

Original article

Optimizing sarcopenia screening in type 2 diabetes mellitus: A ROC curve evaluation of the SARC-F and the SARC-CalF

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ABSTRACT

Objectives: Sarcopenia is highly prevalent in older adults with type 2 diabetes mellitus (T2DM), significantly increasing fall and disability risks. While the Questionnaire composed of “Strength, Assistance in walking, Rising from a chair, Climbing stairs, and Falls” (SARC-F) is commonly used for sarcopenia screening, its diagnostic accuracy in T2DM patients remains unclear. SARC-CalF, an extended version incorporating calf circumference, may enhance screening effectiveness. This study aimed to evaluate the reliability, validity, and diagnostic accuracy of SARC-F and SARC-CalF in older T2DM adults.

Methods: A cross-sectional study was conducted with 157 T2DM patients aged 60 years and above. Sarcopenia was assessed using both SARC-F and SARC-CalF, with the 2019 Asian Working Group for Sarcopenia criteria serving as the reference standard. Collected data included demographics, muscle mass (via bioelectrical impedance analysis), muscle strength (handgrip and five-time sit-to-stand tests), and physical performance (timed up-and-go test). Reliability, validity, and diagnostic accuracy were analyzed using validated statistical techniques.

Results: SARC-F demonstrated good internal consistency (Cronbach’s $\alpha = 0.80$) and test-retest reliability (ICC = 0.89), moderate diagnostic accuracy (AUC = 0.65, 95% CI: 0.565–0.743) with an optimal cut-off score of 2.5 (sensitivity = 51.4%, specificity = 78.2%). SARC-CalF shows superior diagnostic performance (AUC = 0.98, 95% CI: 0.956–1.000 with higher sensitivity (92%) and specificity (94%).

Conclusions: While the SARC-F is a reliable and valid screening tool for T2DM patients, its diagnostic accuracy is limited. SARC-CalF significantly improves screening performance and is preferable for chronic care monitoring.

1. Introduction

Sarcopenia, an age-related condition characterized by the progressive loss of skeletal muscle mass, strength, and function, is closely associated with adverse health outcomes such as reduced mobility, increased fall risk, fractures, hospitalization, and mortality [1]. As the global population ages, sarcopenia has emerged as a significant public health concern, placing substantial burdens on individuals, healthcare systems, and the economy [2,3]. The economic impact is particularly evident in healthcare settings, where studies indicate that hospitalization costs for sarcopenic patients can be up to five times higher than those without sarcopenia [4,5].

Although sarcopenia is commonly linked to aging, research suggests

that its onset may occur before the age of 60, particularly in individuals with chronic conditions such as Type 2 diabetes mellitus (T2DM) [6,7]. T2DM patients face an approximately threefold increased risk of developing sarcopenia compared to individuals with normal glucose levels [8]. This heightened vulnerability is attributed to metabolic dysfunction, insulin resistance, chronic inflammation, and microvascular complications associated with diabetes [9]. Moreover, sarcopenia in T2DM patients is linked to severe consequences, including an elevated risk of cardiovascular disease [10,11], diabetic foot ulcers, and lower limb amputations [12]. Given that skeletal muscle plays a crucial role in glucose metabolism, sarcopenia may further impair glycemic control, exacerbating diabetes-related complications. Moreover, the concept of geriatric syndromes—including sarcopenia and frailty—has been

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recognized as a critical aspect of aging-related complications in T2DM patients [13]. These findings underscore the need for early identification and intervention to mitigate the progression and consequences of sarcopenia in T2DM patients.

Despite increasing recognition of sarcopenia's clinical importance, challenges remain in its diagnosis and screening. Both the European Working Group on Sarcopenia in Older People (EWGSOP) and the Asian Working Group for Sarcopenia (AWGS) define sarcopenia as low muscle mass combined with either reduced muscle strength or impaired physical performance [6,14]. These organizations recommend a combination of methods for sarcopenia assessment, including dual-energy X-ray absorptiometry (DXA) or bioelectrical impedance analysis (BIA) for muscle mass, handgrip dynamometry for muscle strength, and walking speed or chair stand tests for functional performance [14]. However, these methods require specialized equipment and trained personnel, limiting their feasibility in routine outpatient and community settings. The cost and complexity of these diagnostic tools highlight the urgent need for simple, rapid, and reliable screening tools for sarcopenia.

To address this gap, Malmstrom and Morley (2013) developed the SARC-F, a brief, self-reported sarcopenia screening tool consisting of five components: Strength, Assistance in walking, Rising from a chair, Climbing stairs, and Falls. Each item is scored from 0 to 2, with a total score of ≥ 4 indicating an increased risk of sarcopenia [15]. The SARC-F has been validated across various populations and settings, demonstrating high specificity but relatively low sensitivity [16]. Beaudart et al. (2016) demonstrated its efficacy in hospitalized patients, reinforcing its role in identifying individuals at risk of sarcopenia [17]. Shaw et al. (2017) further validated the SARC-F in community-dwelling older adults, highlighting its applicability in non-hospitalized populations [2]. However, its performance in specific clinical populations, particularly T2DM patients, remains unclear and warrants further investigation.

Furthermore, in an effort to enhance the diagnostic performance of the SARC-F, researchers in Brazil introduced the SARC-CalF, which incorporates calf circumference measurement, thereby improving sensitivity of the measure from 33% to 67% while maintaining specificity [18]. Similarly, a Slovenian study reported that combining SARC-F with calf circumference measurement increased sensitivity to 77.4% and specificity to 89.8% in detecting sarcopenia based on EWGSOP criteria [19]. These findings suggest that supplementing the SARC-F with calf circumference measurement may enhance its utility as a sarcopenia screening tool. However, no previous studies have examined the validity of the SARC-CalF in addressing sarcopenia among clinical populations with T2DM.

Given that T2DM patients experience not only muscle loss due to insulin resistance [20] but also potential exacerbation from poor glycemic control [8] and diabetes-related complications, including vascular disorders, a more comprehensive evaluation of sarcopenia screening tools in this population is essential. This study aims to examine the reliability, validity, and responsiveness of the SARC-F compared to the SARC-CalF tool in older T2DM patients. By evaluating the diagnostic accuracy and applicability of these tools in this population, we seek to provide recommendations for a practical and efficient sarcopenia screening tool tailored to clinical and primary care settings. The findings of this study will contribute to optimizing sarcopenia screening strategies and provide valuable insights for healthcare practitioners managing T2DM patients at risk for sarcopenia.

2. Methods

2.1. Study design and participants

This cross-sectional study was conducted in the emergency department of a medical center in northern Taiwan from September 12, 2023, to April 30, 2024. Participants were recruited via convenience sampling based on the following inclusion criteria: (1) age 60 years or older; (2) diagnosed with T2DM; (3) able to ambulate independently; and (4)

capable of communicating in Mandarin or Taiwanese. Exclusion criteria included: (1) wheelchair users or those requiring assistance to stand; (2) major surgery within the past three months; (3) evident upper or lower limb dysfunction; (4) significant lower limb edema; and (5) history of lower limb joint replacement surgery. Sample size calculation was performed using MedCalc software, setting α at 0.05 and power at 0.8. For single proportion, the proportion was set at 65%, and for the AUROC curve, the AUC was set at 0.65, estimating a sample size between 85 and 102 participants. To ensure adequate statistical power, 157 subjects were ultimately enrolled. Ethical approval was granted by the hospital's Human Research Ethics Committee (202301087B0C501).

2.2. Measures

2.2.1. Demographic and T2DM variables

A structured interview questionnaire was used to collect participants' demographic characteristics, including gender, age, occupation, education level, comorbidities, body mass index, diet, smoking, and alcohol history. T2DM-related clinical data, such as disease duration, glycated hemoglobin (HbA1c) levels, and complications, were also collected.

2.2.2. Body composition and muscle mass assessment

Muscle mass was assessed using BIA, a non-invasive method for estimating body composition, including body fat, lean tissue mass, and total body water [21,22]. BIA measured participants' body fat percentage, body mass index (BMI), skeletal muscle mass ratio, and body weight. According to the 2019 Asian Working Group for Sarcopenia (AWGS) guidelines, low muscle mass was defined as a skeletal muscle index of $\leq 7.0 \text{ kg/m}^2$ for males and $\leq 5.7 \text{ kg/m}^2$ for females.

2.2.3. Physical performance and strength measurements

Upper limb strength was evaluated using an electronic dynamometer to measure maximal handgrip strength in both hands. Participants stood in a relaxed posture with their arms naturally extended at their sides while firmly gripping the dynamometer with their dominant hand for 5 seconds. After a 15-second rest, the test was repeated with the non-dominant hand. Each hand was tested three times, and the highest value was recorded as the result. According to AWGS 2019 criteria, reduced muscle strength was defined as a handgrip strength of $< 28 \text{ kg}$ for men and $< 18 \text{ kg}$ for women. Handgrip strength is widely recognized as a key indicator of overall health and physical function.

Lower limb strength and function were assessed through the five-time sit-to-stand test. Participants were instructed to sit on an armless chair with their arms crossed over their chest and perform five consecutive repetitions of standing up and sitting down as quickly as possible while ensuring full knee extension and flexion. The total completion time was recorded, with times ≥ 12 seconds suggesting insufficient lower limb strength.

Additionally, the Timed Up-and-Go (TUG) test was conducted to assess functional mobility. Participants were required to rise from a seated position without using arm support, walk 3 meters, turn around, return to the starting position, and sit down. The total time to complete the task was recorded. A TUG time exceeding 20 seconds was considered indicative of impaired physical function. The TUG test is widely employed as an objective measure of functional mobility and the ability to perform daily activities [6].

2.2.4. Sarcopenia screening

Sarcopenia screening utilized the SARC-F, which assesses muscle strength, walking assistance, rising difficulty, stair climbing difficulty, and falls. Each item is scored from 0 to 2 based on self-reported difficulty, with a total score range of 0–10. Following the 2020 AWGS guidelines (AWGS 2019), calf circumference measurement was added to form the SARC-CalF [18,23]. Calf circumference $\geq 34 \text{ cm}$ (males) or $\geq 33 \text{ cm}$ (females) scores 0, while $< 34 \text{ cm}$ (males) or $< 33 \text{ cm}$ (females)

scores 10, with a total score range of 0–20. SARC-F ≥ 4 or SARC-CalF ≥ 11 indicates a higher risk of sarcopenia and poor prognosis [14]. This study utilized a validated Chinese-translated version of the SARC-F, ensuring its simplicity and efficiency in clinical settings.

Calf circumference was also measured as a proxy for muscle mass using the SARC-CalF questionnaire. Participants sat with knees flexed at 90°, and measurements were taken at the widest point of the calf using a flexible, non-stretch tape measure. According to AWGS 2019 criteria, low muscle mass was indicated by a calf circumference of < 34 cm for males and < 33 cm for females [14].

2.3. Statistical analysis

Data analysis was conducted using SPSS 27.0. Categorical variables were summarized as frequencies and percentages, while continuous variables were expressed as mean $\pm$ standard deviation (SD). The reliability of the SARC-F questionnaire was assessed through Cronbach’s α coefficient for internal consistency, while test-retest reliability was evaluated using the kappa coefficient, based on a reassessment of 20 participants 2 days after the initial evaluation [24,25]. For construct validity, Pearson correlation coefficients were used to examine associations between SARC-F scores and AWGS 2019 criteria, including grip strength, five-time sit-to-stand time, BIA, calf circumference, and TUG time. Spearman correlation coefficients were used to assess criterion-related validity by comparing SARC-F scores with AWGS 2019 diagnostic criteria. Known-group validity was examined through independent samples t-tests, comparing SARC-F and SARC-CalF scores across groups. To evaluate diagnostic performance, logistic regression analysis was conducted to determine sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy of the SARC-F and SARC-CalF questionnaires. The area under the receiver operating characteristic (ROC) curve was calculated to compare diagnostic accuracy and identify optimal cut-off points. All statistical tests were two-tailed, with statistical significance set at $P < 0.05$.

2.4 Ethics statement

The study was approved by the Ethics Committee of the Institutional Review Board of Chang Gung Memorial Hospital [No. 202301087B0C501]. All procedures were carried out in accordance with relevant guidelines and regulations. Informed consent was obtained from all individual participants included in the study.

3. Results

3.1. Demographic characteristics

A total of 183 individuals met the inclusion and exclusion criteria, but 26 declined to participate in the study. Ultimately, 157 eligible participants were enrolled, including 85 males (54.1%) and 72 females (45.9%), with no dropouts. The participants had a mean age of 70.1 years (SD = 6.0, range: 57.7–85.8). Regarding education, 37.6% had no formal schooling or only completed primary school, while 55.4% completed middle or high school. Most participants (90.4%) had comorbidities such as heart disease, kidney disease, or stroke. The results, including measures of handgrip strength, chair stand performance, calf circumference, and TUG test, are summarized in Table 1.

The distribution of SARC-F scores is shown in Table 1. Among the five items, “climbing stairs” was identified as the most difficult (102 participants, 65.0%), followed by “rising from a chair” (72 participants, 45.9%). SARC-F total scores ranged from 0 to 9. Using a cut-off score of ≥ 4 to suggest suspected sarcopenia [26], 36 participants (22.9%) were classified as potentially sarcopenic.

Significant differences in SARC-F total scores across various categories are highlighted in Table 1. Females scored higher than males ($P < 0.01$); retired individuals scored higher than non-retired ($P < 0.05$); and significant differences were found across education levels ($P < 0.01$). While comorbidities did not show significance ($P > 0.05$), specific

Table 1
Demographic Characteristics, Clinical Measurements, and SARC-F and SARC-CalF scores of the sample (N = 157).

Characteristics	Mean ($\pm$ SD), number (%)
Age (57.7–85.8), yrs	70.1 ($\pm$ 6.0)
Gender	
Male	85 (54.1%)
Female	72 (45.9%)
Education	
No formal schooling or Primary school	59 (37.6%)
Middle school	46 (29.3%)
High school	41 (26.1%)
University or above	11 (7.1%)
Clinical measurement	
Chronic conditions	142 (90.4%)
HbA1c (4.9–15.7), %	7.2 ($\pm$ 1.5)
BMI (14.3–37.0), kg/m ²	25.2 ($\pm$ 4.1)
Waist circumference (8.4–118.9), cm	92.7 ($\pm$ 11.7)
Hip circumference (79.0–123.2), cm	96.2 ($\pm$ 7.3)
Visceral fat (3.0–25.0), %	12.0 ($\pm$ 4.4)
Body fat (4.9–51.1), %	28.6 ($\pm$ 9.3)
Muscle strength	
Handgrip strength (6.4–44.0), kg	24.2($\pm$ 8.4)
5- time chair stand (7.1–55.8), sec	16.4($\pm$ 6.3)
Muscle mass: BIA (13.0–22.9), kg	16.8($\pm$ 2.2)
Calf circumference (27.0–46.5), cm	34.4($\pm$ 3.5)
Timed Up-and-Go (6.8–42.2), sec	13.5($\pm$ 5.7)
SARC-F total score	2.12 ($\pm$ 2.07)
SARC-CalF total score	6.01 ($\pm$ 5.59)

SD, standard deviation; HbA1c, glycated hemoglobin; BMI, body mass index; BIA, bioelectrical impedance analysis; SARC-F, Strength, Assistance in walking, Rising from a chair, Climbing stairs, and Falls; SARC-CalF, Strength, Assistance in walking, Rising from a chair, Climbing stairs, and Falls, and calf measurement.

conditions such as heart disease ($P < 0.05$), hypertension ($P < 0.05$), and kidney disease ($P < 0.05$) demonstrated statistical significance.

3.2. Correlation analysis between SARC-F, SARC-CalF and AWGS standards

Pearson correlation analysis revealed significant positive correlations between SARC-F total scores and participants’ age ($r = 0.320$, $P < 0.001$), five-time sit-to-stand test time ($r = 0.556$, $P < 0.001$), TUG time ($r = 0.591$, $P < 0.001$), and fall frequency ($r = 0.507$, $P < 0.001$). Significant negative correlations were also found between SARC-F total scores and grip strength ($r = -0.465$, $P < 0.001$), BIA ($r = -0.212$, $P = 0.007$), and calf circumference ($r = -0.172$, $P = 0.032$). Similar to the SARC-F, SARC-CalF total scores were positively correlated to participants’ age ($r = 0.357$, $P < 0.001$), five-time sit-to-stand test time ($r = 0.343$, $P < 0.001$), TUG time ($r = 0.354$, $P < 0.001$), and fall frequency ($r = 0.016$, $P = 0.045$), but negatively correlated with grip strength ($r = -0.433$, $P < 0.001$) and BIA ($r = -0.436$, $P = 0.001$). These results indicate that higher SARC-F and SARC-CalF scores were associated with older age, longer sit-to-stand and up-and-go times, and more frequent falls, but lower grip strength and BIA.

3.3. Reliability analysis

Cronbach’s α coefficient for the SARC-F scale was 0.80, indicating good internal consistency. To assess test-retest reliability, 20 participants were reevaluated after a 2-day interval. The intraclass correlation coefficient (ICC) was 0.89, and Cohen’s Kappa coefficient was 0.66, reflecting substantial agreement and good test-retest reliability [27,28]. These findings demonstrate that repeated measurements using the SARC-F questionnaire yielded consistent results.

3.4. Validity

Sarcopenia classification was determined using SARC-F and SARC-CalF scores based on AWGS 2019 diagnostic criteria (Table 2). Independent samples t-tests were performed to compare individuals with no sarcopenia (N = 87) and those with sarcopenia (N = 70). Results indicated statistically significant differences in total scores between the two groups for both SARC-F and SARC-CalF ($P < 0.01$), confirming a satisfactory known-group validity of these screening tools.

Spearman correlation coefficients between 0.00 and 0.39 indicate weak correlation, 0.40 to 0.59 indicate moderate correlation, and coefficients greater than 0.6 indicate strong correlation [29]. As shown in Table 3, this study found moderate correlations between SARC-F total scores and handgrip strength, five-time sit-to-stand test time, and TUG time. Weak correlations were observed between SARC-F total scores and BIA and calf circumference. All correlations reached statistical significance ($P < 0.01$), indicating good criterion-related validity for the SARC-F tool.

3.5. Diagnostic accuracy analysis

Using the AWGS 2019 diagnostic criteria as the reference standard, ROC curve analysis was performed to evaluate the diagnostic accuracy of SARC-F and SARC-CalF in screening for sarcopenia among diabetic patients. Fig. 1 presents the ROC curves for both SARC-F and SARC-CalF. The Area Under the Curve (AUC) for SARC-F was 0.65 (95% CI: 0.565–0.743, $P < 0.01$), while for SARC-CalF it was 0.98 (95% CI: 0.956–1.000, $P < 0.001$). These results suggest that SARC-CalF, which includes calf circumference measurement, provides superior diagnostic accuracy compared to the SARC-F when used alone. Through ROC curve analysis, the optimal cut-off point for the SARC-F in our study population was determined to be 2.5 points. At this threshold, sensitivity and specificity were optimized, with sensitivity at 51.4% and specificity at 78.2% (Table 4). Furthermore, through ROC curve analysis, the optimal cut-off point for the SARC-CalF in our study population was determined to be 7.5 points, sensitivity at 51.4% and specificity at 78.2%. Table 5 presents the sensitivity, specificity, positive predictive value, and negative predictive value for both SARC-F and SARC-CalF tools, as evaluated using logistic regression analysis.

4. Discussion

This study identified a moderate positive correlation between SARC-F and SARC-CalF scores and age, supporting the finding of Cruz-Jentoft et al. (2019), who reported that sarcopenia is an age-related condition that may begin before the age of 60 [6]. Additionally, sarcopenia is commonly associated with chronic diseases, including heart disease, respiratory disorders, and metabolic syndrome, with Type 2 diabetes mellitus patients exhibiting a threefold higher prevalence than individuals with normal blood glucose levels [8]. In our sample of 157 T2DM patients aged 60 and above, multiple comorbidities were prevalent, particularly hypertension, heart disease, and chronic obstructive pulmonary disease, all of which contribute to an increased risk of sarcopenia [30–34].

Contrary to the findings by Sinclair et al. (2017) [35] which suggested that poor glycemic control increases sarcopenia risk, our study found no significant correlation between HbA1C levels and SARC-F

self-assessment scores or SARC-CalF scores. This discrepancy may be due to our smaller sample size relative to other studies, potentially limiting the generalizability of our findings. Nevertheless, glycemic control remains a key factor in reducing diabetes-related complications, which underscores the need for routine sarcopenia screening in long-term T2DM management. Notably, the SARC-F self-assessment and SARC-CalF both indicated that a considerable proportion of participants experienced difficulties in rising from a chair and climbing stairs. This finding suggests that lower limb muscle weakness is a common functional impairment in T2DM patients reflecting the complex relationship between T2DM and sarcopenia pathophysiology. These findings further underscore the need for targeted interventions to preserve lower limb strength and mobility in this population.

The SARC-F tool demonstrated good internal consistency (Cronbach's $\alpha = 0.80$) and test-retest reliability (ICC = 0.89) in our study, consistent with previous findings in general elderly populations [1,16,36]. The consistency of these findings across different populations highlights the potential of SARC-F as a cross-cultural sarcopenia screening tool. Our study further confirms the stable reliability of SARC-F in T2DM patients, reinforcing its potential clinical utility.

Validity analysis indicated that both the SARC-F and SARC-CalF demonstrate good content and known-group validity in T2DM patients. Specifically, SARC-F scores effectively differentiated between non-sarcopenic and suspected sarcopenic patients, consistent with the findings by Kim et al. (2018) in the Korean elderly [37]. Regarding criterion-related validity, SARC-F total scores showed moderate correlations with AWGS 2019 diagnostic criteria, including handgrip strength, five-time sit-to-stand test, and TUG time. These results align with those reported by Krzyńska-Siemaszkó et al. (2020) [38]. The consistency of these correlations across studies reinforces the stable validity of SARC-F across diverse cultural backgrounds and populations, further supporting its role in sarcopenia screening. However, our study found weaker correlations between SARC-F and BIA measurements, as well as calf circumference. This discrepancy may reflect the functional performance focus of SARC-F rather than direct muscle mass assessment, suggesting that a combination of screening methods may be necessary for a comprehensive evaluation of sarcopenia in T2DM patients.

While a SARC-F cut-off score of ≥ 4 is commonly used to indicate suspected sarcopenia, no optimal threshold has been established for T2DM patients [16]. Using AWGS 2019 diagnostic criteria as a reference, our ROC curve analysis identified an optimal cut-off score of 2.5 for T2DM patients, with a sensitivity of 51.4%, specificity of 78.2%, and AUC of 0.65. Compared with previous studies, our results demonstrated higher sensitivity, lower specificity, and AUC value comparable to that reported by Kim et al. (2018) (AUC = 0.67) but lower than that observed in Yang et al. (2019) (AUC = 0.89) [26,37,39]. These discrepancies may be attributed to differences in study populations, variations in sarcopenia prevalence among T2DM patients, or methodological differences in the assessment of muscle function and mass. Importantly, our participants were recruited exclusively from an emergency department, which may limit the generalizability of the findings to broader T2DM populations. Moreover, the relatively small sample size could have contributed to the exceptionally high diagnostic performance observed for the SARC-CalF (AUC = 0.98), raising the possibility of sample-specific bias or overestimation. Accordingly, these findings should be interpreted with caution and regarded as preliminary evidence requiring confirmation in larger, multicenter, and community-based cohorts. Future studies are also needed to determine whether adopting a lower SARC-F threshold could enhance sarcopenia detection in this population without compromising clinical applicability.

Our study found that the SARC-CalF, which incorporates calf circumference measurement, significantly improved diagnostic performance. Compared to SARC-F, SARC-CalF demonstrated markedly increased sensitivity and specificity, with an AUC of 0.98. This aligns with findings by Barbosa-Silva et al. (2016) and Yang et al. (2018) in

Table 2
Validity of SARC-F and SARC-CalF Scores in AWGS 2019 criteria.

AWGS 2019 criteria	Mean (SD)		P-value
	No sarcopenia (N = 87)	Sarcopenia (N = 70)	
SARC-F Score	1.57 (1.64)	2.80 (2.35)	<0.01
SARC-CalF Score	1.57 (1.64)	11.51(3.43)	<0.01

SD, standard deviation; AWGS, The Asian Working Group for Sarcopenia.

Table 3
Correlation between SARC-F and SARC-CalF scores and AWGS 2019 criteria.

	SARC-F			SARC-CalF		
	Spearman's r_s	P	95% CI	Spearman's r_s	P	95% CI
Handgrip strength	−0.465	<0.001	[−0.582, −0.328]	−0.471	<0.001	[−0.588, −0.335]
5-time Sit-to-Stand	0.503	<0.001	[0.372, 0.615]	0.386	<0.001	[0.240, 0.516]
BIA	−0.244	<0.001	[−0.390, −0.086]	−0.437	<0.001	[−0.559, −0.297]
Calf circumference	−0.209	0.002	[−0.358, −0.049]	−0.746	<0.001	[−0.810, −0.665]
TUG time	0.537	0.009	[0.411, 0.642]	0.382	<0.001	[0.235, 0.512]

Spearman's r_s : Spearman's rank correlation coefficient; CI, confidential intervals; BIA, bioelectrical impedance analysis; TUG, Timed Up-and-Go.

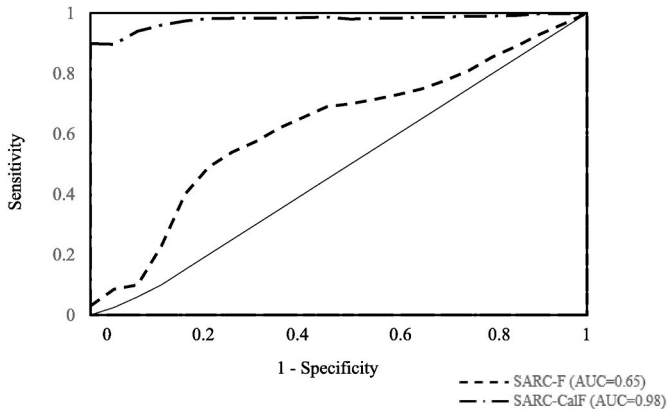


Fig. 1. The ROC curves of SARC-F and SARC-CalF against the AWGS 2019 criteria.

Table 4
SARC-F score and SARC-CalF score cut-off points: Sensitivity and specificity.

Score	Sensitivity (%)	1 – Specificity (%)	Specificity (%)	Sensitivity + Specificity (%)
SARC-F				
−1	100	100	0	100
0.5	76	68	32	108
1.5	69	44	56	125
2.5	51	22	78	130
3.5	36	13	87	123
4.5	23	6	94	117
5.5	10	5	95	105
6.5	9	1	99	107
7.5	4	0	100	104
8.5	3	0	100	103
10	0	0	100	100
SARC-CalF				
−1.00	100	100	0	100
0.50	99	68	32	130
1.50	99	44	56	159
2.50	99	22	78	177
3.50	97	13	87	185
4.50	94	6	94	186
5.50	90	5	95	185
6.50	90	1	99	189
7.50	90	0	100	190
8.50	89	0	100	187
9.50	87	0	100	187
10.50	64	0	100	164
11.50	57	0	100	157
12.50	40	0	100	140
13.50	26	0	100	126
14.50	16	0	100	116
15.50	7	0	100	107
16.50	6	0	100	106
18.00	1	0	100	101
20.00	0	0	100	100

Table 5
Sensitivity/specificity analyses for SARC-F and SARC-CalF validation against the AWGS 2019 criteria.

Tool	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
SARC-F	51.40	78.20	78.10	51.40	66.20
SARC-CalF	92.00	94.00	95.00	90.00	93.00

PPV, positive predictive value; NPV, negative predictive value.

general elderly populations, reinforcing the value of calf circumference measurement in sarcopenia screening among T2DM patients [18,40]. These findings have significant implications for clinical practice, suggesting that SARC-CalF should be prioritized as a preferred screening tool for sarcopenia in T2DM patients.

There are several important limitations to consider when interpreting these findings. First, the cross-sectional design precludes long-term predictive evaluations of both the SARC-F and SARC-CalF. Second, our study sample was recruited from an emergency department and thus consisted of older patients with greater comorbidity and functional impairment compared to community-based or outpatient T2DM cohorts. These characteristics likely contributed to the higher prevalence of sarcopenia observed and may limit the external validity of the findings. Accordingly, the potential for selection bias should be considered. Third, the relatively small sample size may have contributed to the exceptionally high diagnostic performance of the SARC-CalF, raising the possibility of sample-specific bias or overestimation. Fourth, the 2-day test–retest interval, although chosen to minimize clinical changes in an acute care setting, may have been too short and could have introduced memory effects or overestimated reliability. Previous studies evaluating health-related scales with test–retest intervals ranging from 24 hours to 2 weeks have reported good agreement and satisfactory reliability [41,42]. Finally, reliance on self-assessment introduces the possibility of response bias and greater subjective variability in reporting certain measures. Although this study identified optimal cut-off points for both tools in older T2DM patients, these thresholds may not be generalized to other groups. Future research should refine scoring criteria, standardize item difficulty, and employ longitudinal designs to validate the responsiveness and predictive value of the SARC-F and SARC-CalF over time.

5. Conclusions

The findings of the study provide insights into the applicability of both the SARC-F and SARC-CalF for sarcopenia screening in patients with type 2 diabetes, emphasizing the need for population-specific cut-offs and offering practical guidance for clinical screening strategies. The SARC-F demonstrates strong reliability in identifying sarcopenia among elderly T2DM patients, and may be particularly suitable for rapid screening in acute care settings, especially when a lower cut-off score of 2.5 is applied. Given its simplicity and ease of use, SARC-F may be particularly suitable for rapid screening in acute care settings. By contrast, the SARC-CalF showed superior diagnostic performance in this

acute care sample, highlighting its potential utility in detecting sarcopenia in clinical practice. Further studies in chronic care and community settings are warranted to evaluate its applicability for routine follow-ups and long-term management. Integrating both tools into practice may ultimately optimize early detection and intervention for sarcopenia across different care phases in T2DM patients.

CRedit author statement

Shu-Ying Su: Conceptualization, data collection, analysis, and interpretation, writing-original draft, & editing. **Chizimuzo T. C. Okoli:** Writing-review & editing, critical revision. **Li-Fen Chao:** Conceptualization, methodology, supervision, writing-review & editing, visualization, supervision and secured funding for the project.

Data availability statement

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

Conflicts of interest

The authors declare no competing interests.

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