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Original Article

Association of Subjective Global Assessment and Adductor pollicis muscle thickness with the Sarcopenia in older patients with type 2 diabetes

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SUMMARY

Background and Aim: Sarcopenia is prevalent in older patients and increases the risk for negative outcomes during hospitalization and after hospital discharge. In patients with type 2 diabetes (T2D) this association may be even worse. Upon hospital admission, it is often difficult to identify sarcopenia, so the objective of this study was to assess whether the subjective global assessment (SGA), the European Society for Clinical Nutrition and Metabolism (ESPEN) and Global Leadership Initiative on Malnutrition (GLIM) criteria and/or usual anthropometric measures can predict sarcopenia. A secondary objective, to evaluate the accuracy of variables in the prediction of sarcopenia.
Methodology: Patients ≥60 years old and with T2D were included. Malnutrition was evaluated in accordance with the guidelines of ESPEN and GLIM, and SGA. Anthropometric measurements were performed by Mid-arm circumference (MAC), mid-upper arm muscle circumference (MUAMC), and adductor pollicis muscle thickness (APMT) was performed. The sarcopenia was evaluated by handgrip strength, timed Up and Go (TUG) test and muscle mass by measuring the calf circumference (CC). Logistic regression was performed to assess the association of variables with Sarcopenia.
Results: A total of 311 patients were included. The prevalence of malnutrition in accordance to ESPEN, GLIM and SGA was 18 (5.8%),

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65 (21%) and 15 (4%), respectively. The MAC and MUAMC showed a negative relationship with sarcopenia (HR: 0.92 CI95% 0.85–0.99). However, patients with overweight had a 66% reduction in the risk of sarcopenia (HR: 0.34 CI95% 0.19–0.59). After adjustments, malnourished patients according to the SGA had a risk of HR: 5.65 (CI95% 1.64–19.38) of sarcopenia, similarly to patients with APMT <5 th HR: 2.81 (CI95% 1.53–5.13), ESPEN and GLIM criteria presented HR:3.10 (CI95%1.12–8.22) and HR:2.94 (CI95%1.64–5.27), respectively. The interaction between SGA and APMT after adjusting the model has been significant (HR: 7.23 CI95% 2.98 –17.67). In the area under the curve (ROC), only SGA + APMT showed greater accuracy in the prediction of sarcopenia (AUC: 0.713 CI95% 0.650–0.803).

Conclusion: In our sample, it was possible to predict sarcopenia through the malnutrition criteria of ESPEN and GLIM, SGA, MAC and APMT. Measures such as APMT associated with the SGA tool seem to better predict sarcopenia in older patients with T2D.

Introduction

Older people with type 2 diabetes (T2D) are more susceptible to adverse events and complications during a hospitalization which can cause an increased length of stay, malnutrition, functional decline, unscheduled surgeries, and higher rates of mortality [1–6]. Studies in different clinical conditions show the damage caused by the presence of sarcopenia in older patients and the sarcopenia and DM2 coexist tends to increase the chance of mortality, even after hospital discharge [4].

The body composition of patients with diabetes has particularities, such as high body fat, accelerated and early decline in muscle mass and strength [7–9], as well as poor muscle quality when compared to non-diabetic subjects [10,11]. The presence of sarcopenia in individuals with T2D increases the risk of falls and fractures [12], thus, the nutritional assessment of these patients needs to be carried using tools that make it possible to detect body changes and identify the risk of sarcopenia.

The Subjective Global Assessment (SGA) is a tool widely used in different locations and hospitals [1319], it presents a good prediction with a length of hospital stay [13], nutritional status [14], and mortality [15,16] and is related to sarcopenia, identifying that those with sarcopenia are also malnourished [17]. The new guidelines proposed for assessing malnutrition can also be used in individuals with sarcopenia [18,19]. The European Society for Clinical Nutrition and Metabolism (ESPEN) criteria considers sarcopenia as one of the arms of the conceptual tree of nutritional disorders [18]. The Global Leadership Initiative on Malnutrition (GLIM) criteria included three phenotypic criteria (weight loss, low body mass index, and reduced muscle mass) and two etiologic criteria (reduced food intake or assimilation, and inflammation or disease burden) and can be used for assessing malnutrition in adults, people with cachexia, frailty and sarcopenia [19].

Anthropometric measures are used to complement the nutritional assessment of adult and older patients [20], are easy-to-measure and low-cost measures. The Mid-arm circumference (MAC) and the tricipital skinfold (TS), from which we can use the MAC alone or calculate the mid-upper arm muscle circumference (MUAMC). The MUAMC has a good relationship with the muscular depletion of older patients [20], a good association with sarcopenia in institutionalized patients [21], patients with cirrhosis [22], and cancer patients in palliative care [23], in addition to being a predictor for mortality [24]. The measurement of the adductor pollicis muscle (APMT) demonstrates a good association with sarcopenia in cancer patients, as well as a good marker for low muscle strength [25].

Due to the differences in body composition of the older with T2D and the increased risk of sarcopenia in these patients, as well as the difficulty of assessing sarcopenia on hospital admission, this study aimed to assess whether SGA, ESPEN and GLIM criteria, classic anthropometric measurements such as MAC, MUAMC, APMT, predicts sarcopenia in hospitalized older patients. As a second objective, we evaluated the accuracy of the tools in prediction.

Materials and methods

Study population

A prospective review was performed in a cohort of 311 patients ≥60 years old with T2D, admitted to the Southern Brazil University Hospital from July 2015 to December 2017 were considered eligible. We did not include surgical patients or with neurological sequelae, those who could not walk, and those who could not communicate. This study had its protocol approved by the ethics committee, all participants signed an informed consent term and according to the recommendations established by the Declaration of Helsinki and approved by the Ethics Committee (# 150068).

The diagnosis of T2D was confirmed through the use of drugs to treat T2D, glycated hemoglobin >6.5% as well as confirmation by the medical team. Medications to control DM2 were consulted in medical records and confirmed with the patient or family member.

A general questionnaire was applied to evaluate data such as socioeconomic situation, consulting the medical record for general admission data. Other covariates were collected through the Hospital information system through patient records and questionnaires. Patients were asked about the practice of physical exercise and the registration in the database was carried out as follows: practice physical activity (yes) or sedentary (not).

Cognitive status was assessed in all patients using the Mini-Mental State Examination (MMSE), the score can vary from a minimum of 0 to a maximum total of 30 points. The cut-off point is according to schooling, being considered with less cognitive development those with less than 25 points (schooling from 1 to 4 years); 26.5 (schooling from 5 to 8 years); 28 (9–11 years), and 29 for more than 11 years [26].

To evaluate the independence level, the Instrumental Activities of Daily Living test (IADL) [27] was performed. The IADL is a scale that assesses eight tasks providing information about functional skills necessary to live independently in the community.

The nutritional screening was assessed using Nutritional Risk Screening 2002 (NRS-2002): scores ≥ 3 indicate nutritional risk and <3 no risk [28].

Nutritional assessment

One trained nutritionist performed the anthropometric and data collection sarcopenia-related. Mid-arm circumference (MAC) and triceps skin-fold thickness (TS) were measured for calculated the mid-upper arm muscle circumference (MUAMC) [MUAMC= MAC - (3,14 * PCT)] [24]. The MAC was measured with an inelastic tape, positioned in the arm midpoint, between the acromion and olecranon and TS was measurement (scientific adipometer, 0.1 mm precision; Cescorf) at the location of the midpoint between the acromion and the olecranon, with the flexed arm forming an angle of 90 ° [24].

The body mass index (BMI) was calculated although the height and weight and to classify the nutritional status we use the values proposed for older people: <22kg/m^2 underweight, 22–27 kg/m^2: normal nutrition, and> 27 kg/m^2 as overweight [29]. At the time of the interview, the patient was asked about weight loss prior to hospitalization. The usual weight was questioned and subtracted from the current weight.

The nutritional status was evaluated in the admission through the Subjective global assessment (SGA). The patients were classified according to the cut points by SGA those who obtained SGA-A were considered with normal nutrition, SGA-B moderate malnutrition and SGA-C with severe malnutrition [13].

In accordance with GLIM, the risk of malnutrition was confirmed with NRS-2002 and then malnutrition was diagnosed with a combination with a least one etiological and one phenotypic component. GLIM criteria [19] for phenotypic evaluation included: non-voluntary weight loss (>5% within past 6 months) and/or low BMI (<20 kg/m2 if <70 years, or <22 kg/m2 if 70 years) [19]. The etiological evaluation of GLIM involved ≤50% of energy requirements >1 week, or any reduction for >2 weeks, or chronic disease, inflammatory conditions.

The ESPEN definition was applied using and diagnostic criteria involved: low BMI (<20 kg/m2 if less than 70 years or <22 kg/m2 if more than 70 years) and/or unintentional weight loss (>5% within the past 6 months) [18].

Adductor pollicis muscle thickness

The APMT was performed according to the proposed technique per Lameu *et al.* [30]: The average of 3 measurements of the dominant hand was considered as the average adductor muscle thickness. The APMT was considered as < or equal 18 mm for men and < or equal 16 mm for women as an indicator of muscle depletion and malnutrition. These values refer to the 5th percentile, proposed in a previous study that described cutoffs, stratified by sex, for healthy adults and older people [31]. Therefore, we have used APMT lower 5th percentile (APMT<p5) as a group of risk.

Sarcopenia

The presence of sarcopenia was evaluated by handgrip strength (HS), calf circumference (CC), and timed up and Go test (TUG). The TUG required patients to stand up out of the chair, walk 3 m, turn around, walk back to the chair, and sit down. Patients were given the following instructions: "stand up on the word 'go,' walk to the tape, turn around, walk back to the chair, and sit down." The timing of the test began at the word "go," and ended when the participant was seated. This course is timed and the cutoff points> 20s were used to consider the patient with low mobility [32].

HS was measured via a dynamometer (Jamar), three consecutive HS measurements were obtained using the dominant hand while in a seated position, elbow bent at a 90°angle. The average of the 3 measures was recorded and was considered with low muscle strength by the dynamometer (<17 Kgf for women and <27 Kgf for men) [33].

Two measurements of the CC of the right leg were performed alternately with an inextensible tape measure (Cerscorf, Brazil) by trained interviewers. The subject was instructed to stand with his legs apart and positioned approximately 20 cm apart. The measurement was taken at the point of greatest horizontal circumference [34]. The mean of the two right calf measurements was used for analytical purposes. CC of ≤34 cm (men) and ≤33 cm (women) was indicative of low muscle mass [35].

To assess sarcopenia, we have considered the updated consensus of the European Working Group on Sarcopenia in Older People (EWGSOP) [36]. Patients with low muscle strength by the dynamometer (<17 Kgf for women and <27 Kgf for men), calf circumference lower than (<33cm for women and <34 for men), and > the 20s in the TUG test were considered sarcopenic.

Statistical analysis

All variables had normality assessed by Kolmogorov-Smirnov test, the results were described as average and standard deviation or median and interquartile range (IQR). Categorical variables were reported as frequencies. Between-group comparisons of baseline and anthropometric variables and sarcopenia were performed using T-test, Fisher's exact, or Mann Whitney for non-parametric variables were performed. The association between anthropometric variables, SGA, GLIM, and ESPEN criteria with sarcopenia was analyzed by Univariate and multivariate regression models were applied to calculate the hazard ratio (HR) and 95% confidence interval (CI). The test was adjusted for the variables: Model 1: age and gender; model 2: age, gender, physical activity, mini-mental state exam and Instrumental activities of daily living.

In the interaction analysis of the SGA and other anthropometric variables, were made the following adjustments: Model 1: age and gender; model 2: age, gender, physical activity, BMI, mini mental state exam and Instrumental activities of daily living.

The prognostic performance of SGA, APMT, and MAC for predict sarcopenia was evaluated using the area under the receiver operating characteristic curve (AUC), considering as excellent ≥0.90; adequate: 0.70–0.89 and poor <0.70. All statistical analyzes were performed in the SPSS program version 23 (SPSS Inc. Chicago, IL, USA), and $p<0.05$ was considered statistically significant. The sample of patients in this study is part of a cohort of older patients with and without diabetes admitted to a university hospital [4].

Results

The study population consisted of 311 T2D patients ≥60 years old (73.7 ± 6.34y) hospitalized for different reasons: cardiovascular disease [80 (25%)], neoplasia [50 (26%)], infectious diseases [98 (18.80)]. Table 1 shows the baseline characteristics for all subjects. In accordance with nutritional status

Table 1
Baseline clinical and nutrition characteristics of older patients with T2D

	All patients (n=311)
Age (years)	73.7 ± 6.34
Gender (Women)	159 (51)
Caucasian	224 (72)
Sedentary	264 (84,9)
HbA1C (%)	7.52 ± 2.05
Glucose (g/dl)	147.99 ± 72.8
T2D medication	
Insulin	107 (34.4)
Metformin	90 (28.93)
SGLT2i	19 (6.1)
DPP4i	32 (10.28)
Metformin + DPP4i	12 (3.85)
Diet control	13 (4.18)
None	38 (12.21)
IADL (dependent)	246 (79)
BMI (kg/m2)	27.91 ± 5.71
Normal weight	108 (35.1)
Malnutrition	32 (10.4)
Overweight	168 (54.5)
SGA	
Well nutrition	192 (61.7)
moderate malnutrition	104 (33.4)
Malnutrition	15 (4)
ESPEN (malnutrition)	18 (5.8)
GLIM (malnutrition)	65 (21)
Weight Loss (>5%)	59 (19)
Calf circumference (cm)	33.51 ± 3.77
APMT <P5 (mm)	207 (67)
Sarcopenia	96 (30.8)
Causes of hospitalization	
Cardiovascular	115 (37)
Neoplasias	80 (25.7)
Infectious diseases	98 (31,5)
Others	18 (5.78)

Student's t-test or Pearson chi-square test when appropriate. ¥ Mann-Whitney test. IADL: Instrumental Activity of Daily Living; LOS: length of stay; BMI: body mass index; SGA: subjective global assessment; MMSE: mini mental state exam; CC: calf circumference; APMT: adductor pollicis muscle tickness; DPP4: Dipeptidyl peptidase-4 inhibitor; SGLT-2: sodium-glucose cotransporter 2 inhibitor.

by BMI, 168 (54.5%) patients were overweight at admission and well nutrition in accordance with SGA [168 (54.5%)]. The sarcopenia was identified in 96 (30.8%) and 207 (67%) show the APMT <5th.

In Table 2 the patients were stratified into two groups with and without sarcopenia according to the consensus (EWGSOP). The sarcopenia was identified in 96 (30.8%) patients. Older patients with T2D and sarcopenia have lower BMI (25.99 ± 4.96 vs 28.77±5.19; p<0.001), MAC (28.93 ± 3.68 vs 30.82 ± 3.96 cm; p<0.001), MUAMC (23.44 ± 3.37 vs 24.38 ± 3.40, p:0.030), CC (30.38 ± 3.86 vs 35.97 ± 3.59, p:0.004), APMT (9.38 ± 3.65 vs. 11.86 ± 4.44, p:0.003), Handgrip (15.69 ± 5.67 vs. 23.72 ± 7.10, p.001) and TUG (11.90 ±3.14 vs. 10.20 ± 2.40, p:0.003) when compared to patients without sarcopenia. In addition, 46.7% of patients with sarcopenia were moderately malnourished (vs.28%, p <0.001) in accordance with SGA.

The Pearson correlation analysis is described in Table 3. BMI presented a strong correlation with MAC (r^2:0.769, p:0.00), MUAC (r^2:0.559, p<0.001) and CC (r^2:0.534, p<0.001).

Table 4 show the univariate and multivariate logistic regression analyses that were performed to determine the association of anthropometric variables, BMI, GLIM, and ESPEN criteria with sarcopenia. The MAC and MUAMC showed a negative relationship with sarcopenia (HR: 0.86 CI95% 0.80–0.93; HR: 0.92 CI95% 0.85–0.99), respectively. However, patients identified as overweight on admission had a 66% reduction in the risk of sarcopenia (HR: 0.34 CI95% 0.19–0.59). Malnutrition in accordance with SGA, ESPEN and GLIM criteria showed a risk of sarcopenia of 4.96 (CI95% 1.51–4.27), 2.90 (CI95% 1.67–5.02) and 2.86 (CI95% 1.58–4.95) of sarcopenia, respectively and APMT <5th (HR: 2.63 CI95% 1.47–4.72). After adjust for age and sex for each variable (model 1), malnutrition according to the SGA had a risk of sarcopenia of HR: 5.65, ESPEN criteria HR: 2.93 and GLIM HR:2.8, and APMT <5th (HR: 2.78), on the other hand, BMI (HR:0.32) and MAC (0.86) showed a lower risk of sarcopenia. In model 2, the same variables remained associated with sarcopenia.

The interaction between SGA and APMT with sarcopenia are show in Table 5. In the model 1, malnourished patients with APMT <5th had a higher risk of sarcopenia when compared to patients without sarcopenia and with normal APMT (HR: 9.01 CI95 % 3.86–21.01). In model 2, the association remained significant (HR: 7.23 CI95% 2.96–17.62). On the other hand, patients with MAC normal and well-nourished have a reduced risk for sarcopenia.

Table 2
Clinical and nutritional characteristics on hospital admission of older patients with type 2 diabetes according to the presence of sarcopenia

Variables	Sarcopenia (n=96)	Without sarcopenia (n=215)	P
Weight (Kg)	65.37 ± 13.39	76.52 ± 15.39	<0.001
BMI (Kg/m2)	25.99 ± 4.96	28.77 ± 5.19	<0.001
Normal nutrition	47 (46.7%)	65 (30.4%)	<0.001
malnutrition	18 (19.6%)	13 (6.1%)	
overweight	31 (33.7%)	136 (63.6%)	
MAC (cm)	28.93 ± 3.68	30.82 ± 3.96	<0.001
TS (mm)	17.50 ± 5.83	20.75 ± 7.95	0.001
MUAMC (cm)	23.44 ± 3.37	24.38 ± 3.40	0.030
CC (cm)	30.38 ± 3.86	35.97 ± 3.59	0.004
APMT (mm)	9.38 ± 3.65	11.86 ± 4.44	0.003
Handgrip (Kgf)	15.69 ± 5.67	23.72 ± 7.10	<0.001
TUG (seconds)	11.90 ± 3.14	10.20 ± 2.40	0.003
Glucose (mg/dl)	154.78 ± 89.78	142.67 ± 56.42	0.43
HbA1c (%)	7.61 ± 2.22	7.43 ± 1.87	0.47
SGA- A	44 (45.7%)	149 (69.6%)	
SGA- B	45 (46.7%)	60 (28%)	<0.001
SGA- C	7 (6.7%)	5 (2.3%)	
ESPEN (malnutrition)	9 (9.8)	8 (3.7)	0.036
GLIM (malnutrition)	31 (33.7)	33 (15.3)	0.001
MMSE (low cognition)	66 (71.7%)	164 (76.3%)	0.24
normal cognition	26 (28.3%)	51 (23.7%)	

MAC: mid-arm circumference; MUAMC: Mid-upper arm muscle circumference; TS: tricipital skinfold thickness; CC: calf circumference; APMT: adductor pollices muscle tickness; SGA: subjective global assessment (A: well nourished, B: moderately malnourished, C: malnourished); MMSE: mini mental state exam.

Table 3
Correlation between BMI and parameters of sarcopenia

	BMI	MAC	CC	APMT	Handgrip	MUAC
BMI	1.0	0.769[a]	0.534[a]	0.09	0.07	0.559[a]
MAC	0.769[a]	1.00	0.551[a]	0.07	0.143[b]	0.807[a]
CC	0.534[a]	0.551[a]	1.00	0.329[a]	0.262[a]	0.364[a]
AMPT	0.09	0.07	0.329[a]	1.00	0.306[a]	0.123[b]
Handgrip	0.07	0.143[b]	0.262[a]	0.306[a]	1.00	0.241[a]
MUAC	0.559[a]	0.807[a]	0.364[a]	0.123[b]	0.241[a]	1.00

[a] Correlation is significant at the 0.01 level (2-tailed).
[b] Correlation is significant at the 0.05 level (2-tailed).

The area under the curve (AUC) can be seen in Figs 1 and 2. Only SGA + APMT showed greater accuracy in the prediction of sarcopenia (AUC: 0.713 CI95% 0.650–0.803).

Discussion

The objective of this study was to investigate the relationship between anthropometric variables, SGA, ESPEN, and GLIM with sarcopenia in older patients with T2D and as a secondary objective, to

Table 4
Association between clinical and anthropometric variables with sarcopenia

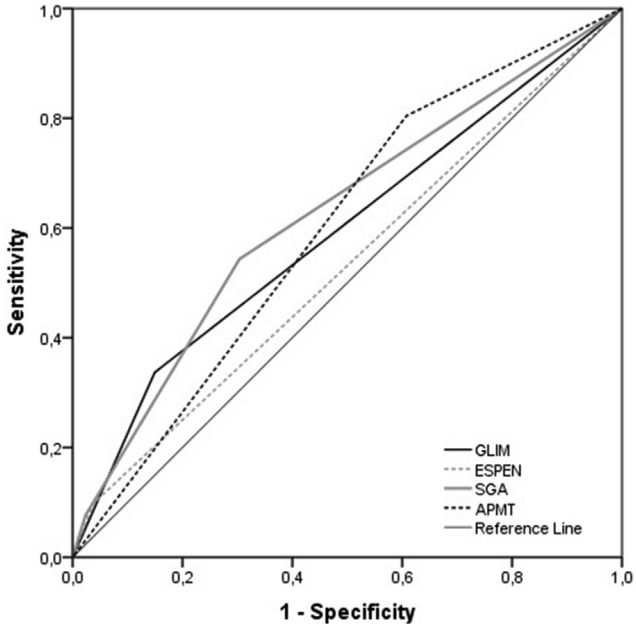
Variables	HR not adjusted	CI 95%	p	Model 1			Model 2		
				HR adjusted	CI 95%	p	HR adjusted	CI 95%	p
MAC (cm)	0.86	0.80–0.93	0.001	0.86	0.80–0.92	<0.001	0.86	0.79–0.82	0.000
MUAMC (cm)	0.92	0.85–0.99	0.03	0.76	0.31–1.88	0.55	––	––	––
SGA-C	4.96	1.49–16.45	0.009	5.65	1.66–19.24	0.006	5.65	1.64–19.38	0.004
SGA-B	2.54	1.51–4.27	0.001	2.72	1.59–4.65	0.00	2.68	1.56–4.59	0.000
BMI (overweight)	0.34	0.19–0.59	0.001	0.32	0.18–0.56	0.001	0.31	0.17–0.55	0.000
ESPEN criteria	2.90	1.67–5.02	0.001	2.93	1.08–8.01	0.034	3.10	1.12–8.22	0.032
GLIM criteria	2.86	1.58–4.95	0.000	2.89	1.62–5.15	0.000	2.94	1.64–5.27	0.001
APMT< 5th	2.63	1.47–4.72	0.001	2.78	1.53–5.05	0.001	2.81	1.53–5.13	0.001

MAC: mid arm circumference; MUAMC: mid-upper arm muscle circumference; SGA: subjective global assessment; BMI: body mass index; APMT: adductor pollices muscle tickness; MMSE: mini mental state exam; IADL: Instrumental activities of daily living.
The model was adjusted for each variable described in the table. Model 1 adjusted for age and gender and model 2: age, gender, physical activity, mini mental state exam; Instrumental activities of daily living.

Table 5
Relationship of sarcopenia with interactions between SGA and AMPT or MAC

	Parameter	HR	CI 95%	p
Model 1	SGA-C + APMT <p5	9.01	3.05–19.95	0.001
	SGA-A+ APMT normal	1		
Model 1	SGA- C + MAC	0.92	0.83–1.02	0.12
	SGA- B + MAC	0.91	0.84–1.32	0.061
	SGA- A + MAC	0.88	0.82–0.95	0.002
Model 2	SGA-C + APMT <p5	7.23	2.96–17.62	<0.001
	SGA-A+ APMT normal	1		
Model 2	SGA- C + MAC	0.99	0.89–1.10	0.89
	SGA- B + MAC	0.96	0.88–1.50	0.38
	SGA- A + MAC	0.56	0.26–1.24	0.06

SGA: Subjective Global Assessment; APMT: adductor pollicis muscle tickness.
Model 1: adjusted for age and gender.Model 2: age, gender, physical activity, mini mental state exam, BMI, Instrumental activities of daily living.
SGA- A: well nourished; SGA-B: moderadly malnourished; SGA-C: Malnourished.



	AUC	CI 95%	p
GLIM	0.594	0.522-0.666	0.009
ESPEN	0.530	0.458-0.602	0.402
SGA	0.625	0.555-0.695	0.001
APMT	0.577	0.510-0.645	0.032

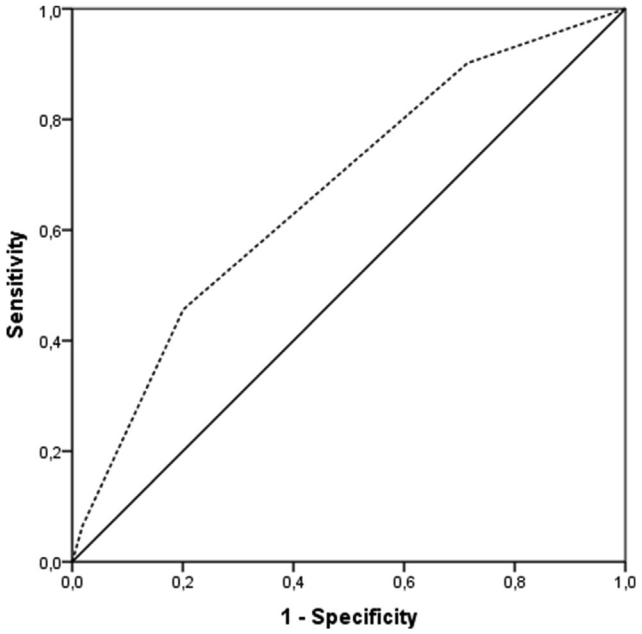
Fig. 1. Receiver Operating Characteristic (ROC) curve for prediction of sarcopenia based on the GLIM, ESPEN, SGA and APMT. AUC: area under curve; CI: confidence interval.

evaluate the accuracy of variables in the prediction of sarcopenia. Malnutrition defined according to the SGA, guideline ESPEN and GLIM, and APMT < 5th was associated with sarcopenia. Additionally, we observed that overweight patients had a lower risk for sarcopenia.

These results demonstrate the importance of assessing older patients with T2D in the hospital environment more broadly to avoid a wrong nutritional diagnosis. In this sample, 168 (54.4%) were overweight according to the BMI and 192 (61.7%) were well nourished according to the SGA. The combination of obesity and sarcopenia - sarcopenic obesity - is a challenge that increases rapidly in times of rapid increase in older adults with overweight or even obesity [37]. However, these patients had APMT below the 5th percentile and 29.6% had sarcopenia on admission.

Patients with sarcopenia had lower MAC and MUAMC, CC, and APMT. The MUAMC showed an inverse relationship with sarcopenia, however, after adjusting the model, the association was not statistically significant, perhaps due to the higher percentage of overweight patients and because we do not divide MUAMC according to the cutoff point. Other studies involving institutionalized older or with specific diseases such as cirrhosis [22], found a good relationship between MUAMC and sarcopenia, however, the older patients in these studies also had a higher percentage of malnutrition. Santos AA *et al.* (2019) [22], identified MUAC in cirrhotic patients as a good anthropometric measure to predict sarcopenia, however, the analysis did not present adjustments. Rodriguez-Rejon *et al.* (2020) [21] assessed 249 older people from a long-term care facility and in those with MUAMC (below 19.2 cm in females and 22.1 cm in males) the risk for sarcopenia increased 4-fold (OR = 3.95; 95% CI 1.68–9.29) [21].

In our sample, malnutrition assessed by GLIM criteria increased the risk of sarcopenia 2.94-fold. Similarly, the study by Belanti F. *et al.* (2020) [38], with 152 older hospitalized, those with malnutrition



SGA + APMT		
AUC	**CI 95%**	**Sig**
0.715	0.65-0.803	<0.001

Fig. 2. Receiver Operating Characteristic (ROC) curve for prediction of sarcopenia based on the SGA+APMT. SGA: subjectiva Global Assessment, APMT: aductor pollicis muscle tickness; AUC: area under curve; CI: confidence interval.

according to the GLIM criteria increased risk of sarcopenia 2.7-fold (95% CI 1.4–4.9, p = 0.0029). In a study the four-year follow-up, Baldart C. *et al.* (2019) [39] evaluated the risk of developing sarcopenia/severe sarcopenia in accordance with GLIM [sarcopenia: (HR) = 3.23 (CI) 1.73–6.05]; and ESPEN [sarcopenia: HR = 4.28 (95% CI 1.86–9.86]. The prevalence of malnutrition in accordance to ESPEN, GLIM, and SGA was 18 (5.8%), 65 (21%), and 15 (4%), respectively, similarly to the study of Beaudart C. *et al.* (2019) [39]; the prevalence of malnutrition by ESPEN [19 (5.65%)] and GLIM [59 (17.6%)]. The APMT showed a good association with sarcopenia, patients with APMT <5th increased risk of sarcopenia 2.63-fold. Other studies have also shown that APMT appears to be sensitive for malnutrition measures in different clinical conditions [40–44], and in the healthy population [32]. Richinelli *et al.* [25] identified that 158 cancer patients (mean age 54 ± 14 years) and reduced APMT had a higher risk of dynapenia (low muscle strength) (considering surgical patients <13.4 mm as the cutoff point). The APMT association has also been associated with a risk of sarcopenia through SARC-F [45]. The effectiveness of APMT as a marker of sarcopenia was assessed in a study with older patients, identifying an area under the curve of 0.70 (95% CI 0.63–0.76; P <0.001) [46].

In this paper, the thickness of the adductor pollicis muscle was assessed using the technique proposed by Lameu et a. (2004) [31] which was studied through images performed by tomography and magnetic resonance and on anatomical parts. This technique allows the assessment of muscle thickness using a caliper in the region in the vertex of an imaginary triangle formed by the extension of the thumb and index finger [31]. The SARCUS project is a European initiative that harmonizes sarcopenia assessment by ultrasound (US) [47]. US assessment has been highlighted in recent studies in the assessment of sarcopenia and/or sarcopenic obesity. Deni O *et al.* (2020) [48] evaluated elderly patients considering the sarcopenic obese group as BMI ≥ 30 and HGS < 16 kg and <27 kg, for women and men,

respectively. Anthropometric parameters that estimate muscle mass were lower in the sarcopenic group and the measures evaluated by US were more effective to assess sarcopenia than the bioimpedance method. Similarly, Sari A *et al.* (2020) [49]. US measurement of the gastrocnemius or rectus abdominis thickness and calf muscle thicknesses were considered a good screening method to detect low muscle mass in patients with systemic sclerosis, high sensitivity, and negative predictive value. Esme M *et al.* (2021) [50] identify that the Muscle thicknesses measured by ultrasonography are helpful for the diagnosis of sarcopenia that may develop in chronic diseases.

Several studies pointed out by the US as the reference method for evaluating an early diagnosis of sarcopenia in older patients [47–51]. Due to the higher cost and lack of resources to perform this ultrasound assessment, we chose to assess using a caliper, as it is available in most hospitals in this country and its replication becomes more accessible. Unfortunately, the cohort study that originated this article was not designed to assess muscle thickness using the US method.

Although our patients were more overweight and had good nutritional status, the presence of malnutrition or being moderately malnourished increased the risk of sarcopenia by 4.96 and 2.54 times, respectively. When adjusting the analysis for other factors, the presence of malnutrition remained significant, but with less statistical strength (HR: 1.84). However, the interaction of SGA and APMT <5th was strongly associated with sarcopenia (HR: 7.23), even after adjustments. The interaction between SGA and MUAMC was not related to the risk of sarcopenia. These data reflect the need to associate anthropometric measures and nutritional screening/assessment when evaluating older patients with T2D.

The SGA is a tool widely used worldwide and has a good prediction for the length of hospital stay [2] and mortality [15,16]. Onishi *et al.* (2018) [17] evaluated 303 older people with digestive diseases and those with sarcopenia had a worse nutritional status by SGA and lower MUAMC [17]. Bellanti *et al.* (2020) [38], compared tools such as SGA, Malnutrition Universal Screening Tool (MUST) and GLIM and verified their association with sarcopenia in 152 older and the patient high risk of malnutrition according to MUST are at high risk of presenting with sarcopenia [38].

This was the first study to evaluate the relationship between ESPEN, GLIM criteria, APMT and sarcopenia exclusively in older patients with T2D. It is known that patients with T2D have lower muscle mass when compared to patients without T2D [10] but most studies assess the relationship between overweight and obesity with negative outcomes without assessing muscle mass. In our data, patients with T2D were overweight, evaluated by the BMI, and also lower muscle mass.

As for shortcomings, the APMT measurement was performed only once, 48 hours after admission, and it was not possible to assess whether the patients further reduced the thickness during hospitalization. The evaluation of muscle mass in sarcopenia was performed using CC, although, some studies have already demonstrated its effectiveness (42). As a strength of our study, we highlight the prospective design, as well as the significant number of patients evaluated.

Conclusions

In fact, the nutritional status during the hospitalization is important and can be a risk factor for other problems, often not related to the main reason for hospitalization. Thus, body changes in older patients with type 2 diabetes can mask muscle and functional status loss. Despite technological advances in body assessment methods, anthropometrics assessments, such as the circumference of the arm and the thickness of the adductor pollicis muscle, are still a safe, low-cost, and validated method that can be used in combination with other tools to identify body changes in older patients.

Statement of authorship

Beretta MV and Rodrigues TC were responsible for the study concept design, data analysis, interpretation of findings and drafted the manuscript. All authors read and approved the final manuscript.

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Declaration of competing interest

The authors declare no conflict of interest.

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