± 0.1 cm; P = 0.01)). No differences were found in any parameter when dichotomizing the pain dimension

A correlation analysis was performed among the two parameters of the EuroQol-5D test and biochemical, anthropometric, and ultrasound parameters (Table 3). This analysis shows positive correlations with RF ultrasound values (CSA, MT, and pennation angle), BIA (phase angle, SMM, ASMM, aSMMi), muscle strength, and negative with CRP and the CRP/prealbumin ratio.

Table 2
Biochemical parameters in patients with cancer (mean ± SD)

Parameters	Mean ± SD
CRP (mg/dL)	6.3 ± 1.2
Albumin (g/dL)	4.6 ± 0.4
Prealbumin (mg/dL)	119.7 ± 23.6
Transferrin (mg/dL)	53.1 ± 9.6
Ratio CRP/prealbumin (mg/dL)	118.4 ± 21.7

CRP, C reactive protein.

Table 3
Correlation analysis between PhA and ultrasound and biochemical parameters in patients with cancer

Parameters	VISUAL scale	Parameters	EQ-5D index
CSA RF (cm^2/m^2)	$r = 0.32$, $P = 0.001$	**CSA RF (cm^2/m^2)**	$r = 0.18$, $P = 0.01$
MT RF (cm)	$r = 0.31$, $P = 0.001$	**MT RF (cm)**	$r = 0.15$, $P = 0.01$
Pennation angle (°)	$r = 0.12$, $P = 0.05$	**Pennation angle (°)**	$r = 0.14$, $P = 0.04$
Body weight (kg)	$r = 0.21$, $P = 0.008$	**Body weight (kg)**	$r = 0.14$, $P = 0.02$
Dynamometry kg	$r = 0.24$, $P = 0.002$	**Dynamometry kg**	$r = 0.22$, $P = 0.001$
Phase Angle (°)	$r = 0.27$, $P = 0.001$	**Phase angle (°)**	$r = 0.28$, $P = 0.001$
SMM (kg)	$r = 0.15$, $P = 0.02$	**SMM (kg)**	$r = 0.18$, $P = 0.03$
aSMM (kg)	$r = 0.16$, $P = 0.03$	**aSMM (kg)**	$r = 0.15$, $P = 0.04$
aSMMI (kg/m^2)	$r = 0.11$, $P = 0.01$	**aSMMI (kg/m^2)**	$r = 0.11$, $P = 0.04$
Reactive C protein (g/dL)	$r = -0.19$, $P = 0.02$	**Reactive C protein (g/dL)**	$r = -0.59$, $P = 0.001$
Ratio CRP/prealbumin	$r = -0.10$, $P = 0.13$	**Ratio CRP/Prealbumin**	$r = -0.50$, $P = 0.001$

aSMM, appendicular skeletal muscle mass; aSMMi, appendicular skeletal muscle mass index; CRP, C reactive protein; CSA, cross-sectional area; FATi, fat index; MC, muscle circumference; Mi, muscular index; MT, muscle thickness; NMNFi, no muscular no at index; RF, rectus femoris; SMM, skeletal muscle mass.

We divided the sample by the median of the EuroQol-5D test scores (visual scale, 60 points) and by the median of the EQ5D index (0.85 points). Patients in the groups below the median value for the visual scale score and the Eq5D index had lower RF ultrasound values (CSA and MT), BIA (phase angle, SMM, ASMM, aSMMi), muscle strength values, and higher values of CRP and the CRP/prealbumin ratio than patients in the group with the highest quality of life scores (Table 4). There were no differences in the distribution of tumors in the groups, nor in the mean age of the patients, nor in the gender distribution.

Stepwise multivariate linear regression adjusted by age, sex, tumor location, and body weight were used to investigate the determinants of visual scale of quality of life and EQ5D index. In the first multivariate model, variables related to visual scale in the univariate analysis ($P < 0.05$) were included. CSA determined by an artificial intelligence−based muscle ultrasound system (beta 4.25, 95% CI 2.03−6.47) remained in the model as dependent variable. In the second multivariate model (EQ5D index), muscle strength by dynamometry (beta 0.008, 95% CI 0.003−0.14) remained in the model as dependent variable

Discussion

This is the first study evaluating the association between HRQOL and RF muscle mass determined by an artificial intelligence−based muscle ultrasound system in outpatients with cancer. Our study showed that HRQOL determined by EQol5D was correlated with CSA, MT, pennation angle, and other BIA parameters. Furthermore, muscle strength and pennation angle by US were associated with better score in dimensions of mobility, self-care, and daily activities, too.

Some previous studies have shown the good relationship between RF and BIA muscle ultrasound parameters [29]. On the other hand, ultrasonography has advantages over CT; a technique usually used in coronary composition, since it is a faster, cheaper technique and does not require ionizing radiation. Interobserver or intraobserver variability can be reduced by using artificial intelligence systems, such as the one used in our work [23]. HRQOL is a multidimensional concept that includes domains related to health status and life expectancy. Therefore, HRQOL depends on both the physical and psychological condition of patients, and both factors can in turn influence nutritional status [30]. The number of generic or specific tools available in the literature and used for research protocols or clinical activities is countless. However, here we want to focus on a particularly simple tool, quick to administer, widely used in the literature, generic in nature, and therefore capable of covering the entire spectrum of patients with cancer. The used tool in our design is the EuroQol-5 Dimension (EuroQol-5D), which, precisely because of these characteristics, can be used as a screening tool even for large populations. Its ease and speed of administration make it suitable for elderly and/or very debilitated patients, and, lastly, it can be used in various settings: inpatient care,

Table 4
Analysis of parameters with the sample divided by the median of the EQ5D test scores (visual scale, 60 points) and by the median of the EQ 5 index (0.85 points) in patients with cancer

Parameters	Low visual scale $n = 79$	High visual scale $n = 79$	P	Low EQ-5D index $n = 79$	High EQ-5D index $n = 79$	P
Colon-rectum cancer%	31.6%	34.9%	0.45	28.5%	31.4%	0.47
Esophageal-stomach cancer %	49.7%	47.7%	0.53	45.9%	40.9%	0.51
Pancreatic cancer %	9.5%	9.1%	0.68	10.2%	8.2%	0.60
CS RF (cm^2/m^2)	2.56 ± 0.8	3.44 ± 1.0	0.01	2.72 ± 0.6	3.23 ± 0.2	0.03
MT RF (cm)	0.85 ± 0.2	1.11 ± 0.1	0.01	0.90 ± 0.2	0.99 ± 0.1	0.02
Body weight (kg)	60.7 ± 10.8	68.2 ± 8.0	0.01	64.1 ± 7.8	64.6 ± 8.1	0.40
Dinamometry kg	22.9 ± 7.8	27.2 ± 6.0	0.02	23.2 ± 4.8	25.6 ± 3.0	0.03
Phase angle (°)	4.9 ± 0.3	5.3 ± 0.1	0.01	4.8 ± 0.3	5.3 ± 0.2	0.01
SMM (kg)	21.1 ± 2.1	23.9 ± 1.3	0.01	22.3 ± 1.1	23.3 ± 313	0.04
aSMM (kg)	15.8 ± 2.6	17.8 ± 1.7	0.01	16.8 ± 2.1	18.8 ± 1.7	0.03
aSMMI (kg/m^2)	6.1 ± 1.3	6.5 ± 1.2	0.02	6.2 ± 1.4	6.5 ± 1.0	0.03
CRP m (g/dL)	7.2 ± 2.7	13.8 ± 2.2	0.01	7.1 ± 2.9	16.8 ± 4.2	0.01
Ratio CRP/prealbumin	0.48 ± 0.1	0.67 ± 0.2	0.01	0.41 ± 0.1	0.81 ± 0.2	0.01
Pennation angle (°)	6.6 ± 2.1	7.2 ± 1.6	0.02	6.6 ± 1.1	6.9 ± 1.2	0.04
Mi	0.43 ± 0.07	0.45 ± 0.06	0.11	0.42 ± 0.07	0.44 ± 0.05	0.21
FATi	0.41 ± 0.06	0.40 ± 0.05	0.12	0.42 ± 0.06	0.40 ± 0.03	0.15
NMNFi	0.17 ± 0.05	0.14 ± 0.01	0.11	0.16 ± 0.03	0.16 ± 0.01	0.21

aSMM, appendicular skeletal muscle mass; aSMMi, appendicular skeletal muscle mass index; CRP, C reactive protein; CSA, cross-sectional area; FATi, fat index; MC, muscle circumference; Mi, muscular index; MT, muscle thickness; NMNFi, no muscular no at index; RF, rectus femoris; SMM, skeletal muscle mass.

outpatient clinics, and telephone follow-ups [24]. The EuroQol-5D (EQ-5D) is a widely recognized instrument for measuring HRQoL, offering a standardized yet simple approach with only five dimensions. As noted by Balestroni and Bertolotti [26], although EQ-5D is not extensively utilized in oncology, its brevity and ease of application make it particularly advantageous for patients undergoing multiple diagnostic tests and treatments. Cancer patients often experience high levels of physical and psychological burden, making lengthy assessments impractical. Despite its limited use in oncology, EQ-5D has demonstrated validity across diverse clinical populations, supporting its feasibility in evaluating HRQoL even in complex patient groups. The ability to generate a single index value for HRQoL enhances comparability across studies, facilitating cost-utility analyses in healthcare decision-making. Incorporating EQ-5D in oncology research could provide a standardized approach for assessing treatment impact, aligning with the growing emphasis on patient-centered outcomes in clinical and health policy research.

In a recent meta-analysis, Hanna et al. [31] reported that reduced muscle mass may be linked to lower overall and physical functioning HRQOL scores in adults with cancer. However, all these studies were performed with CT, and most of them were done with patients admitted to hospital, which limits their generalization to routine clinical practice at outpatient level with cancer. Other limitation of the evidence base [31] is the use of varying cut-off points across studies to classify skeletal muscle status, which reduces the reliability of these analyses. However, in our study, the analysis performed was not only dichotomized (using HRQOL medians) but also included a correlation analysis and adjusted linear regression analysis. Therefore, continuous variables were used across their entire spectrum of clinical representation for the patients. The findings from the above-mentioned meta-analyses and our own design, which show an association between low muscle mass and poorer global and physical functioning HRQOL scores, may indicate a multifactorial and bidirectional relationship between skeletal muscle status and overall well-being. A decrease in SMM is recognized as a contributing factor to diminished physical strength [32] and evidence supports a connection between strength and HRQOL in cancer patients [33]. On the other hand, the decrease in HRQOL linked to the side effects of cancer treatment, recovery from surgery, and/or the emotional impact of facing a life-threatening illness could plausibly lead to reduced participation in daily routines. This decrease in activity may result in physical inactivity, which is a well-established contributing factor to muscle wasting [34]. For example, the questionnaire EuroQol-5 describes health status in terms of five dimensions: mobility, self-care, daily activities, pain or discomfort, and anxiety or depression. In our study, patients with lower scores in the mobility, self-care, and daily dimensions exhibited poorer values for the CSA of the RF and pennation angle, reinforcing the previously mentioned hypothesis.

It is important to remember that in patients with cancer, SMM and quality decline due to various molecular pathways [35], the quantity and quality of muscle are both important. In our studied with an artificial intelligence–based muscle ultrasound system, we have determined different muscle quality parameters such as Muscular index (Mi), fat index (FATi), and pennation angle and muscle quantity (CSA and MT). CSA and MT were correlated with HRQOL, with CSA remaining independent in the final multiple regression with the visual scale. Pennation angle also showed positive correlations, and although it did not remain as an independent variable in the multiple regression model, in the dimensions of mobility self-care, and daily activities, presented higher values in patients with better health in these dimensions. The pennation angle, measured via ultrasound in the RF muscle, reflects muscle architecture and efficiency. Clinically, it indicates muscle health, strength potential, and adaptations to conditions like aging, disease, or disuse. Changes in the pennation angle can signal atrophy, recovery progress, or the effectiveness of rehabilitation and training interventions. Gaining deeper insights into HRQOL is essential for advancing patient-centered care, as it enables the identification of areas requiring supportive interventions, informs clinical decision-making, and challenges assumptions regarding what patients prioritize in their care.

Our study has several limitations. First, physical performance was not assessed using methods such as the timed up-and-go test or chair-test, we measured only muscle strength with dynamometry. The absence of these measures may limit the comprehensiveness of the results, potentially overlooking the role of muscle function in patients with cancer. Second, our study has a cross-sectional design, which prevents us from generating hypotheses about causality. Third, although the EuroQol-5D is a tool that is not widely used in cancer patients, its simplicity, with only five questions, makes it easy to apply in patients undergoing multiple diagnostic tests and treatments. However, it may limit the ability to detect subtle differences in HRQOL related to muscle mass. Fourth, the single-center nature of the study could introduce sample selection bias and limit the generalizability of the findings. Finally, since the study is cross-sectional, it does not track muscle mass or HRQOL changes over time, which would provide a stronger foundation for clinical recommendations. Nevertheless, our study has notable strengths, including a case mixed population of outpatients with cancer. A novel validated artificial intelligence–based muscle ultrasound system [23] was used, which generates a wide range of parameters related to muscle quality and quantity.

In conclusion, CSA, MT, and pennation angle of RF determined by an artificial intelligence–based muscle ultrasound system in outpatients with cancer were related to HRQOL by EuroQol-5D. The findings of this study can significantly inform clinical interventions, particularly nutritional strategies and physical therapy programs, for cancer patients with malnutrition. The study establishes a clear association between SMM, as assessed by an AI-based ultrasound system, and HRQoL, as measured by the EuroQol-5D tool. Given the strong correlation between muscle mass parameters (CSA, MT, and pennation angle) and HRQoL, interventions should be aimed at preserving or enhancing muscle function. Nutritional strategies could be focussed on protein-rich diets and supplementation to counteract muscle degradation, potentially improving patient outcomes. Additionally, physical therapy programs should prioritize resistance training and functional exercises targeting muscle preservation, enhancing mobility, self-care, and daily activities. AI-driven muscle ultrasound provides a precise and non-invasive tool for monitoring the effectiveness of interventions, allowing clinicians to personalize treatment. By integrating these findings into oncological care, healthcare providers can improve functional status, independence, and overall quality of life for malnourished cancer patients.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Daniel de Luis reports was provided by University of Valladolid. Daniel de LU is reports a relationship with University of Valladolid that includes: board membership. All authors have read and agreed to the published version of the manuscript.

CRediT authorship contribution statement

Daniel de Luis: Writing – review & editing, Writing – original draft, Formal analysis, Conceptualization. **Angela Cebria:** Software, Investigation. **David Primo:** Methodology, Investigation, Funding acquisition. **Olatz Izaola:** Methodology, Investigation, Data curation. **Eduardo Jorge Godoy:** Software, Methodology. **Juan Jose Lopez Gomez:** Writing – original draft, Methodology.

Funding

This research received no external funding.

Institutional Review Board statement

The study was conducted in accordance with the Declaration of Helsinki, and the study protocol received approval from the Ethics Committee for Clinical Research of the Health Council of HCUVA (code pi17-491), as well as from the individual Institutional Review Boards of the participating hospitals.

Informed consent statement

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

Data availability

Data is unavailable due to privacy or ethical restrictions.

Acknowledgments

No AI (Artificial Intelligence) is used for the writing of this manuscript

References

[1] McGough C, Baldwin C, Frost G, Andreyev HJN. Role of nutritional intervention in patients treated with radiotherapy for pelvic malignancy. Br J Cancer 2004;90:2278–87.
[2] Dewey A, Baughan C, Dean TP, Higgins B, Johnson I. Eicosapentaenoic acid (EPA, an omega-3 fatty acid from fish oils) for the treatment of cancer cachexia. Cochrane Database Syst Rev 2007;24:CD004597.
[3] Correia MI, Waitzberg DL. The impact of malnutrition on morbidity, mortality, length of hospital stay and costs evaluated through a multivariate model analysis. Clin Nutr 2003;22:235–9.
[4] Naber THJ, Schermer T, Bree A, Nusteling K, Eggink L, Kruimel JW, et al. Prevalence of malnutrition in nonsurgical hospitalized patients and its association with disease complications. Am J Clin Nutr 1997;66:1232–9.
[5] Schattner M, Shike M, et al. Nutrition support of the patient with cancer. In: Shils ME, editor. Modern nutrition in health and disease, 10th ed., Philadelphia: Lippincott Williams & Wilkins; 2005. p. 1290–313.
[6] Deluche E, Leobon S, Desport JC, Venat-Bouvet L, Usseglio J, Tubiana-Mathieu N. Impact of body composition on outcome in patients with early breast cancer. Support Care Cancer 2018;26:861–8.
[7] Shachar SS, Williams GR, Muss HB, Nishijima TF. Prognostic value of sarcopenia in adults with solid tumours: a meta-analysis and systematic review. Eur J Cancer 2016;57:58–67.
[8] Fearon KC, Moses AGW. Cancer cachexia. Int J Cardiol 2002;85:73–81. https://doi.org/10.1016/S0167-5273(02)00235-8.
[9] Barber MD, Ross JA, Fearon KC. Cancer cachexia. Surg Oncol 1999;8:133–41. https://doi.org/10.1016/S0960-7404(99)00045-6.
[10] Deng H-Y, Zha P, Peng L, Hou L, Huang K-L, Li X-Y. Preoperative sarcopenia is a predictor of poor prognosis of esophageal cancer after esophagectomy: a comprehensive systematic review and meta-analysis. Dis Esophagus 2018;32:1–10.
[11] Chang KV, Chen JD, Wu WT, Huang KC, Hsu CT, Han DS. Association between loss of skeletal muscle mass and mortality and tumor recurrence in hepatocellular carcinoma: a systematic review and meta-analysis. Liver Cancer 2018;7:90–103.
[12] Lieffers JR, Bathe OF, Fassbender K, Winget M, Baracos VE. Sarcopenia is associated with postoperative infection and delayed recovery from colorectal cancer resection surgery. Br J Cancer 2012;107:931–6.
[13] Weerink LBM, van der Hoorn A, van Leeuwen BL, de Bock GH. Low skeletal muscle mass and postoperative morbidity in surgical oncology: a systematic review and meta-analysis. J Cachexia Sarcopenia Muscle 2020;11:636–49.
[14] Jung H-W, Kim JW, Kim J-Y, Kim S-W, Yang HK, Lee JW, et al. Effect of muscle mass on toxicity and survival in patients with colon cancer undergoing adjuvant chemotherapy. Support Care Cancer 2015;23:687–94.
[15] Aleixo G, Williams G, Nyrop K, Muss H, Shachar S. Muscle composition and outcomes in patients with breast cancer: meta-analysis and systematic review. Breast Cancer Res Treat 2019;177:569–79.
[16] Aaronson NK, Ahmedzai S, Bergman B, Bullinger M, Cull A, Duez NJ, et al. The European Organization for Research and Treatment of Cancer QLQ-C30: a quality of-life instrument for use in international clinical trials in oncology. J Natl Cancer Inst 1993;85:365–76.
[17] Allemani C, Weir HK, Carreira H, Harewood R, Spika D, Wang X-S, et al. Global surveillance of cancer survival 1995–2009: analysis of individual data for 25 676 887 patients from 279 population-based registries in 67 countries (CONCORD-2). Lancet 2015;385:977–1010.
[18] Calman KC. Quality of life in cancer patients—an hypothesis. J Med Ethics 1984;10:124–7.
[19] Fallowfield L. Quality of life: a new perspective for cancer patients. Nat Rev Cancer 2002;2:873–9.
[20] Aaronson NK. Methodologic issues in assessing the quality of life of cancer patients. Cancer 1991;67:844–50.
[21] Nipp RD, Fuchs G, El-Jawahri A, Mario J, Troschel FM, Greer JA, et al. Sarcopenia is associated with quality of life and depression in patients with advanced cancer. Oncologist 2018;23:97–104.
[22] Aversa Z, Costelli P, Muscaritoli M. Cancer induced muscle wasting: latest findings in prevention and treatment. Ther Adv Med Oncol 2017;9:369–82.
[23] López-Gómez JJ, Primo-Martín D, Cebria A, Izaola-Jauregui O, Godoy EJ, Pérez-López P, et al. Effectiveness of high-protein energy-dense oral supplements on patients with malnutrition using morphofunctional assessment with AI-assisted muscle ultrasonography: a real-world one-arm study. Nutrients 2024;17(16):3136.
[24] Gomes F, Schuetz P, Bounoure L. ESPEN guidelines on nutritional support for polymorbid internal medicine patients. Clin Nutr 2018;37:336–53.
[25] García-Herreros S, Jose López Gómez J, Cebria A, Izaola O, Salvador Coloma P, Nozal S, et al. Validation of an artificial intelligence-based ultrasound imaging system for quantifying muscle architecture parameters of the rectus femoris in disease-related malnutrition (DRM). Nutrients 2024;16:1806.
[26] Balestroni G, Bertolotti GL. EuroQol-5D (EQ-5D): uno strumento per la misura della qualità della vita [EuroQol-5D (EQ-5D): an instrument for measuring quality of life]. Monaldi Arch Chest Dis 2012;78:155–9.
[27] Lukaski H, Johson PE. Assessment of fat-free mass using bioelectrical impedance measurements of the human body. Am J Clin Nutr 1985;41:810–7.
[28] Sergi G, De Rui M, Veronese N, Bolzetta F, Berton L, Carraro S, et al. Assessing appendicular skeletal muscle mass with bioelectrical impedance analysis in free-living Caucasian older adults. Clin Nutr 2015;34:667–73.
[29] Cruz-Jentoft AJ, Bahat G, Bauer J, Boirie Y, Bruyère O, Cederholm T, et al. Sarcopenia: revised European consensus on definition and diagnosis. Age Ageing 2019;48:16–31.
[30] Liao PS, Chen TS, Chung PC. A fast algorithm for multilevel thresholding. J Inf Sci Eng 2001;17:713–27.
[31] Hanna L, Nguo K, Furness K, Porter J, Huggins CE. Association between skeletal muscle mass and quality of life in adults with cancer: a systematic review and meta-analysis. J Cachexia Sarcopenia Muscle 2022;13:839–57.
[32] Hernandez-Galiot A, Goni I. Quality of life and risk of malnutrition in a home-dwelling population over 75 years old. Nutrition 2017;35:81–6.
[33] Primo D, Izaola O, Gómez JJL, de Luis D. Correlation of the phase angle with muscle ultrasound and quality of life in obese females. Dis Markers 2022;2022:7165126.
[34] Goodpaster BH, Park SW, Harris TB, Kritchevsky SB, Nevitt M, Schwartz AV, et al. The loss of skeletal muscle strength, mass, and quality in older adults: the health, aging and body composition study. J Gerontol A Biol Sci Med Sci 2006;61:1059–64.
[35] Ceševiko R, Eglītis J, Srebnijs A, Timofejevs M, Purmalis E, Erts R, et al. The impact of maximal strength training on quality of life among women with breast cancer undergoing treatment. Exp Oncol 2019;41:166–72.