Li *et al. BMC Geriatrics* (2025) 25:206
https://doi.org/10.1186/s12877-025-05806-y

BMC Geriatrics

RESEARCH

Open Access

# The predictive values of sarcopenia screening tools in preoperative elderly patients with colorectal cancer: applying the diagnostic criteria of EWGSOP2 and AWGS2019

Ling Li[1†], Mengchen Xing[1†], Rong Wang[3], Xiaoyue Ding[1], Xia Wan[3*] and Xin Yu[2*]


## Abstract

**Background** Sarcopenia predicts worse postoperative outcomes and lower survival rates in patients with colorectal cancer (CRC). There is a scarcity of studies on the most effective assessment tools for detecting sarcopenia in preoperative elderly patients with CRC. Our objective was to compare the diagnostic accuracy of various tools such as calf circumference (CC), strength, need for assistance with walking, rising from a sitting position, climbing stairs, and the incidence of falls (SARC-F), SARC-F plus CC (SARC-CalF), the short version of mini sarcopenia risk assessment (MSRA-5), the full version of mini sarcopenia risk assessment (MSRA-7), and Ishii score chart in screening sarcopenia in preoperative elderly patients with CRC.

**Methods** During the period of April 2021 to September 2023, we conducted a cross-sectional study involving consecutive elderly patients who were undergoing colorectal surgery. Sarcopenia was defined using the diagnostic criteria proposed by the European Working Group on Sarcopenia in Older People 2 (EWGSOP2) and the 2019 Asian Working Group for Sarcopenia (AWGS2019). The screening tools' performances were evaluated through receiver operating characteristic (ROC) curves, area under the ROC curves (AUC), and sensitivity/specificity analyses, based on the criteria proposed by EWGSOP2 and AWGS2019.

**Results** We enrolled 482 patients with an average age of 71.86 ± 5.60 years. According to the EWGSOP2 and AWGS2019 diagnostic standards, the incidence of sarcopenia was 19.5% and 21.6% respectively. The sensitivity of SARC-F, SARC-CalF, MSRA-5, MSRA-7, and Ishii score chart ranged from 51.92 to 56.38%, 84.62–85.11%, 86.54–88.30%, 65.96–67.31%, and 73.08–74.47% respectively, while the specificity ranged from 84.92 to 85.05%, 70.36–71.69%, 36.86–37.04%, 60.57–61.64%, and 77.32–78.31% respectively. Regardless of the sarcopenia diagnostic criteria used, the


†Ling Li and Mengchen Xing contributed equally to this work.

*Correspondence:
Xia Wan
angela_wan@126.com
Xin Yu
yxwuxi86@163.com
Full list of author information is available at the end of the article

AUCs of Ishii score chart (0.87 to 0.88) and SARC-CalF (0.89 to 0.90) were significantly larger than those of other tools ($P<0.05$). There was no significant difference in AUCs among SARC-F, SARC-CalF, and Ishii score chart in females.

**Conclusion** Among the five sarcopenia screening tools, Ishii score chart and SARC-CalF had the largest overall diagnostic accuracy for sarcopenia in preoperative elderly patients with CRC.

**Keywords** Colorectal cancer, Sarcopenia, Screening tools, Preoperative, Elderly patients

## Introduction

Colorectal cancer (CRC) ranks as the third most frequently diagnosed cancer globally and stands as the second most fatal cancer worldwide [1]. Typically, prognostic assessment in CRC relies on clinical and pathological stages, as well as treatment outcomes. Nevertheless, postoperative complications and patient-related factors can also have a detrimental impact on long-term overall survival and disease-free survival [2].

There is growing evidence that body composition parameters, such as decreased skeletal muscle mass, reduced skeletal muscle radiodensity, and increased visceral adipose tissue, have prognostic implications for patients with gastrointestinal cancer [3–6]. Sarcopenia is a developing concept and currently lacks a universal definition. Traditionally, sarcopenia is a progressive and generalized skeletal muscle disorder, caused by adverse muscle changes that occur over the course of life, characterized by loss of muscle mass, muscle strength, and/or physical performance [7]. Sarcopenia assessment is not currently a standard part of perioperative management in surgical oncology. However, research has shown a high prevalence of sarcopenia in various gastrointestinal cancers, including colorectal cancer (CRC) [8]. A recent systematic review found that 37% of adults with CRC had sarcopenia [9], and it has been linked to an increased risk of postoperative complications and longer hospital stays after tumor resection in gastrointestinal cancer patients [10–13]. Additionally, studies have indicated that preoperative sarcopenia is associated with worse overall survival, disease-free survival, and cancer-specific survival outcomes [8, 14].

The diagnosis of sarcopenia, according to the European Working Group on Sarcopenia in Older People (EWGSOP2) and Asian Working Group for Sarcopenia (AWGS) 2019, requires the measurement of muscle mass and strength or physical performance [7, 15]. This means that the diagnosis of sarcopenia is dependent on the use of specific devices such as computed tomography (CT), magnetic resonance imaging (MRI), dual-energy X-ray absorptiometry (DXA), and bioelectrical impedance analysis (BIA) [16–18]. However, these diagnostic methods can be inaccessible and costly in many clinical settings. Additionally, they require highly trained professionals, making the process time-consuming. Therefore, there is a need for a reliable and simple screening tool for sarcopenia.

The first step in managing sarcopenia is a timely and accurate screening of potential cases. The updated version of the European Working Group on Sarcopenia in Older People (EWGSOP2) recommends using SARC-F (strength, assistance with walking, rising from a chair, climbing stairs, and falls) for screening for sarcopenia [19]. The Asian Working Group for Sarcopenia (AWGS) 2019 update suggests using either SARC-F, SARC-CalF (SARC-F combined with calf circumference), or calf circumference (CC) for screening sarcopenia [20]. Moreover, Rossi et al. developed the Mini Sarcopenia Risk Assessment (MSRA) in two versions: the full version, MSRA-7, which consists of 7 items, and the short version, MSRA-5, which consists of 5 items [21]. Additionally, a formula called the Ishii score was developed using age, handgrip strength (HGS), and CC as its basis [22]. A recent scoping review also revealed that the five screening tools mentioned above were frequently used as questionnaires in sarcopenia assessment [23]. Meanwhile, different screening tools are designed with specific domains, items, measurements, and cutoffs, which can make it difficult to choose the best tool for different clinical situations. Some tools may be more suitable for certain clinical settings or specific diseases, while others may have a more general application. Understanding the strengths and limitations of different screening tools is crucial for accurately identifying sarcopenia. Currently, there is limited research comparing the accuracy of five different screening tools for sarcopenia in preoperative elderly patients with CRC.

Thus, our study aimed to compare the diagnostic accuracy of SARC-F, SARC-CalF, MSRA-5, MSRA-7, and Ishii score for screening sarcopenia in preoperative elderly patients with CRC.

## Materials and methods

### Study population

The department of Gastrointestinal Surgery at People's Hospital of Wuxi city affiliated to Nanjing Medical University conducted a diagnostic accuracy study from April 2021 to September 2023. This cross-sectional study included elderly patients (≥65 years) consecutively, who had been diagnosed with gastric cancer through endoscopy or pathology. The inclusion criteria were patients who were planning to undergo their first confined operation for colorectal cancer and had signed informed consent to participate in the study. Patients with the following conditions were excluded from the study: (1) physical disability, (2) severe cardiac dysfunction or heart failure, (3) clinically visible edema, (4) severe mental illness, (5) multiple malignant tumors, and (6) received preoperative neoadjuvant therapy including radiotherapy and chemotherapy. The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Ethics and Research Committee of Wuxi People's Hospital Affiliated to Nanjing Medical, and all participants signed a written informed consent.

### Data collection

Trained nurses conducted face-to-face interviews with each patient enrolled in the study to collect participant information. This included patients' characteristics (such as sex and age), anthropometric indicators (body mass index, height, calf circumference), tumor characteristics (TNM stage, tumor location, tumor size), diagnostic indicators of sarcopenia [such as appendicular skeletal muscle mass (ASM), handgrip strength, 4-m gait speed], and a summary of the items from five sarcopenia screening tools. All data was collected within 24 h before surgery. ASM was measured using bioelectrical impedance analysis (InBody 4.0, InBody Co., South Korea), handgrip strength was assessed using a handgrip dynamometer (model EH101, manufactured by Xiangshan in Guangdong Province, China). The average grip strength was calculated by averaging the results of three trials conducted with the participant's dominant hand, as presented in the analysis, and 4-m speed was measured with a stopwatch (AP-7200, Guangzhou, Guangdong Province, China).

Trained nurses conducted anthropometric measurements, gait speed (GS) test, and handgrip strength (HS) test. Calf circumference (CC) was measured with participants lying down, left knee raised, and calf at a right angle to the thigh, using a millimeter graded tape. Body height and weight were measured using a stadiometer and a digital floor scale. Body mass index (BMI) was calculated by dividing body weight (in kg) by height (in cm) squared.

The skeletal muscle mass of each subject was calculated using the validated equation of Janssen et al., which is calculated as [24]: skeletal muscle mass (kg) = [(height$^2$/BIA resistance * 0.401) + (gender*3.825) + (age * −0.071)] + 5.102. In this equation, height is in centimeters, BIA resistance is in ohms, gender is coded as 1 for male and 0 for female, and age is in years. The appendicular skeletal mass is the sum of lean muscle mass in the upper and lower limbs. The appendicular skeletal mass index (ASMI) was then calculated by dividing the ASM by the square of the body height (kg/m$^2$).

### Screening tools for sarcopenia and diagnostic standard

The SARC-F questionnaire is a self-reported assessment that consists of five items related to strength, ambulation, rising from a chair, stair climbing, and falls [25]. Each item is scored from 0 to 2 points, with a total score ranging from 0 to 10. A score of 4 or higher indicates a predictive risk of sarcopenia.

SARC-CalF is a combination of SARC-F and CC [26], with cutoff values of 34 cm for men and 33 cm for women. The CC item is scored as 0 points if its value is above the cutoff values, and 10 points if its value is below or equals to the cutoff values. Additionally, the scores of the other items are consistent with SARC-F. A total score of ≥ 11 out of a maximum of 20 indicates sarcopenia risk.

The MSRA questionnaire is a self-reported tool that measures objective and measurable parameters related to the risk of developing sarcopenia. There are two versions of the questionnaire: a short version (MSRA-5) and a full version (MSRA-7) [21, 27]. The MSRA-5 includes five items such as age, physical activity level, hospitalizations, weight loss, and the number of meals per day. Each item is scored on a scale of 0 to 5, 0 to 10, or 0 to 15, with the total score ranging from 0 to 60. A score of ≤ 45 indicates a risk of sarcopenia. The MSRA-7 includes seven items and includes additional assessments of dairy product and protein consumption. Each item is scored on a scale of 0 to 5 or 0 to 10, with a total score of ≤ 30 out of a maximum of 40 indicating a risk of sarcopenia.

The Ishii score chart is a model to estimate the probability of sarcopenia for both sexes, including three variables: Age, grip strength, and CC [28]. The exact formula to calculate the scores is as follows: Score in men: 0.62 × (age − 64) − 3.09 × (handgrip strength − 50) − 4.64 × (CC − 42); and score in women: 0.80 × (age − 64) - 5.09 × (handgrip strength − 34) − 3.28 × (CC − 42). A score ≥ 105 for man and 120 for woman is defined to be at the risk of sarcopenia.

Since our participants were elderly patients, we relied on the EWGSOP2 and AWGS2019 criteria as the definitive standard for diagnosing sarcopenia. The initial diagnosis of sarcopenia involves assessing gait speed and grip strength. If either of these is found to be diminished, further confirmation through muscle mass measurement is necessary. The specific guidelines for defining sarcopenia according to the EWGSOP2 and AWGS 2019 criteria are present in Table 1.

### Sample size Estimation and statistical analyses

We use the equation below to calculate the sample size [29]: $n = \frac{Z_{\alpha/2} \pm P_0(1-P_0)}{d^2}$. where $P_0$ represents the prevalence of sarcopenia in patients with CRC, which we set as 37% [9], $a$ represents the accepted small probability of a false-positive result, which is 0.05 in this study, and $d$

**Table 1** The diagnostic criteria for sarcopenia

| | ①Low skeletal muscle mass | ②Low handgrip strength (kg) | ③Low gait speed (m/s) | Diagnostic criteria |
|---|---|---|---|---|
| EWGSOP2 | ASMI < 7.0 kg/m$^2$ for males;<br>ASMI < 5.5 kg/m$^2$ for females, tested by BIA | < 27 for males;<br>< 16 for females | ≤ 0.8 for both sex | ①+② or ①+②+③ |
| AWGS2019 | ASMI < 7.0 kg/m$^2$ for males;<br>ASMI < 5.7 kg/m$^2$ for females, tested by BIA | < 28 for males;<br>< 18 for females | < 1.0 for both sex | ①+② or ①+③ |

EWGSOP2: the updated version of European Working Group on Sarcopenia in Older People; AWGS2019: the updated version of the Asian Working Group for Sarcopenia; ASMI: Appendicular skeletal muscle mass index; BIA: Bioelectrical impedance analysis

represents the admissible error of 0.1.Thus, the sample size was calculated to be 90, and the final sample size was estimated to be 108 by considering a 20% rate of no-response and lost visit cases, and 482 elderly patients with CRC were finally enrolled in our study.

For categorical variables, the data were presented as numbers (percentages) and differences between groups were compared using chi-squared test. For continuous variables with normal distribution, the data were presented as the mean (standard deviation), and the differences between groups were compared using one-way ANOVA test. The normality of continuous data was examined by the Kolmogorov–Smirnov test. Continuous variables with skewed distribution were presented as the median (interquartile range), and the differences between groups were compared with the Mann-Whitney *U* test. Using the EWGSOP2 and AWGS2019 criterions as the gold standard, we evaluated the sensitivity, specificity, positive likelihood ratio (PLR), and negative likelihood ratio (NLR) of the SARC-F, SARC-CalF, MSRA-5, MSRA-7 and Ishii score chart to identify sarcopenia. We also used the receiver operating characteristic (ROC) curve to compare the overall diagnostic accuracy of the SARC-F, SARC-CalF, MSRA-5, MSRA-7 and Ishii score chart. We calculated the area under the ROC curve (AUC) and 95% CI. The difference across ROC curves was compared using the DeLong method. All statistical analyses were performed using SPSS software, version 25.0 (IBM SPSS, Chicago, IL, USA) and MedCalc software, version 19.0.4 (MedCalc Software bvba, Ostend, Belgium). Two-sided levels of significance were calculated, $P < 0.05$ indicates statistical significance.

## Results

### Baseline demographic and clinical characteristics

We recruited a total of 518 participants for our study during the study period. However, 36 patients were excluded from the study for various reasons, including 18 due to pacemaker implantation and 7 due to moderate to severe edema. Additionally, 11 patients were excluded due to physical disability. Ultimately, 482 elderly patients with colorectal cancer, consisting of 324 males and 158 females, were enrolled in the study, with an average age of 71.86 ± 5.60 years.

Table 2 presents the basic characteristics and calculated proportions of participants with sarcopenia. Using EWGSOP2 diagnostic criteria, 19.5% ($n = 94$) of participants were identified as having the risk of sarcopenia, while 21.5% ($n = 104$) were identified using AWGS2019 criteria. Additionally, the use of SARC-F, SARC-CalF, MSRA-5, MSRA-7, and Ishii score chart identified 23.0%, 40.5%, 68.0%, 44.6%, and 32.8% of all participants as having sarcopenia. Figure 1 illustrates the percentages of patients identified with sarcopenia using both screening tools and the diagnostic criteria of EWGSOP2 and AWGS2019. Specifically, the percentages are as follows: SARC-F identified 39.0% of patients with EWGSOP2 and 40.0% with AWGS2019; SARC-CalF identified 41.0% with EWGSOP2 and 45.0% with AWGS2019; MSRA-5 identified 25.0% with EWGSOP2 and 27.0% with AWGS2019; MSRA-7 identified 29.0% with EWGSOP2 and 33.0% with AWGS2019; and the Ishii score chart identified 44.0% with EWGSOP2 and 48.0% with AWGS2019. Elderly patients diagnosed with sarcopenia, based on both EWGSOP2 and AWGS2019 criteria, exhibit characteristics such as advanced age, reduced BMI, ASMI, calf circumference, gait speed, and handgrip strength. Additionally, these patients are more likely to have rectal cancer and stage III colorectal cancer (CRC) than those without sarcopenia ($P$<0.05).

### Comparison of five sarcopenia screening tools among all elderly patients with CRC

As shown in Table 3, the sensitivity, specificity, and AUCs of five sarcopenia screening tools (SARC-F, SARC-CalF, MSRA-5, MSRA-7, and Ishii score chart) were analyzed using the EWGSOP2 and AWGS2019 criteria as diagnostic criteria. When using the EWGSOP2 criteria, the SARC-F had a sensitivity of 56.38% and a specificity of 85.05%, the SARC-CalF had a sensitivity of 85.11% and a specificity of 70.36%, the MSRA-5 had a sensitivity of 88.30% and a specificity of 36.86%, the MSRA-7 had a sensitivity of 65.96% and a specificity of 60.57%, and the Ishii score chart had a sensitivity of 74.47% and a specificity of 77.32%. The AUCs of the screening tools were 0.79, 0.89, 0.71, 0.68, and 0.88 for SARC-F, SARC-CalF, MSRA-5, MSRA-7, and Ishii score chart, respectively. Figure 2 displays the ROC curves of all five screening tools.

The sensitivity and specificity of various sarcopenia screening tools were evaluated using the AWGS2019 as the reference standard. The SARC-F had a sensitivity of 51.92% and a specificity of 84.92%, the SARC-CalF had

**Table 2** Characteristics of the study population according to the EWGSOP2/AWGS2019 sarcopenia definition

| Characteristics | Total (*n* = 482) | EWGSOP2 | | *P*-value | AWGS2019 | | *P*-value |
|---|---|---|---|---|---|---|---|
| | | Sarcopenia (*n* = 94) | Non-sarcopenia (*n* = 388) | | Sarcopenia (*n* = 104) | Non-sarcopenia (*n* = 378) | |
| Sex, n (%) | | | | 0.117 | | | 0.353 |
| Male | 313 (64.9) | 68 (72.3) | 245 (63.1) | | 72 (69.2) | 241 (63.8) | |
| Female | 169 (35.1) | 26 (27.7) | 143 (36.9) | | 32 (30.8) | 137 (36.2) | |
| Age (years), mean ± SD | 71.04 ± 6.47 | 74.73 ± 7.64 | 70.15 ± 5.82 | <0.001 | 74.57 ± 7.49 | 70.07 ± 5.80 | <0.001 |
| BMI (kg/m$^2$), mean ± SD | 22.41 ± 3.10 | 21.15 ± 2.77 | 22.71 ± 3.10 | <0.001 | 21.25 ± 2.72 | 22.73 ± 3.12 | <0.001 |
| CC (cm), mean ± SD | 33.53 ± 3.47 | 31.44 ± 2.59 | 34.03 ± 3.47 | <0.001 | 31.72 ± 2.82 | 34.02 ± 3.48 | <0.001 |
| HS (kg), mean ± SD | 30.19 ± 4.76 | 24.12 ± 3.07 | 31.66 ± 3.85 | <0.001 | 23.91 ± 3.36 | 31.91 ± 3.47 | <0.001 |
| GS (m/s), median (IQR) | 1.10 (0.20) | 0.70 (0.03) | 1.30 (0.40) | <0.001 | 0.80 (0.10) | 1.40 (0.20) | <0.001 |
| ASMI (kg/m$^2$), median (IQR) | 5.70 (1.30) | 5.40 (0.90) | 5.80 (1.30) | <0.001 | 5.40 (0.80) | 5.80 (1.50) | <0.001 |
| Hypertension, n (%) | 71 (14.7) | 16 (17.0) | 55 (14.2) | 0.517 | 18 (17.3) | 53 (14.0) | 0.435 |
| Diabetes, n (%) | 55 (11.4) | 14 (14.9) | 41 (10.6) | 0.277 | 15 (14.4) | 40 (10.6) | 0.296 |
| Tumor location, n (%) | | | | 0.035 | | | 0.024 |
| Rectum | 198 (41.1) | 48 (51.1) | 150 (38.7) | | 53 (51.0) | 145 (38.4) | |
| Colon | 284 (58.9) | 46 (48.9) | 238 (61.3) | | 51 (49.0) | 233 (61.6) | |
| Tumor size ≥ 5 cm, n (%) | 167 (34.6) | 36 (38.3) | 131 (33.8) | 0.401 | 39 (37.5) | 128 (33.9) | 0.488 |
| TNM stage, n (%) | | | | <0.001 | | | <0.001 |
| I–II | 343 (71.2) | 51 (54.3) | 292 (75.3) | | 55 (52.9) | 288 (76.2) | |
| III | 139 (28.8) | 43 (45.7) | 96 (24.7) | | 49 (47.1) | 90 (23.8) | |
| SARC-F classification, n (%) | | | | <0.001 | | | <0.001 |
| Non-sarcopenia | 371 (77.0) | 41 (43.6) | 330 (85.1) | | 50 (48.1) | 321 (84.9) | |
| Sarcopenia | 111 (23.0) | 53 (56.4) | 58 (14.9) | | 54 (51.9) | 57 (15.1) | |
| SARC-CalF classification, n (%) | | | | <0.001 | | | <0.001 |
| Non-sarcopenia | 287 (59.5) | 14 (14.9) | 273 (70.3) | | 16 (15.4) | 271 (71.7) | |
| Sarcopenia | 195 (40.5) | 80 (85.1) | 115 (29.6) | | 88 (84.6) | 107 (28.3) | |
| MSRA-5 classification, n (%) | | | | <0.001 | | | <0.001 |
| Non-sarcopenia | 154 (32.0) | 11 (11.7) | 143 (36.9) | | 14 (13.5) | 140 (37.0) | |
| Sarcopenia | 328 (68.0) | 83 (88.3) | 245 (63.1) | | 90 (86.5) | 238 (63.0) | |
| MSRA-7 classification, n (%) | | | | <0.001 | | | <0.001 |
| Non-sarcopenia | 267 (55.4) | 32 (34.0) | 235 (60.6) | | 34 (32.7) | 233 (61.6) | |
| Sarcopenia | 215 (44.6) | 62 (66.0) | 153 (39.4) | | 70 (67.3) | 145 (38.4) | |
| Ishii score chart classification, n (%) | | | | <0.001 | | | <0.001 |
| Non-sarcopenia | 324 (67.2) | 24 (25.5) | 300 (77.3) | | 28 (26.9) | 296 (78.3) | |
| Sarcopenia | 158 (32.8) | 70 (74.5) | 88 (22.7) | | 76 (73.1) | 82 (21.7) | |

Notes Continuous variables were presented as mean ± standard deviation or median (interquartile range). Categorical variables were presented as frequency (percentage). Comparison of the differences between the two groups were examined by Student's t-test, Mann–Whitney U-test or chi-square test, respectively

Abbreviations BMI, body mass index; CC, calf circumference; HS, handgrip strength; GS, gait speed; ASMI, appendicular skeletal muscle index

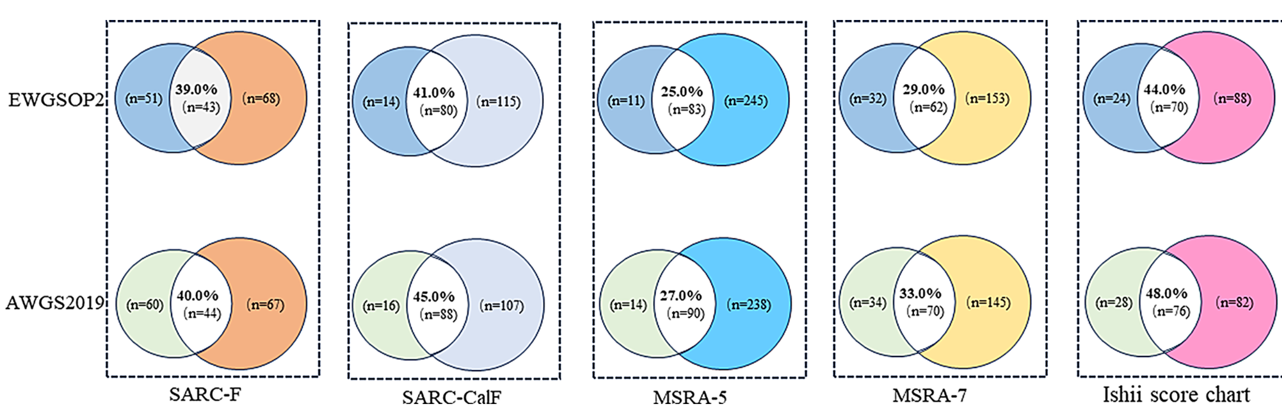


**Fig. 1** The proportion of sarcopenia risk defined by screening tools in patients with sarcopenia of different diagnostic criteria by Venn Diagram

**Table 3** Sensitivity/specificity analyses and receiver operating curve models for five sarcopenia screening tools against the EWGSOP2/AWGS2019 criteria

| Screening tools | Sensitivity, % | Specificity, % | PLR | NLR | AUC |
|---|---|---|---|---|---|
| **EWGSOP2** | | | | | |
| SARC-F | 56.38(45.76–66.59) | 85.05(81.11–88.45) | 3.77(2.80–5.07) | 0.51(0.41–0.65) | 0.79(0.75–0.84) [bc] |
| -CalF | 85.11(76.28–91.61) | 70.36(65.55–74.86) | 2.87(2.41–3.42) | 0.21(0.13–0.35) | 0.89(0.85–0.92) [abc] |
| MSRA-5 | 88.30(80.03–94.01) | 36.86(32.04–41.87) | 1.40(1.26–1.55) | 0.32(0.18–0.56) | 0.71(0.66–0.76) |
| MSRA-7 | 65.96(55.46–75.42) | 60.57(55.51–65.46) | 1.67(1.38–2.02) | 0.56(0.42–0.75) | 0.68(0.61–0.74) |
| Ishii score chart | 74.47(64.43–82.91) | 77.32(72.82–81.39) | 3.28(2.64–4.09) | 0.33(0.23–0.47) | 0.88(0.85–0.92) [abc] |
| **AWGS2019** | | | | | |
| SARC-F | 51.92(41.91–61.83) | 84.92(80.91–88.38) | 3.44(2.55–4.66) | 0.57(0.46–0.69) | 0.80(0.75–0.84) [bc] |
| SARC-CalF | 84.62(76.22–90.94) | 71.69(66.86–76.18) | 2.99(2.50–3.58) | 0.22(0.14–0.34) | 0.90(0.84–0.92) [abc] |
| MSRA-5 | 86.54(78.45–92.44) | 37.04(32.16–42.12) | 1.37(1.23–1.53) | 0.36(0.22–0.60) | 0.71(0.66–0.77) |
| MSRA-7 | 67.31(57.41–76.19) | 61.64(56.53–66.57) | 1.76(1.46–2.11) | 0.53(0.40–0.71) | 0.69(0.63–0.75) |
| Ishii score chart | 73.08(63.49–81.31) | 78.31(73.81–82.36) | 3.37(2.69–4.22) | 0.34(0.250–0.47) | 0.88(0.84–0.91) [abc] |

Data are presented with the 95% confidence interval in parenthesis

PLR, positive likelihood ratio; NLR, negative likelihood ratio

a Significantly different with SARC-F ($p < 0.05$)

b Significantly different with MSRA-5 ($p < 0.05$)

c Significantly different with MSRA-7 ($p < 0.05$)

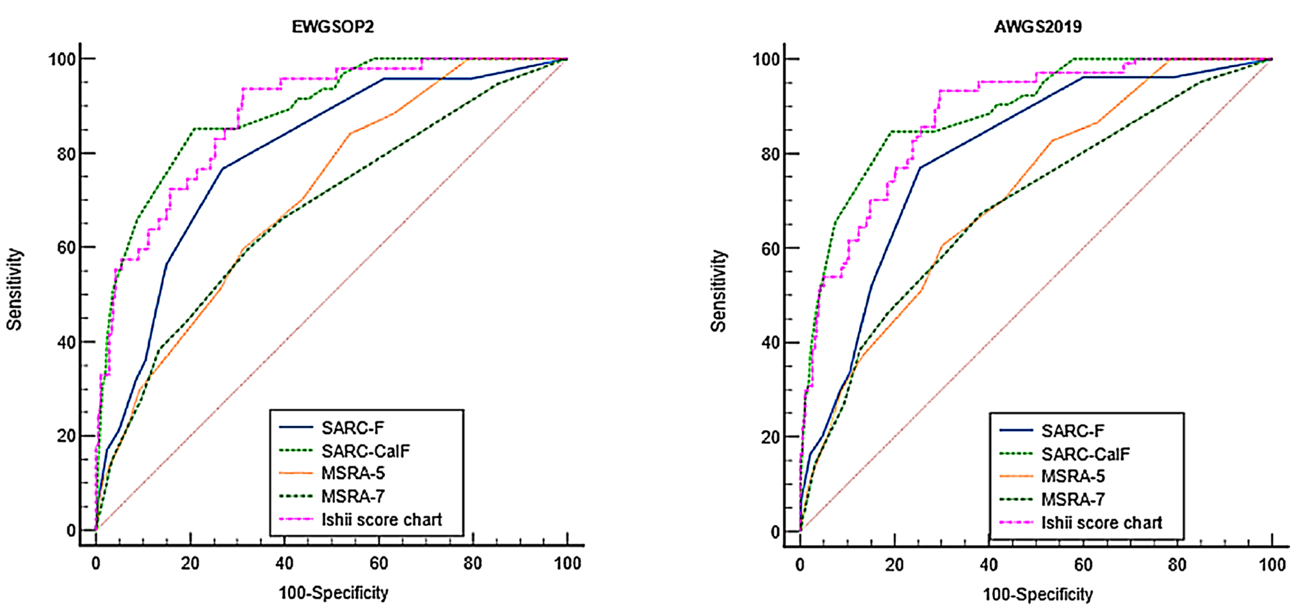


**Fig. 2** The ROC curves of sarcopenia screening tools against different reference standards

a sensitivity of 84.62% and a specificity of 71.69%, the MSRA-5 had a sensitivity of 86.54% and a specificity of 37.04%, the MSRA-7 had a sensitivity of 67.31% and a specificity of 61.64%, and the Ishii score chart had a sensitivity of 73.08% and a specificity of 78.31%. The AUCs of SARC-F, SARC-CalF, MSRA-5, MSRA-7, and Ishii score chart were 0.80, 0.90, 0.71, 0.69, and 0.88, respectively. Both SARC-CalF and Ishii score chart had significantly larger AUCs compared to other screening tools ($P < 0.001$).

### Comparison of five sarcopenia screening tools among all elderly patients with CRC by gender

Figure 3 displays the AUCs (95%CI) of the SARC-F, SARC-CalF, MSRA-5, MSRA-7, and Ishii score chart, stratified by gender using the EWGSOP2 and AWGS2019 criteria as the reference standard. Among males, when using the EWGSOP2 criteria, the AUCs of SARC-CalF and Ishii score chart were 0.89 (95% CI, 0.85–0.92) and 0.86 (95% CI, 0.81–0.89) respectively. When using the AWGSOP2019 criteria, the AUCs of SARC-CalF and Ishii score chart were 0.87 (95% CI, 0.83–0.91) and 0.86 (95% CI, 0.82–0.89) respectively. Both Ishii score chart and SARC-CalF demonstrated better predictive value

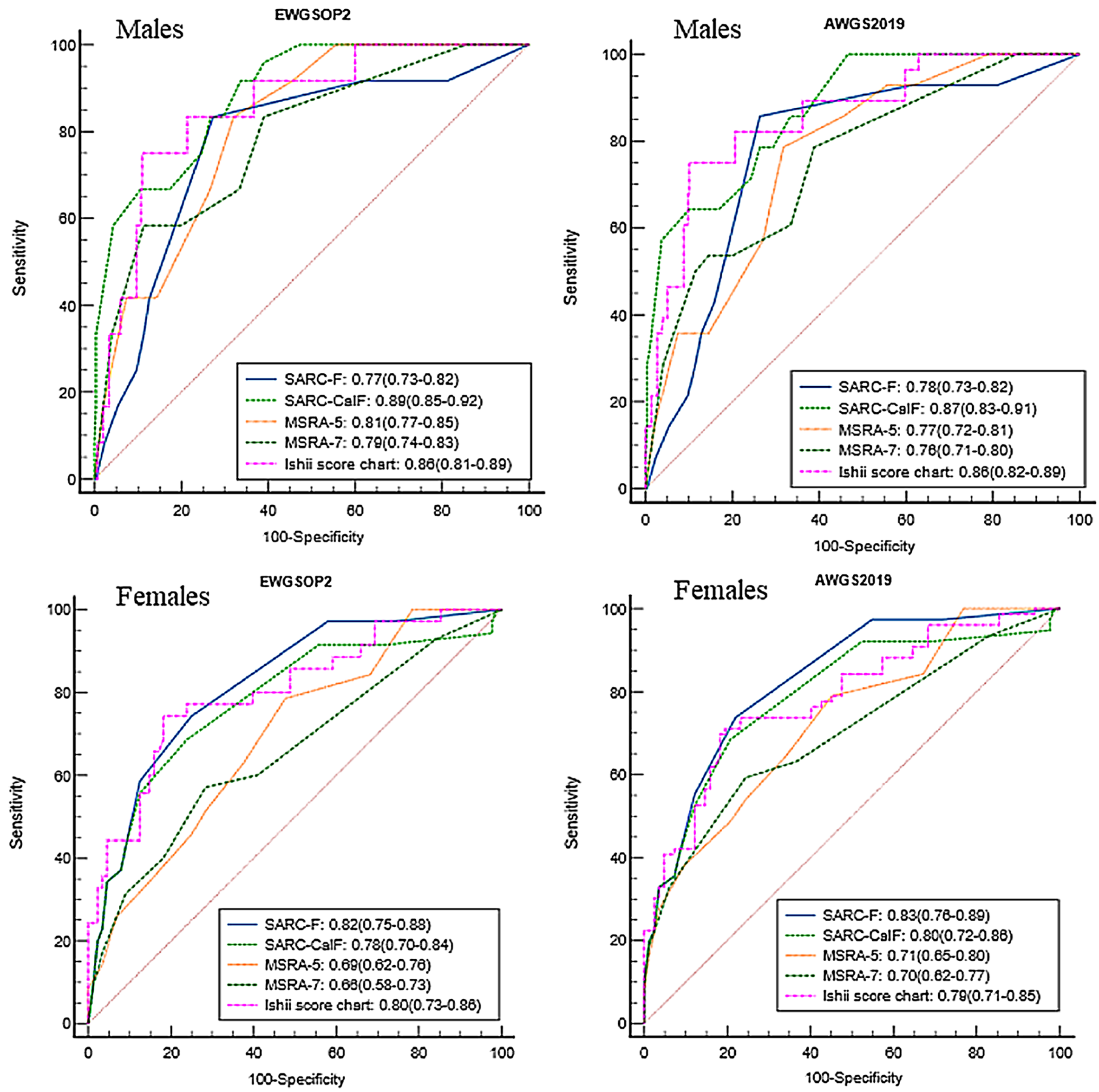


**Fig. 3** The ROC curves of sarcopenia screening tools against different reference standards stratified by gender (AUC: 95%CI)

than other screening tools ($P$<0.05). In females, regardless of the reference criteria used, there were no significant differences in AUCs among SARC-F, SARC-CalF, and Ishii score chart ($P$<0.05). Additionally, the AUCs of SARC-F, SARC-CalF, and Ishii score chart were significantly larger than MSRA-5 and MSRA-7 ($P$<0.05).

## Discussion

In our study, we compared the effectiveness of five different screening tools for sarcopenia in older patients with colorectal cancer (CRC) who were about to undergo surgery. These tools included SARC-F, SARC-CalF, MSRA-5, MSRA-7, and the Ishii score chart, all of which are commonly used for sarcopenia screening. This study is the first of its kind to assess the performance of these tools specifically in patients with CRC. Our results showed that regardless of the criteria used, the screening tools had an area under the curve (AUC) ranging from 0.69 to 0.90. Both SARC-CalF and the Ishii score chart demonstrated the best screening accuracy, with high sensitivity and moderate-to-high specificity for SARC-CalF, and moderate sensitivity/specificity for the Ishii score chart. This suggests that SARC-CalF and the Ishii score chart are more effective in diagnosing sarcopenia in preoperative elderly patients with CRC compared to the other three tools.

In our research, we found that the prevalence of sarcopenia in elderly patients before surgery was 19.5% according to the EWGSOP2 criteria and 21.5% according to the AWGS2019 criteria. The prevalence of sarcopenia risk varied from 23.0 to 68.0%, possibly due to differences in the measurement contents and methods of the five screening scores. We also observed significant differences in the accuracy and sensitivity/specificity of the various sarcopenia screening tools. This inaccurate identification of sarcopenia risk could impact the proposed interventions and public health policies [30]. Therefore, it is important to identify a suitable screening tool for evaluating sarcopenia risk in preoperative elderly patients with CRC.

This study utilized different screening tools to address the need for consensus on the most effective methods for screening and identifying sarcopenia. SARC-F is a scoring system that assesses symptoms to identify those with sarcopenia who may be at risk for negative functional outcomes. This tool has been confirmed for its reliability and validity across different groups, particularly among older adults living in the community, demonstrating robust internal consistency, as well as factorial, criterion-related, and construct validity [31]. Similar to other studies, the specificity of the SARC-F tool was found to be higher than its sensitivity, indicating a greater number of false positive results compared to false negative results [32–34]. This means that many individuals with sarcopenia may not be detected when assessed using these questionnaires. Specifically, our study found that 39.0% and 40.0% of individuals at risk for sarcopenia, as identified by SARC-F, were also identified by EWGSOP2 and AWGS2019, respectively. To address the low sensitivity of SARC-F, Barbosa-Silva et al. proposed a modified version called SARC-CalF, which significantly improved the sensitivity of SARC-F from low to moderate. The SARC-CalF includes an anthropometric marker (CalF circumference) in addition to the muscle functionality markers present in the original SARC-F [32, 35]. This modification resulted in a test sensitivity of 66.7%, a specificity of 82.9%, and an observed AUC of 0.736 when using the EWGSOP criteria as the reference standard [36]. Previous study comparing SARC-F with SARC-CalF in advanced cancer patients found that SARC-CalF significantly increases the sensitivity and overall diagnostic accuracy of SARC-F for screening sarcopenia. This indicates that SARC-CalF has a stronger ability to correctly identify patients with sarcopenia, which is a crucial aspect of validity [37]. Another study evaluated SARC-CalF in patients with chronic musculoskeletal pain and found that SARC-CalF scores significantly correlated with grip power, gait speed, skeletal mass index, numeric rating scale score, and pain disability assessment scale score, indicating good concurrent validity and reliability [38]. The CalF circumference is often measured as the most sensitive anthropometric index of muscle mass in older populations [39, 40]. A study by Krzyminska-Siemaszko et al. found that SARC-CalF was an effective screening tool for sarcopenia in older adults, with a sensitivity of 64.7%, specificity of 89.2%, and AUC of 0.792 [41]. However, our study, which used different diagnostic criteria, showed that SARC-CalF had higher sensitivity (84.62-85.11%) and screening accuracy (AUC: 0.89–0.90) but lower specificity (70.36-71.69%) in detecting sarcopenia in preoperative patients with CRC. This suggests that the SARC-CalF can improve the sensitivity of SARC-F but with reduced specificity [26]. The differences in the characteristics of the study populations may account for the discrepancies between our study and previous research.

Additionally, the Ishii score chart identified 44.0% and 48.0% of subjects at risk for sarcopenia, according to the EWGSOP2 and AWGS2019 criteria, respectively. This screening tool was developed by Ishii and colleagues based on the EWGSOP consensus, using age, calf circumference, and grip strength as objective measures to calculate the likelihood and severity of sarcopenia [28]. The Ishii score chart has demonstrated significant prognostic relevance for individuals facing curative surgery due to obstructive colorectal cancer. Its efficacy in identifying sarcopenia among the elderly in Chengdu's community has been confirmed, boasting an AUC of 0.84 for women and 0.81 for men, which signifies its strong predictive power. The chart's reliability is further underscored by its elevated sensitivity and specificity rates in forecasting sarcopenia [22]. This study also indicated that these rates were 75.5% and 92.0% for women, and 64.94% and 85.46% for men, respectively, when using the initial threshold values. These elevated figures suggest that the Ishii score chart is a dependable instrument for sarcopenia detection. Additionally, the study highlighted the chart's high negative predictive value, essential for excluding sarcopenia in patients prior to colorectal cancer surgery, with negative predictive values reaching 92% for men and 90% for women. This indicates that the Ishii score chart is also reliable in confirming the absence of sarcopenia in these patients. Hax et al. found that the Ishii test had a ROC curve of 0.86 for sarcopenia in patients with systemic sclerosis, with a sensitivity of 86.7% and a specificity of 73.4% [42]. Another study showed that the AUC of the Ishii test for severe sarcopenia in nursing homes was 0.89, with a sensitivity of 89.6% and a specificity of 83.3% [43]. The results of our study indicated that the Ishii test has a moderate-to-high sensitivity and specificity in screening for sarcopenia in preoperative elderly patients with CRC. However, factors such as the type of illness or race may affect its diagnostic ability. Previous studies have shown that the Ishii score can be time-consuming and involve complex calculations in clinical settings. However, with the use of software, the screening for sarcopenia can be easily performed by clinical nurses by entering measurable parameters, making it a simple process in clinical practice.

Our study confirmed that MSRA-5 had high sensitivity but low specificity, while MSRA-7 showed low-to-moderate sensitivity and specificity for overall participants. A previous study recommended MSRA-5 as the primary screening tool for sarcopenia due to its high sensitivity in nursing homes [21, 27]. Recent studies have compared MSRA-5 and SARC-F and found that while they have similar diagnostic accuracy, MSRA-5 has higher sensitivity and lower specificity than SARC-F [20, 41, 44]. A study also found that when MSRA-5 is used to identify sarcopenia in hospitalized individuals, the specificity is significantly lower (16.3%), although sensitivity remains high (90.9%) [45]. Research validating the Thai adaptation of these questionnaires against the AWGS 2019 criteria revealed that both MSRA-5 and MSRA-7 exhibited satisfactory levels of sensitivity and specificity. Specifically, the MSRA-5 and MSRA-7 demonstrated sensitivities of 61.5% and 72.3%, respectively, alongside specificities of 67.4% and 43%, respectively [46]. Furthermore, a separate study assessing the Spanish version of the MSRA in elderly populations determined that both questionnaires possessed elevated sensitivity and satisfactory specificity, with the MSRA-5 outperforming the MSRA-7 in terms of specificity [47]. The AUCs of MSRA-5 and MSRA-7 were significantly lower than three other screening tools, indicating that they may not be suitable for use among preoperative elderly patients with CRC.

Our study has some limitations that should be noted. Firstly, we used BIA instead of the "gold standard" devices (CT, DXA, or MRI) to estimate muscle mass. However, BIA has been shown to be comparable to DXA and is recommended as an alternative option for measuring muscle mass by the EWGSOP and AWGS [48]. Additionally, BIA is practical and cost-effective for community-dwelling older adults. Secondly, our study was cross-sectional and involved a small number of participants from a single center. To validate the diagnostic accuracy of sarcopenia screening tools in preoperative elderly patients with CRC, a multi-center prospective study should be conducted. Lastly, a cohort study should be carried out to compare sarcopenia screening tools in predicting adverse postoperative outcomes, such as postoperative complications, length of stay, 3-month hospital readmission, or short-term mortality.

## Conclusion

The diagnostic precision of the SARC-CalF and Ishii score chart outperforms the SARC-F, MSRA-5, and MSRA-7, making them the superior options among the five screening tools evaluated. This suggests that both SARC-CalF and Ishii score chart are suitable for sarcopenia screening among preoperative elderly patients with CRC. Further studies are necessary to compare the ability and applicability of these screening methods in different settings.

### Abbreviations

| | |
|---|---|
| CRC | Colorectal Cancer |
| EWGSOP2 | The Updated Version of European Working Group on Sarcopenia in Older People |
| AWGS2019 | The Updated Version of the Asian Working Group for Sarcopenia |
| SARC-F | Strength, Assistance with walking, Rise from chair, Climb stairs, Falls |
| SARC-CalF | SARC-F and Calf Circumference |
| MSRA | Mini Sarcopenia Risk Assessment |
| AUC | Area Under the Curve |
| ROC | Receiver Operating Characteristic |
| PLR | Positive Likelihood Ratio |
| NLR | Negative Likelihood Ratio |

### Acknowledgements

The authors would like to thank all participants in this study.

### Author contributions

LL and MX were responsible for analyzing the data and writing the manuscript, while LL, RW, and XD conducted the research. XW and XY designed the research, and XW critically revised the manuscript for important content. All authors read and approved the final version for publication, and agreed to be personally accountable for their contributions and to ensure the accuracy and integrity of the work.

### Funding

This work was supported by the Top Talent Support Program for young and middle-aged people of Wuxi Health Committee (HB2023020).

### Data availability

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

## Declarations

### Ethics approval and consent to participate

The study was approved by the the Ethics and Research Committee of Wuxi People's Hospital Affiliated to Nanjing Medical (No. KY23080). A signed informed consent form was obtained in writing from all subjects and/or their legal guardian(s).

### Consent for publication

Not applicable.

### Competing interests

The authors declare no competing interests.

### Author details

[1]Department of Thyroid, Breast, and Gastrointestinal Surgery, Wuxi People's Hospital, Wuxi Medical Center, Nanjing Medical University, The Affiliated Wuxi People's Hospital of Nanjing Medical University, Wuxi 214023, China
[2]Department of Hepatobiliary Surgery, Wuxi People's Hospital, Wuxi Medical Center, Nanjing Medical University,, The Affiliated Wuxi People's Hospital of Nanjing Medical University, Wuxi 214023, China
[3]Department of Geriatric Medicine, Wuxi People's Hospital, Wuxi Medical Center, Nanjing Medical University, The Affiliated Wuxi People's Hospital of Nanjing Medical University, Wuxi 214023, China

Received: 29 January 2024 / Accepted: 19 February 2025
Published online: 28 March 2025

**References**


1. Rawla P, Sunkara T, Barsouk A. Epidemiology of colorectal cancer: incidence, mortality, survival, and risk factors. Prz Gastroenterol. 2019;14(2):89–103.
2. Sun G, Li Y, Peng Y, Lu D, Zhang F, Cui X, Zhang Q, Li Z. Can sarcopenia be a predictor of prognosis for patients with non-metastatic colorectal cancer? A systematic review and meta-analysis. INT J COLORECTAL DIS. 2018;33(10):1419–27.
3. Zhang Y, Zhu Y. Development and validation of risk prediction model for sarcopenia in patients with colorectal cancer. FRONT ONCOL. 2023;13:1172096.
4. Takenami T, Tsujinaka S, Miyakura Y, Kakizawa N, Maemoto R, Machida E, Hatsuzawa Y, Takahashi R, Kimura Y, Tamaki S, et al. Impact of sarcopenia on surgical and oncologic outcomes of laparoscopic surgery for colorectal cancer. ASIAN J SURG. 2022;45(12):2686–90.
5. Gao S, Li Y. Sarcopenia and interleukin-23 in colorectal cancer survival. CLIN NUTR. 2022;41(1):9–10.
6. Seto Y. Sarcopenia, muscle quality, and gastric cancer surgery. Ann Gastroenterol Surg. 2021;5(4):402–3.
7. Cruz-Jentoft AJ, Bahat G, Bauer J, Boirie Y, Bruyere O, Cederholm T, Cooper C, Landi F, Rolland Y, Sayer AA, et al. Sarcopenia: revised European consensus on definition and diagnosis. AGE AGEING. 2019;48(4):601.
8. Simonsen C, de Heer P, Bjerre ED, Suetta C, Hojman P, Pedersen BK, Svendsen LB, Christensen JF. Sarcopenia and postoperative complication risk in Gastrointestinal surgical oncology: A Meta-analysis. ANN SURG. 2018;268(1):58–69.
9. Trejo-Avila M, Bozada-Gutierrez K, Valenzuela-Salazar C, Herrera-Esquivel J, Moreno-Portillo M. Sarcopenia predicts worse postoperative outcomes and decreased survival rates in patients with colorectal cancer: a systematic review and meta-analysis. INT J COLORECTAL DIS. 2021;36(6):1077–96.
10. Liu P, Hao Q, Hai S, Wang H, Cao L, Dong B. Sarcopenia as a predictor of all-cause mortality among community-dwelling older people: A systematic review and meta-analysis. MATURITAS. 2017;103:16–22.
11. Kim JH, Lim S, Choi SH, Kim KM, Yoon JW, Kim KW, Lim JY, Park KS, Jang HC. Sarcopenia: an independent predictor of mortality in community-dwelling older Korean men. J Gerontol Biol Sci Med Sci. 2014;69(10):1244–52.
12. Hua H, Xu X, Tang Y, Ren Z, Xu Q, Chen L. Effect of sarcopenia on clinical outcomes following digestive carcinoma surgery: a meta-analysis. SUPPORT CARE CANCER. 2019;27(7):2385–94.
13. Su H, Ruan J, Chen T, Lin E, Shi L. CT-assessed sarcopenia is a predictive factor for both long-term and short-term outcomes in Gastrointestinal oncology patients: a systematic review and meta-analysis. Cancer Imaging. 2019;19(1):82.
14. Lee CM, Kang J. Prognostic impact of myosteatosis in patients with colorectal cancer: a systematic review and meta-analysis. J Cachexia Sarcopenia Muscle. 2020;11(5):1270–82.
15. Chen LK, Woo J, Assantachai P, Auyeung TW, Chou MY, Iijima K, Jang HC, Kang L, Kim M, Kim S, et al. Asian working group for sarcopenia: 2019 consensus update on sarcopenia diagnosis and treatment. J AM MED DIR ASSOC. 2020;21(3):300–7.
16. Cruz-Jentoft AJ, Sayer AA. Sarcopenia LANCET. 2019;393(10191):2636–46.
17. Jones KI, Doleman B, Scott S, Lund JN, Williams JP. Simple Psoas cross-sectional area measurement is a quick and easy method to assess sarcopenia and predicts major surgical complications. COLORECTAL DIS. 2015;17(1):O20–6.
18. Barreto EF, Poyant JO, Coville HH, Dierkhising RA, Kennedy CC, Gajic O, Nystrom EM, Takahashi N, Moynagh MR, Kashani KB. Validation of the sarcopenia index to assess muscle mass in the critically ill: A novel application of kidney function markers. CLIN NUTR. 2019;38(3):1362–7.
19. Ackermans L, Rabou J, Basrai M, Schweinlin A, Bischoff SC, Cussenot O, Cancel-Tassin G, Renken RJ, Gomez E, Sanchez-Gonzalez P, et al. Screening, diagnosis and monitoring of sarcopenia: when to use which tool? Clin Nutr ESPEN. 2022;48:36–44.
20. Nishikawa H, Asai A, Fukunishi S, Takeuchi T, Goto M, Ogura T, Nakamura S, Kakimoto K, Miyazaki T, Nishiguchi S, et al. Screen Tools Sarcopenia VIVO. 2021;35(6):3001–9.
21. Rossi AP, Micciolo R, Rubele S, Fantin F, Caliari C, Zoico E, Mazzali G, Ferrari E, Volpato S, Zamboni M. Assessing the risk of sarcopenia in the elderly: the Mini sarcopenia risk assessment (MSRA) questionnaire. J NUTR HEALTH AGING. 2017;21(6):743–9.
22. Chen X, Hou L, Zhang Y, Luo S, Dong B. The accuracy of the Ishii score chart in predicting sarcopenia in the elderly community in Chengdu. BMC GERIATR. 2021;21(1):296.
23. Lian R, Jiang G, Liu Q, Shi Q, Luo S, Lu J, Yang M. Validated tools for screening sarcopenia: A scoping review. J AM MED DIR ASSOC. 2023;24(11):1645–54.
24. Janssen I, Heymsfield SB, Baumgartner RN, Ross R. Estimation of skeletal muscle mass by bioelectrical impedance analysis. J Appl Physiol (1985). 2000;89(2):465–71.
25. Malmstrom TK, Morley JE. SARC-F: a simple questionnaire to rapidly diagnose sarcopenia. J AM MED DIR ASSOC. 2013;14(8):531–2.
26. Barbosa-Silva TG, Menezes AM, Bielemann RM, Malmstrom TK, Gonzalez MC. Enhancing SARC-F: improving sarcopenia screening in the clinical practice. J AM MED DIR ASSOC. 2016;17(12):1136–41.
27. Bramato G, Barone R, Barulli MR, Zecca C, Tortelli R, Filardi M, Logroscino G. Sarcopenia screening in elderly with Alzheimer's disease: performances of the SARC-F-3 and MSRA-5 questionnaires. BMC GERIATR. 2022;22(1):761.
28. Ishii S, Tanaka T, Shibasaki K, Ouchi Y, Kikutani T, Higashiguchi T, Obuchi SP, Ishikawa-Takata K, Hirano H, Kawai H, et al. Development of a simple screening test for sarcopenia in older adults. GERIATR GERONTOL INT. 2014;14(Suppl 1):93–101.
29. Hajian-Tilaki K. Sample size Estimation in diagnostic test studies of biomedical informatics. J BIOMED Inf. 2014;48:193–204.
30. Reginster JY, Cooper C, Rizzoli R, Kanis JA, Appelboom G, Bautmans I, Bischoff-Ferrari HA, Boers M, Brandi ML, Bruyere O, et al. Recommendations for the conduct of clinical trials for drugs to treat or prevent sarcopenia. AGING CLIN EXP RES. 2016;28(1):47–58.
31. Malmstrom TK, Miller DK, Simonsick EM, Ferrucci L, Morley JE. SARC-F: a symptom score to predict persons with sarcopenia at risk for poor functional outcomes. J Cachexia Sarcopenia Muscle. 2016;7(1):28–36.
32. Bahat G, Yilmaz O, Kılıç C, Oren MM, Karan MA. Performance of SARC-F in regard to sarcopenia definitions, muscle mass and functional measures. J NUTR HEALTH AGING. 2018;22(8):898–903.
33. Krzymińska-Siemaszko R, Deskur-Śmielecka E, Kaluźniak-Szymanowska A, Lewandowicz M, Wieczorowska-Tobis K. Comparison of diagnostic performance of SARC-F and its two modified versions (SARC-CalF and SARC-F + EBM) in Community-Dwelling older adults from Poland. CLIN INTERV AGING. 2020;15:583–94.
34. Parra-Rodríguez L, Szlejf C, García-González AI, Malmstrom TK, Cruz-Arenas E, Rosas-Carrasco O. Cross-Cultural adaptation and validation of the Spanish-Language version of the SARC-F to assess sarcopenia in Mexican Community-Dwelling older adults. J AM MED DIR ASSOC. 2016;17(12):1142–6.
35. Yang M, Lu J, Jiang J, Zeng Y, Tang H. Comparison of four sarcopenia screening tools in nursing home residents. AGING CLIN EXP RES. 2019;31(10):1481–9.
36. Barbosa-Silva TG, Bielemann RM, Gonzalez MC, Menezes AM. Prevalence of sarcopenia among community-dwelling elderly of a medium-sized South American City: results of the COMO VAI? Study. J Cachexia Sarcopenia Muscle. 2016;7(2):136–43.
37. Fu X, Tian Z, Thapa S, Sun H, Wen S, Xiong H, Yu S. Comparing SARC-F with SARC-CalF for screening sarcopenia in advanced cancer patients. CLIN NUTR. 2020;39(11):3337–45.
38. Tsuji H, Tetsunaga T, Tetsunaga T, Misawa H, Oda Y, Takao S, Nishida K, Ozaki T. Evaluation of SARC-F and SARC-CalF for sarcopenia screening in patients with chronic musculoskeletal pain: A prospective cross-sectional study. Med (Baltim). 2022;101(29):e29568.
39. Champaiboon J, Petchlorlian A, Manasvanich BA, Ubonsutvanich N, Jitpugdee W, Kittiskulnam P, Wongwatthananart S, Menorngwa Y, Pornsalnuwat S, Praditpornsilpa K. Calf circumference as a screening tool for low skeletal muscle mass: Cut-off values in independent Thai older adults. BMC GERIATR. 2023;23(1):826.
40. Pagotto V, Santos K, Malaquias SG, Bachion MM, Silveira EA. Calf circumference: clinical validation for evaluation of muscle mass in the elderly. Rev Bras Enferm. 2018;71(2):322–8.
41. Krzyminska-Siemaszko R, Tobis S, Lewandowicz M, Wieczorowska-Tobis K. Comparison of four sarcopenia screening questionnaires in community-dwelling older adults from Poland using six sets of international diagnostic criteria of sarcopenia. PLoS ONE. 2020;15(4):e231847.
42. Hax V, Do ESR, Dos SL, Farinon M, de Oliveira MS, Tres GL, Gasparin AA, de Andrade N, Bredemeier M, Xavier RM, et al. Practical screening tools for sarcopenia in patients with systemic sclerosis. PLoS ONE. 2021;16(1):e245683.
43. Zhu L, Li J, Li M, Li Z, Lin X, Liu L, Chen X. Accuracy of SARC-F, SARC-CalF, and Ishii test in assessing severe sarcopenia in older adults in nursing homes. J NUTR HEALTH AGING. 2022;26(6):576–80.
44. Yang M, Hu X, Xie L, Zhang L, Zhou J, Lin J, Wang Y, Li Y, Han Z, Zhang D, et al. Comparing Mini sarcopenia risk assessment with SARC-F for screening sarcopenia in Community-Dwelling older adults. J AM MED DIR ASSOC. 2019;20(1):53–7.

45. Rossi AP, Caliari C, Urbani S, Fantin F, Brandimarte P, Martini A, Zoico E, Zoso G, Babbanini A, Zanotelli A et al. Sarcopenia risk evaluation in a sample of hospitalized elderly men and women: combined use of the Mini sarcopenia risk assessment (MSRA) and the SARC-F. NUTRIENTS 2021, 13(2).
46. Akarapornkrailert P, Muangpaisan W, Boonpeng A, Daengdee D. Validation of the Thai version of SARC-F, MSRA-7, and MSRA-5 questionnaires compared to AWGS 2019 and sarcopenia risks in older patients at a medical outpatient clinic. Osteoporos Sarcopenia. 2020;6(4):205–11.
47. Moreno-Sanchez I, Aibar-Almazan A, Carcelen-Fraile M, Parra-Diaz AB, Sanchez-Montesinos GI, Sanchez-Alcala M, Cano-Sanchez J, Hita-Contreras F. Cross-Cultural Adaptation and Clinical Validation of the Mini Sarcopenia Risk Assessment Questionnaire in Community-Dwelling Spanish Older Adults. Diagnostics (Basel) 2024, 14(19).
48. Ballesteros-Pomar MD, González-Arnáiz E, Pintor-de-la MB, Barajas-Galindo D, Ariadel-Cobo D, González-Roza L, Cano-Rodríguez I. Bioelectrical impedance analysis as an alternative to dual-energy x-ray absorptiometry in the assessment of fat mass and appendicular lean mass in patients with obesity. NUTRITION. 2022;93:111442.

## Publisher's note