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ORIGINAL RESEARCH

# Comparison of Diagnostic Value of the SARC-F and Its Four Modified Versions in Polish Community-Dwelling Older Adults

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**Purpose:** Sarcopenia is associated with adverse outcomes in elderly persons, including functional disability, falls, and even death. Therefore, older adults should be routinely screened for sarcopenia. Due to the unsatisfactory sensitivity of the SARC-F questionnaire, four modified versions have been elaborated: SARC-CalF, SARC-F+EBM, SARC-F+AC, and SARC-CalF+AC. The diagnostic performance of the four modifications of SARC-F has yet to be compared.

**Materials and Methods:** We performed the sensitivity/specificity analysis and compared the overall diagnostic accuracy of the five questionnaires in 260 community-dwelling volunteers aged ≥ 60 yrs from Poland. The study was performed against three reference standards: the European Working Group on Sarcopenia in Older People (EWGSOP1), EWGSOP2, and modified EWGSOP2 criteria.

**Results:** The prevalence of sarcopenia based on these criteria was 20.8%, 11.2%, and 17.3%, respectively. Concerning the three reference standards, the sensitivity of SARC-F, SARC-CalF, SARC-F+EBM, SARC-F+AC, and SARC-CalF+AC ranged from 31.5–44.8%, 57.4–65.5%, 48.1–62.1%, 71.4–79.2% and 71.4–79.2%, respectively. The specificity ranged from 86.6–87.4%, 86.1–90.3%, 82.3–84.0%, 69.4–78.2%, and 72.1–79.7%, respectively. The AUCs of SARC-F, SARC-CalF, SARC-F+EBM, SARC-F+AC, and SARC-CalF+AC ranged from 0.643–0.700, 0.757–0.792, 0.740–0.775, 0.767–0.812 and 0.771–0.852, respectively.

**Conclusion:** The SARC-F questionnaire has low diagnostic accuracy, which limits its usefulness as a sarcopenia screening tool. Incorporating two simple anthropometric measurements, ie, arm and calf circumference, notably improves the diagnostic performance of SARC-F. Based on our results, SARC-CalF+AC seems to be the best screening tool for sarcopenia screening in community-dwelling older adults.

**Keywords:** sarcopenia, screening, older individuals, ROC analysis

## Introduction

Sarcopenia is a muscle disease common in elderly subjects. It is associated with adverse health outcomes, such as poor functional capacity, falls and fractures, and ultimately death.[1] The prevalence of sarcopenia in community-dwelling older adults ranges from 1 to 29%.[2] Diagnosing sarcopenia in its early phase is difficult because of the lack of evident symptoms and signs; physical disability becomes apparent only in its late stage.[3] Identifying individuals with early stages of sarcopenia and preventing this condition is essential for the reasonable use of public health resources, especially in rapidly aging societies.

The International Clinical Practice Guidelines for Sarcopenia recommend annual screening for this condition in all persons aged 65 and more; such screening should also be performed after any important adverse health event, eg, a fall resulting in hospitalization.[4] The SARC-F questionnaire, recommended as a screening tool, assesses five items: 1) Strength, 2) Assistance in walking, 3) Rising from a chair, 4) Climbing stairs, and 5) Falls.[5] The original SARC-F questionnaire, investigated since 2013, has moderate to high specificity but low to moderate sensitivity.[6] Therefore,



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attempts have been made to improve its diagnostic value. Among other factors, relatively low sensitivity of the SARC-F may result from the fact the questionnaire does not assess muscle mass which is a key component of sarcopenia.[7–9]

The first modification of the SARC-F questionnaire (SARC-CalF) incorporated calf circumference (CC) to the original version.[7] Since its publication in 2016, the SARC-CalF has been widely used in research on sarcopenia, especially in South America and Asia.[6] Three years later (in 2019), Japanese investigators suggested another modified version containing age and body mass index (BMI) – SARC-F+EBM.[8] This modification, however, has not been widely explored – we found only three papers assessing its diagnostic performance.[10–12]

Even though most studies found the SARC-CalF[7,10–14] and SARC-F+EBM[8,10–12] had better diagnostic performance than the original version, Chinese researchers[15] proposed further modifications incorporating arm circumference (AC) to SARC-F and SARC-CalF in 2021 -SARC-F+AC and SARC-CalF+AC. Both versions with arm circumference had four-times higher sensitivity against the European Working Group on Sarcopenia in Older People 2 (EWGSOP2) criteria than the original SARC-F questionnaire while maintaining relatively high specificity (≥70%) and AUC (area under the curve) value (≥0.800).

Calf and arm circumferences are simple to measure anthropometric parameters, with a long history of use in the diagnostics of malnutrition in elderly subjects. The World Health Organization recognized calf circumference as the most sensitive anthropometric measure of muscle mass in older persons.[16] Equally, arm circumference could be used as alternative indicator to identify sarcopenia.[3,17,18] Moreover, some evidence indicates that BMI may be suitable for diagnosing sarcopenia.[8,17,19] A recent analysis by Cassio Limaa Esteves et al[17] has shown an independent and inverse association between anthropometric parameters and sarcopenia in a group of 411 community-dwelling older adults ≥ 60 yrs from Brazil (Amazonia region). The increase in BMI, AC, CC, and waist circumference by one unit was associated with a reduction of the risk of sarcopenia by 36, 37, 27, and 7%, respectively. Among anthropometric parameters included in this analysis, BMI and AC were the best predictors of sarcopenia in older adults of both sexes. Similar results were obtained by Endo et al,[3] who observed that sarcopenia became more frequent in both sexes, along with decreasing values of AC, CC, and BMI.

To our knowledge, the diagnostic performance of the SARC-F's newest modified versions has yet to be assessed in the European population. Therefore, we decided to apply the SARC-F+AC and SARC-CalF+AC questionnaires in community-dwelling older adults in Poland. In addition to the study concept by Zhou et al,[15] who compared the diagnostic performance of the SARC-F, SARC-CalF, SARC-F+AC, and SARC-CalF+AC, we also included the SARC-F+EBM tool in our analysis.

The aim of our study was to compare the overall diagnostic accuracy of SARC-F and its four modified versions (SARC-CalF, SARC-F+EBM, SARC-F+AC, and SARC-CalF+AC) in community-dwelling older adults from Poland.

# Materials and Methods

## Study Design and Subject Recruitment

Between March 2019 and 2022, we recruited 270 community-dwelling volunteers aged ≥ 60 years, living in Wielkopolska voivodship in Poland. Eighty percent of them were living in Poznan (the provincial capital). The inclusion criteria were as follows: age (60 years or more), lack of cognitive impairment [defined as Abbreviated Mental Test Score (AMTS) ≥ 7 points], the ability to take a vertical position [necessary for measuring body height and analyzing body composition for the assessment of Appendicular Lean Mass (ALM)], and the ability to perform a 4-m usual walking speed test (USG). The exclusion criteria were factors precluding the evaluation of body composition with the bioimpedance method (BIA) (eg, edema, implanted artificial pacemaker, or the presence of metal implants). Based on the exclusion criteria, ten persons did not enter the study: five because of cognitive impairment, two because of having a pacemaker, and three because of physical disability preventing a USG test.

## Measurement of Muscle Mass

The muscle mass level was assessed in each study participant using the BIA method (InBody 120, Biospace, Seoul, South Korea). We described the detailed methodology in our previous paper.[10] We used only the segmental lean mass data for calculating the Appendicular Lean Mass index and further analysis. The ALM index [the ratio of ALM (kg) and squared height ($m^2$)] was calculated for each subject. We assessed the subjects' height with a mobile stadiometer (Tanita, Poznan, Poland). The cut-off points applied for the ALM index are shown in Table 1.

**Table 1** Three Sets of European Diagnostic Criteria for Sarcopenia

| | Low Muscle Strength | Low Muscle Mass | Low Physical Performance | Diagnostic Criteria |
|---|---|---|---|---|
| Sarcopenia, according to EWGSOP1 | HGS < 30 kg for M<br>HGS < 20 kg for W | ALM/height$^2$ ≤ 7.40 kg/m$^2$ for M*<br>ALM/height$^2$ ≤ 5.60 kg/m$^2$ for W* | UGS ≤ 0.8 m/s for both sexes | HGS + LMM and/or UGS + LMM |
| Sarcopenia, according to EWGSOP2 | HGS < 27 kg for M<br>HGS < 16 kg for W<br>and/or<br>CST>15 s for five rises<br>for both sexes | ALM/height$^2$ ≤ 7.00 kg/m$^2$ for M<br>ALM/height$^2$ ≤ 5.50 kg/m$^2$ for W | – | HGS and/or CST + LMM |
| Sarcopenia, according to modified EWGSOP2 | HGS < 27 kg for M<br>HGS < 16 kg for W<br>and/or<br>CST>15 s for five rises<br>for both sexes | ALM/height$^2$ ≤ 7.40 kg/m$^2$ for M*<br>ALM/height$^2$ ≤ 5.60 kg/m$^2$ for W* | – | HGS and/or CST + LMM |

**Note**: *Polish cut-off points for reference population aged 18–40 yrs.[20]
**Abbreviations**: EWGSOP1, the European Working Group on Sarcopenia in Older People; EWGSOP2, extended group for the European Working Group on Sarcopenia in Older People; M, men; W, women; HGS, handgrip strength; CST, chair stand test; ALM, appendicular skeletal muscle mass; UGS, 4m usual gait speed; LMM, low muscle mass.

## Measurement of Muscle Strength and Physical Performance

Muscle strength was assessed with a handgrip dynamometer (Saehan, Changwon, South Korea). The handgrip strength test was measured sitting, with arms bent to 90 degrees in the elbow and shoulder joints. Both the left and right arms were measured twice. The mean value of all measurements was used as the final score for each individual. The results were expressed in kilograms (kg). According to the EWGSOP2 criteria,[1] we additionally used The Chair Stand Test (CST) to assess lower limb strength. Each subject was asked to rise five times from a chair with arms folded across the chest, and the time needed to complete the test was measured (in seconds, s).

The 4-m usual gait speed test (UGS) was used to assess physical performance. Subjects were allowed to use walking aids (canes, walkers) during the test, if necessary. Time taken to perform a distance of 4 meters was recorded, and the result was expressed as meters per second.

The cut-off points for the muscle strength and physical performance parameters are presented in Table 1.

## Anthropometrics Measurements

Anthropometric indicators included weight, height, arm circumference, and calf circumference. We used participants' weight and height to calculate their BMI (weight divided by squared height [kg/m$^2$]). Arm circumference was assessed with a measuring tape, in a standing position, in the middle of the arm of the non-dominant upper limb (half of the distance between acromion and olecranon). Calf circumference was measured in a standing position, with legs relaxed and feet 20 centimeters apart, in the widest part of the right calf (methodology described by Barbosa-Silva et al).[7]

All parameters were taken by researchers who were qualified dieticians and had the skills necessary for accurate measurements.

## Reference Standard of Sarcopenia Diagnosis

We used two sets of European diagnostic criteria for sarcopenia: the most commonly used EWGSOP published in 2010 (EWGSOP1)[21] and EWGSOP2[1] (a modification of EWGSOP criteria launched in 2018). As recommended by the experts from the EWGSOP in 2010,[21] we used sex-specific Polish cut-off points for low muscle mass. We had previously assessed these cut-off points in 1512 healthy subjects aged 18–40 years with a BIA method (body composition analyzer InBody 170, Biospace, South Korea).[20] In contrast to the EWGSOP recommendations from 2010[21] to use cut-off points derived from the local population, the EWGSOP2 experts in 2018[1] suggested using fixed cut-off points for low muscle mass (5.5 kg/m$^2$ in women and 7.0 kg/m$^2$ in men). After thorough discussion, we acknowledged using cut-off points derived from the local population was more appropriate, especially while using a relatively imprecise method of muscle mass assessment (BIA). We decided to use both sets of cut-off points for low muscle mass: the cut-off points recommended by the EWGSOP2 in 2018[1] and the Polish cut-off points[20] (modified EWGSOP2[10]). Consequently, we obtained three sets of diagnostic criteria (EWGSOP1[21], EWGSOP2[1], and modified EWGSOP2[10]), as shown in Table 1.

## Sarcopenia Screening Tools

We used the SARC-F, SARC-CalF, SARC-F+EBM, SARC-F+AC, SARC-CalF+AC as screening tools for sarcopenia.

The standard SARC-F[5] examines five domains: 1) strength, 2) assistance in walking, 3) rising from a chair, 4) climbing stairs, and 5) falls, scored from 0 to 2. A score of ≥ 4 out of 10 points indicates a risk of sarcopenia. We used the Polish language version of the SARC-F questionnaire, which was validated in community-dwelling older adults from Poland.[22]

The SARC-CalF[7] is composed of six items, the first five being scored the same as the standard SARC-F and the sixth additional item being the calf circumference. The CC score is interpreted separately for each gender. The CC item is scored as 0 points if its value is above the cut-off points (> 33 cm for women, > 34 cm for men) and as 10 if its value is below or equals the cut-off points (≤ 33 cm for women, ≤ 34 cm for men). The maximal score is 20 points. A score of ≥ 11 points indicates a risk of sarcopenia.

The SARC-F+EBM[8] examines seven domains. The first five domains are identical to the original SARC-F questionnaire, and the remaining two include age and BMI. Subjects aged ≥ 75 years are given additional 10 points, while persons < 75 score 0 points. Ten points are also given for BMI ≤ 21 kg/m$^2$ (0 if BMI > 21 kg/m$^2$). The maximal score of the SARC-F+EBM is 30 points. A score of ≥ 12 points indicates a risk of sarcopenia.

The SARC-F+AC[15] examines 6 items: the standard SARC-F and arm circumference. The arm circumference item is scored 0 or 10 points for values above and below cut-off points, respectively. This scoring system has been proposed by Zhou et al.[15] The maximal score in this modified version is 20 points. We did not want to use the Chinese cut-off points for low arm circumference,[15] so we elaborated sex-specific optimal thresholds for our sample. Like Zhou et al,[15] we have determined the optimal cut-off points of SARC-F+AC, shown in the Results.

The SARC-CalF+AC[15] contains all items assessed in the SARC-CalF questionnaire (as described above) and the arm circumference. The calf and arm circumference items are scored 0 for results higher than the cut-off values and 10 points for results equal to or lower than the cut-off points. The maximal score is 30 points. Like Zhou et al,[15] we assessed the optimal cut-off points for SARC-CalF+AC (see Results).

## Covariates

Face-to-face interviews were conducted to collect sociodemographic (age, sex, marital status, education level, living condition) and clinical (self-reported comorbidity and number of drugs taken regularly) data. Nutritional status was screened with a full version of the Mini Nutritional Assessment (full MNA), and independence in basic (ADL) and instrumental (IADL) activities of daily living was assessed with the Katz scale and Lawton scale, respectively. The cognitive performance was evaluated with the Abbreviated Mental Test Score (AMTS). All the tools used in the study have been described in detail in our previous publication.[10]

## Statistical Analysis and Ethical Consideration

Statistical analysis was performed using the STATISTICA 12.0 package (StatSoft, Poland). Sociodemographic and clinical characteristics were summarized using descriptive statistics. Continuous data were presented as mean ± SD and compared using a Student's *t*-test, the Cochran-Cox test, or the Mann–Whitney test as appropriate. Categorical variables were expressed as numbers (percentage) and compared with the $\chi^2$ test (applying the Yates correction when necessary). The EWGSOP1[21], EWGSOP2[1], and modified EWGSOP2 criteria[10] were used as the reference standards. In our analysis, we adopted an "exclusion" screening test (focusing on sensitivity and negative predictive value (NPV) combined with AUC to assess the accuracy of SARC-F, SARC-CalF, SARC-EBM, SARC-F+AC, SARC-CalF+AC (similarly to the work of Chen et al).[12] The sensitivity (Se), specificity (Sp), positive predictive value (PPV), and NPV of the tools mentioned above were calculated. These parameters were specified with 95% confidence intervals (CI). Moreover, we generated receiver operating characteristic (ROC) curves to compare the diagnostic performance of the SARC-F and its four modified versions. The areas under the ROC curve (AUC with 95%Cl) indicate the overall diagnostic accuracy. We assumed that the AUC values >0.9, >0.7 to 0.9, and 0.5 to 0.7 corresponded to the high, moderate and low diagnostic accuracy of the screening test, respectively.[11,14] Comparisons between ROC curves were performed using the DeLong method.[23] The optimal cut-off points for arm circumference, SARC-F+AC, and SARC-CalF+AC were calculated by the best compromise between Se and Sp.[3]

This study was conducted in accordance with the Declaration of Helsinki and the study protocol was approved by the Bioethics Committee of the Poznan University of Medical Sciences, Poland (approval No: 872/18). Informed consent was obtained from each subject before the study.

# Results

## Characteristics of the Study Group

We enrolled 260 community-dwelling volunteers aged 60 years and older (age range: 60–93 years); 39.2% of them were male (n=102). More than two-thirds of subjects were younger olds (< 75 years). Table 2 shows the baseline characteristics (including the sociodemographic and clinical parameters) for the total study population and sarcopenic and non-sarcopenic groups according to the EWGSOP1[21], EWGSOP2[1], and modified EWGSOP2[10] criteria.

We found no significant difference in age between participants in the sarcopenic and non-sarcopenic groups. Subjects with sarcopenia were thinner ($p<0.001$) and had lower BMI ($p<0.0001$) than non-sarcopenic groups, regardless of the applied diagnostic criteria set (Table 2). Percentage of persons with low BMI (≤ 21 kg/m$^2$), malnutrition, and being at risk of malnutrition was higher in all sarcopenic groups. Subjects in sarcopenic groups also had lower calf and arm circumferences, ALM index, muscle strength of both upper and lower limbs, and worse physical performance than the non-sarcopenic group. They also had more disabilities in instrumental activities of daily living (Lawton scale) and were at higher risk of cognitive impairment (AMTS questionnaire). Participants with and without sarcopenia declared having the same number of chronic diseases (n=3). However, the percentage of subjects taking at least six medications daily was significantly higher in persons with sarcopenia diagnosed with EWGSOP1[21] and modified EWGSOP2[10] criteria ($p<0.05$ for both comparisons). Sociodemographic variables did not differ between the study groups.

Mean scores of SARC-F, SARC-CalF, SARC-F+EBM, SARC-F+AC, and SARC-CALF+AC questionnaires were significantly lower in all sarcopenic groups ($p<0.001$) in comparison with non-sarcopenic subjects.

Table 3 shows the answers to the questions from the SARC-F questionnaire, the results of measurements predicting sarcopenia (ie, calf and arm circumferences), age, and BMI. Forty percent of all participants reported difficulties with lifting and carrying a weight of 5 kg. This problem was significantly more frequent in all sarcopenic groups ($p<0.01$). One out of ten subjects declared at least moderate difficulties walking across a room. These difficulties were more common in sarcopenic groups, but the difference versus the non-sarcopenic group was significant only for EWGSOP2[1] and modified EWGSOP2[10] criteria. About a quarter of study subjects reported problems standing up from a chair or bed, climbing ten stairs, or experiencing at least one fall in the past year. Subjects with sarcopenia declared these problems more frequently than non-sarcopenic ones. The differences in climbing stairs and falls items were significant for all sarcopenic groups. In contrast, the difference in standing up from a chair or bed was significant only for the modified EWGSOP2[10] group. Low CC was found in 1/4 of subjects, while low AC in 1/3 of participants. Low arm and calf circumferences were significantly more frequent in all sarcopenic groups ($p<0.0001$ for all comparisons). The percentage of participants with low BMI was almost 13% in the total study sample, and it was significantly higher in sarcopenic groups, regardless of the diagnostic criteria ($p<0.001$).

## The Cut-Off Points of the Arm Circumference

According to the EWGSOP1[21] criteria, the AUCs of the AC in women and men were 0.889 and 0.820, respectively. The optimal arm circumference cut-off points for sarcopenia screening were ≤25.3 cm in women and ≤27.0 cm in men. The Se/Sp of AC in women and men were 83.3%/84.1% and 75.9%/69.0%, respectively.

**Table 2** Characteristics of the Whole Study Population and Subgroups with and without Sarcopenia Based on EWGSOP1, EWGSOP2, and Modified EWGSOP2 Criteria

| | Total | Sarcopenia (EWGSOP1) | Without Sarcopenia (EWGSOP1) | p | Sarcopenia (EWGSOP2) | Without Sarcopenia (EWGSOP2) | p | Sarcopenia (Modified EWGSOP2) | Without Sarcopenia (Modified EWGSOP2) | p |
|---|---|---|---|---|---|---|---|---|---|---|
| Age | 72.1±6.9 | 73.1±7.3 | 71.8±6.8 | 0.2079 | 73.1±7.4 | 72.0±6.9 | 0.4204 | 73.4±7.6 | 71.8±6.8 | 0.1783 |
| Sex* | | | | | | | | | | |
| Women | 158 (60.8) | 24 (44.4) | 134 (65.0) | 0.0058 | 15 (51.7) | 143 (61.9) | 0.2899 | 19 (42.2) | 139 (64.7) | 0.0051 |
| Men | 102 (39.2) | 30 (55.6) | 72 (35.0) | | 14 (48.3) | 88 (38.1) | | 26 (57.8) | 76 (35.3) | |
| Age cohort* | | | | | | | | | | |
| 60–74 yrs | 178 (68.5) | 33 (61.1) | 145 (70.4) | 0.1916 | 18 (62.1) | 160 (69.3) | 0.4319 | 27 (60.0) | 151 (70.2) | 0.1792 |
| 75 yrs or more | 82 (31.5) | 21 (38.9) | 61 (29.6) | | 11 (37.9) | 71 (30.7) | | 18 (40.0) | 64 (29.8) | |
| Living conditions*[a] | | | | | | | | | | |
| Living alone | 75 (29.2) | 13 (25.0) | 62 (30.2) | 0.4575 | 7 (25.0) | 68 (29.7) | 0.6060 | 11 (25.6) | 64 (29.9) | 0.5692 |
| Living with others | 182 (70.8) | 39 (75.0) | 143 (69.8) | | 21 (75.0) | 161 (70.3) | | 32 (74.4) | 150 (70.1) | |
| Marital status*[a] | | | | | | | | | | |
| Unmarried | 108 (42.0) | 20 (38.5) | 88 (42.9) | 0.5602 | 14 (50.0) | 94 (41.0) | 0.3650 | 19 (44.2) | 89 (41.6) | 0.7529 |
| Married | 149 (58.0) | 32 (61.5) | 117 (57.1) | | 14 (50.0) | 135 (59.0) | | 24 (55.8) | 125 (58.4) | |
| Level of education*[b] | | | | | | | | | | |
| No education or primary | 14 (5.5) | 2 (3.8) | 12 (5.9) | 0.8143 | 2 (7.1) | 12 (5.3) | 0.9780 | 2 (4.7) | 12 (5.6) | 0.9131 |
| Higher than primary | 242 (94.5) | 50 (96.2) | 192 (94.1) | | 26 (92.9) | 216 (94.7) | | 41 (95.3) | 201 (94.4) | |
| Number of chronic diseases[a] | 3.2±1.8 | 3.5±1.4 | 3.1±1.9 | 0.0750 | 3.8±1.6 | 3.1±1.8 | 0.0522 | 3.6±1.5 | 3.1±1.8 | 0.0609 |
| Number of medication daily taken[c] | 5.5±3.7 | 6.7±3.5 | 5.2±3.7 | 0.0047 | 6.3±3.2 | 5.4±3.8 | 0.1095 | 6.5±3.2 | 5.3±3.8 | 0.0187 |
| SARC-F+EBM score | 6.0±6.5 | 10.4±6.5 | 4.8±6.0 | <0.0001 | 12.1±6.9 | 5.2±6.0 | <0.0001 | 10.8±6.6 | 5.0±6.0 | <0.0001 |
| SARC-F score | 1.6±1.9 | 2.5±2.3 | 1.4±1.7 | 0.0008 | 3.1±2.6 | 1.4±1.7 | 0.0003 | 2.8±2.4 | 1.4±1.7 | <0.0001 |
| SARC-CalF score | 4.2±5.2 | 9.3±5.7 | 2.8±4.1 | <0.0001 | 9.7±6.5 | 3.5±4.6 | <0.0001 | 9.2±5.9 | 3.1±4.3 | <0.0001 |
| SARC-F+AC score | 4.9±5.3 | 10.3±4.9 | 3.5±4.5 | <0.0001 | 10.0±5.8 | 4.3±4.9 | <0.0001 | 10.1±5.3 | 3.8±4.7 | <0.0001 |
| SARC-CalF+AC score | 7.6±8.6 | 17.2±8.2 | 5.0±6.6 | <0.0001 | 16.5±9.9 | 6.5±7.7 | <0.0001 | 16.7±8.6 | 5.6±7.3 | <0.0001 |
| Calf circumference (cm) | 35.9±4.0 | 32.0±3.7 | 36.9±3.3 | <0.0001 | 31.5±4.2 | 36.4±3.6 | <0.0001 | 32.1±3.7 | 36.7±3.5 | <0.0001 |
| MNA-full score | 25.1±3.5 | 21.6±4.6 | 26.0±2.6 | <0.0001 | 21.2±4.6 | 25.5±3.1 | <0.0001 | 21.7±4.5 | 25.8±2.8 | <0.0001 |
| MNA-full, status* | | | | | | | | | | |
| Malnutrition | 8 (3.1) | 8 (14.8) | 0 (0.0) | <0.0001 | 4 (13.8) | 4 (1.7) | <0.0001 | 6 (13.3) | 2 (0.9) | <0.0001 |
| Risk of malnutrition | 66 (25.4) | 30 (55.6) | 36 (17.5) | | 17 (58.6) | 49 (21.2) | | 26 (57.8) | 40 (18.6) | |
| Normal nutritional status | 186 (71.5) | 16 (29.6) | 170 (82.5) | | 8 (27.6) | 178 (77.1) | | 13 (28.9) | 173 (80.5) | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ADL, status* | | | | | | | | | |
| Independent | 257 (98.8) | 53 (98.1) | 204 (99.0) | 0.8602 | 28 (96.6) | 229 (99.1) | 0.7603 | 44 (97.8) | 213 (99.1) | 0.9765 |
| Partially dependent | 3 (1.2) | 1 (1.9) | 2 (1.0) | | 1 (3.4) | 2 (0.9) | | 1 (2.2) | 2 (0.9) | |
| Dependent | 0 (0.0) | 0 (0.0) | 0 (0.0) | | 0 (0.0) | 0 (0.0) | | 0 (0.0) | 0 (0.0) | |
| IADL score | 23.0±2.0 | 21.9±2.6 | 23.2±1.7 | <0.0001 | 21.3±3.0 | 23.2±1.8 | <0.0001 | 21.6±2.8 | 23.3±1.7 | <0.0001 |
| IADL, status* | | | | | | | | | | |
| Independent | 159 (61.2) | 23 (42.6) | 136 (66.0) | 0.0057 | 10 (34.5) | 149 (64.5) | 0.0017 | 17 (37.8) | 142 (66.0) | 0.0005 |
| Partially dependent | 80 (30.8) | 23 (42.6) | 57 (27.7) | | 12 (41.4) | 68 (29.4) | | 19 (42.2) | 61 (28.4) | |
| Dependent | 21 (8.1) | 8 (14.8) | 13 (6.3) | | 7 (24.1) | 14 (6.1) | | 9 (20.0) | 12 (5.6) | |
| AMTS score | 9.5±0.6 | 9.3±0.7 | 9.5±0.6 | 0.0683 | 9.1±0.7 | 9.5±0.6 | 0.0089 | 9.3±0.7 | 9.5±0.6 | 0.0476 |
| Handgrip strength (kg) | 24.6±9.0 | 19.6±6.1 | 25.9±9.2 | <0.0001 | 17.2±4.0 | 25.6±9.0 | <0.0001 | 18.6±5.7 | 25.9±9.0 | <0.0001 |
| Usual gait speed (m/s) | 1.0±0.3 | 0.9±0.2 | 1.0±0.3 | <0.0001 | 0.8±0.3 | 1.0±0.3 | <0.0001 | 0.8±0.2 | 1.0±0.3 | <0.0001 |
| Chair stand test (s)[d] | 12.7±4.4 | 15.1±5.5 | 12.0±3.8 | <0.0001 | 16.5±6.5 | 12.2±3.8 | 0.0002 | 15.7±5.8 | 12.0±3.8 | <0.0001 |
| ALM (kg) | 18.9±4.6 | 16.4±4.3 | 19.6±4.5 | <0.0001 | 15.0±3.7 | 19.4±4.5 | <0.0001 | 16.5±4.3 | 19.5±4.6 | 0.0003 |
| ALM index (kg/m$^2$) | 7.0±1.2 | 6.1±1.0 | 7.3±1.1 | <0.0001 | 5.6±0.8 | 7.2±1.1 | <0.0001 | 6.1±1.0 | 7.2±1.1 | <0.0001 |
| Weight (kg) | 73.4±15.3 | 60.6±14.9 | 76.7±13.5 | <0.0001 | 58.0±15.6 | 75.3±14.1 | <0.0001 | 61.1±14.9 | 76.0±14.1 | <0.0001 |
| Height (cm) | 163.0±9.2 | 163.0±10.5 | 163.0±8.9 | 0.8772 | 161.6±10.4 | 163.2±9.0 | 0.3770 | 163.4±10.3 | 162.9±9.0 | 0.7222 |
| BMI (kg/m$^2$) | 27.6±5.3 | 22.5±3.9 | 28.9±4.8 | <0.0001 | 22.0±4.2 | 28.3±5.0 | <0.0001 | 22.6±3.8 | 28.6±5.0 | <0.0001 |
| Low BMI (≤21 kg/m$^2$)* | | | | | | | | | | |
| Yes | 33 (12.7) | 22 (40.7) | 11 (5.3) | <0.0001 | 15 (51.7) | 18 (7.8) | <0.0001 | 18 (40.0) | 15 (7.0) | <0.0001 |
| No | 227 (87.3) | 32 (59.3) | 195 (94.7) | | 14 (48.3) | 213 (92.2) | | 27 (60.0) | 200 (93.0) | |

**Notes**: Most variables are shown as mean ± SD, except *Data are presented as n (%); [a]Data missing for three subjects; [b]Data missing for four subjects; [c]Data missing for seven subjects; [d]Seven subjects did not complete the chair stand test due to various reasons, ie, low back pain.

**Abbreviations**: MNA, Mini Nutritional Assessment; ADL, activities of daily living; IADL, instrumental activities of daily living; AMTS, Abbreviated Mental Test Score; ALM, appendicular lean mass, BMI, body mass index.

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**Table 3** The Characteristics of Answers Given to the Questions from the SARC-F and Additional Items (CC, AC, Age, BMI) of the Whole Study Population and According to EWGSOP1, EWGSOP2 and Modified EWGSOP2 Criteria

| **SARC-F Components** | | **Total** | **Sarcopenia (EWGSOP1)** | **Without Sarcopenia (EWGSOP1)** | **p** | **Sarcopenia (EWGSOP2)** | **Without Sarcopenia (EWGSOP2)** | **p** | **Sarcopenia (Modified EWGSOP2)** | **Without Sarcopenia (Modified EWGSOP2)** | **p** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Q1. Strength - difficulty lifting and carrying about 5 kg | None | 155 (59.6) | 21 (38.9) | 134 (65.0) | 0.0014 | 10 (34.5) | 145 (62.8) | 0.0081 | 16 (35.6) | 139 (64.7) | 0.0014 |
| | Some | 67 (25.8) | 19 (35.2) | 48 (23.3) | | 10 (34.5) | 57 (24.7) | | 18 (40.0) | 49 (22.8) | |
| | A lot or unable | 38 (14.6) | 14 (25.9) | 24 (11.7) | | 9 (31.0) | 29 (12.6) | | 11 (24.4) | 27 (12.6) | |
| Q2. Assistance in walking - difficulty walking across a room | None | 232 (89.2) | 44 (81.5) | 188 (91.3) | 0.1355 | 20 (69.0) | 212 (91.8) | 0.0053 | 35 (77.8) | 197 (91.6) | 0.0395 |
| | Some | 21 (8.1) | 8 (14.8) | 13 (6.3) | | 7 (24.1) | 14 (6.1) | | 8 (17.8) | 13 (6.0) | |
| | A lot, use aids or unable | 7 (2.7) | 2 (3.7) | 5 (2.4) | | 2 (6.9) | 5 (2.2) | | 2 (4.4) | 5 (2.3) | |
| Q3. Rise from a chair - difficulty transferring from a chair or bed | None | 195 (75.0) | 35 (64.8) | 160 (77.7) | 0.1487 | 17 (58.6) | 178 (77.1) | 0.1191 | 26 (57.8) | 169 (78.6) | 0.0172 |
| | Some | 60 (23.1) | 18 (33.3) | 42 (20.4) | | 11 (37.9) | 49 (21.2) | | 18 (40.0) | 42 (19.5) | |
| | A lot or unable without help | 5 (1.9) | 1 (1.9) | 4 (1.9) | | 1 (3.4) | 4 (1.7) | | 1 (2.2) | 4 (1.9) | |
| Q4. Climb stairs - difficulty climbing a flight of 10 stairs | None | 188 (72.3) | 32 (59.3) | 156 (75.7) | 0.0057 | 14 (48.3) | 174 (75.3) | 0.0006 | 24 (53.3) | 164 (76.3) | 0.0027 |
| | Some | 60 (23.1) | 15 (27.8) | 45 (21.8) | | 9 (31.0) | 51 (22.1) | | 15 (33.3) | 45 (20.9) | |
| | A lot or unable | 12 (4.6) | 7 (13.0) | 5 (2.4) | | 6 (20.7) | 6 (2.6) | | 6 (13.3) | 6 (2.8) | |
| Q5. Falls - times have fallen in the past year | None | 189 (72.7) | 34 (63.0) | 155 (75.2) | 0.0441 | 15 (51.7) | 174 (75.3) | 0.0175 | 26 (57.8) | 163 (75.8) | 0.0095 |
| | 1–3 falls | 59 (22.7) | 14 (25.9) | 45 (21.8) | | 10 (34.5) | 49 (21.2) | | 13 (28.9) | 46 (21.4) | |
| | ≥ 4 falls | 12 (4.6) | 6 (11.1) | 6 (2.9) | | 4 (13.8) | 8 (3.5) | | 6 (13.3) | 6 (2.8) | |
| **Additional items** | | | | | | | | | | | |
| Calf circumference (cm) | W ≤ 33 cm / M ≤ 34 cm | 68 (26.2) | 38 (70.4) | 30 (14.6) | <0.0001 | 19 (65.5) | 49 (21.2) | <0.0001 | 30 (66.7) | 38 (17.7) | <0.0001 |
| | W > 33 cm / M > 34 cm | 192 (73.8) | 16 (29.6) | 176 (85.4) | | 10 (34.5) | 182 (78.8) | | 15 (33.3) | 177 (82.3) | |
| Arm circumference (cm) | W ≤ 25 cm / M ≤ 27 cm | 85 (34.0) | 42 (79.2) | 43 (21.8) | <0.0001 | 20 (71.4) | 65 (29.3) | <0.0001 | 33 (75.0) | 52 (25.2) | <0.0001 |
| | W > 25 cm / M > 27 cm | 165 (66.0) | 11 (20.8) | 154 (78.2) | | 8 (28.6) | 157 (70.7) | | 11 (25.0) | 154 (74.8) | |
| Age | < 75 yrs | 178 (68.5) | 33 (61.1) | 145 (70.4) | 0.1916 | 18 (62.1) | 160 (69.3) | 0.4319 | 27 (60.0) | 151 (70.2) | 0.1792 |
| | ≥ 75 yrs | 82 (31.5) | 21 (38.9) | 61 (29.6) | | 11 (37.9) | 71 (30.7) | | 18 (40.0) | 64 (29.8) | |
| Body Mass Index | ≤ 21 kg/m$^2$ | 33 (12.7) | 22 (40.7) | 11 (5.3) | <0.0001 | 15 (51.7) | 18 (7.8) | <0.0001 | 18 (40.0) | 15 (7.0) | <0.0001 |
| | > 21 kg/m$^2$ | 227 (87.3) | 32 (59.3) | 195 (94.7) | | 14 (48.3) | 213 (92.2) | | 27 (60.0) | 200 (93.0) | |

**Notes:** Data are presented as n (%).
**Abbreviations**: Q, question; EWGSOP1, the European Working Group on Sarcopenia in Older People; EWGSOP2, extended group for the European Working Group on Sarcopenia in Older People; CC, calf circumference; AC, arm circumference; W, women; M, men.

According to the EWGSOP2[1] criteria, the AUCs of the AC in women and men were 0.831 and 0.771, respectively. The optimal AC cut-off points for sarcopenia screening were ≤25.0 cm in women and ≤27.0 cm in men. The Se/Sp of AC in women and men were 81.3%/61.5%, and 80.6%/58.6%, respectively.

According to the modified EWGSOP2[10] criteria, the AUCs of the AC in women and men were 0.840 and 0.815, respectively. The optimal AC cut-off points for sarcopenia screening were ≤25.5 cm in women and ≤27.0 cm in men. The Se/Sp of AC in women and men were 78.9%/72.0% and 78.6%/65.3%, respectively.

ROC curves of AC for identifying sarcopenia according to the three sets of reference standards (EWGSOP1[21], EWGSOP2[1], and modified EWGSOP2[10] criteria) were presented in (Figure 1A and B).

The optimal cut-off point of AC in men was 27.0 cm, regardless of the applied diagnostic criteria. In women, the optimal cut-off points varied slightly depending on the diagnostic criteria used. We rounded up the obtained values to the nearest integer (25 cm) and used them for further analysis.

## The Cut-Off Points of SARC-F+AC and SARC-CalF+AC

The optimal cut-off point of SARC-CalF+AC was 11 according to all diagnostic criteria used (EWGSOP1[21], EWGSOP2[1], and modified EWGSOP2[10]). For SARC-F+AC, the optimal cut-off point was 10 for EWGSOP1[21] and EWGSOP2[1] and 8 for the modified EWGSOP2[10] criteria. We decided to use both optimal cut-off points of SARC-F+AC in further analysis. Therefore, we developed two versions: version 1 with SARC-F+AC optimal cut-off point ≥ 8 and version 2 with SARC-F+AC optimal cut-off point ≥ 10. Sensitivity and AUC for SARC-F+AC were the same in both versions, while Sp, PPV, and NPV were slightly better in version 2 (with a cut-off point of ≥ 10).

## Prevalence of Sarcopenia

The frequency of risk of sarcopenia varied from 16.9% to 35.2%, depending on the version of the SARC-F questionnaire (Figure 2). The original SARC-F tool identified the lowest number of subjects with a risk of sarcopenia (44 persons, including 17 men), whereas SARC-F+AC (version 1 with cut-off ≥ 8 points) – the highest (88 persons, including 44 men). Sarcopenia was diagnosed in only 11.2% of participants (n=29, including 14 men) with the EWGSOP2[1] criteria and 17.3% of subjects (n=45, including 26 men) with modified EWGSOP2[10] criteria. The highest percentage (20.8%) of

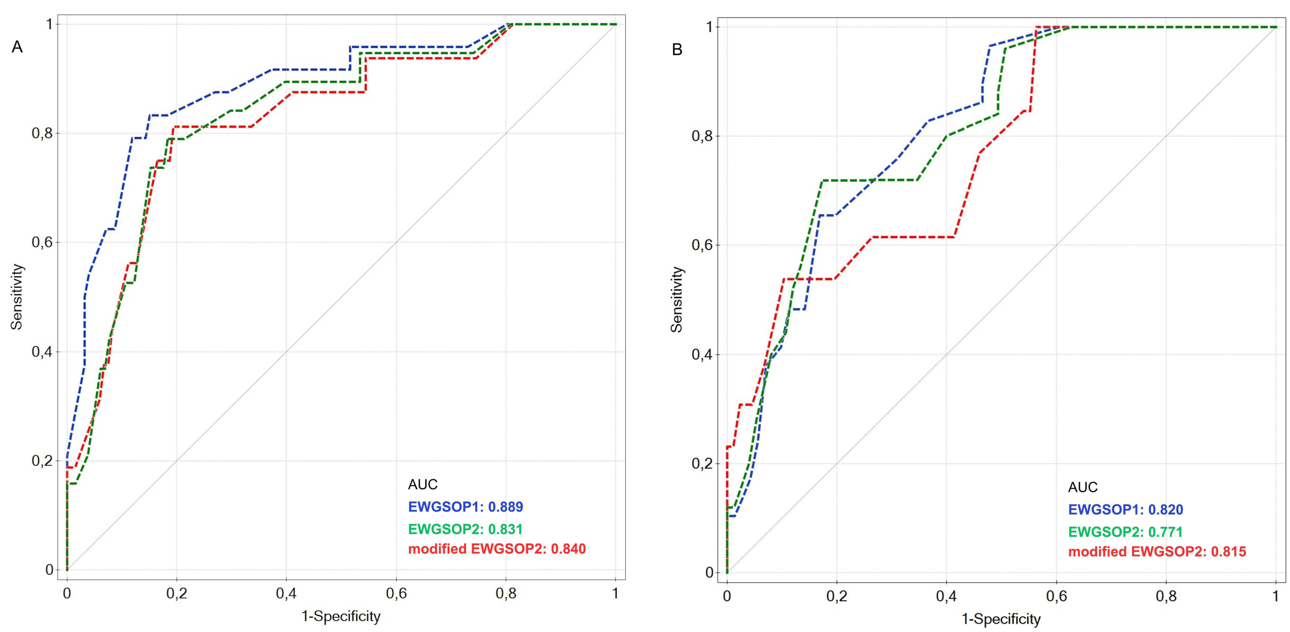
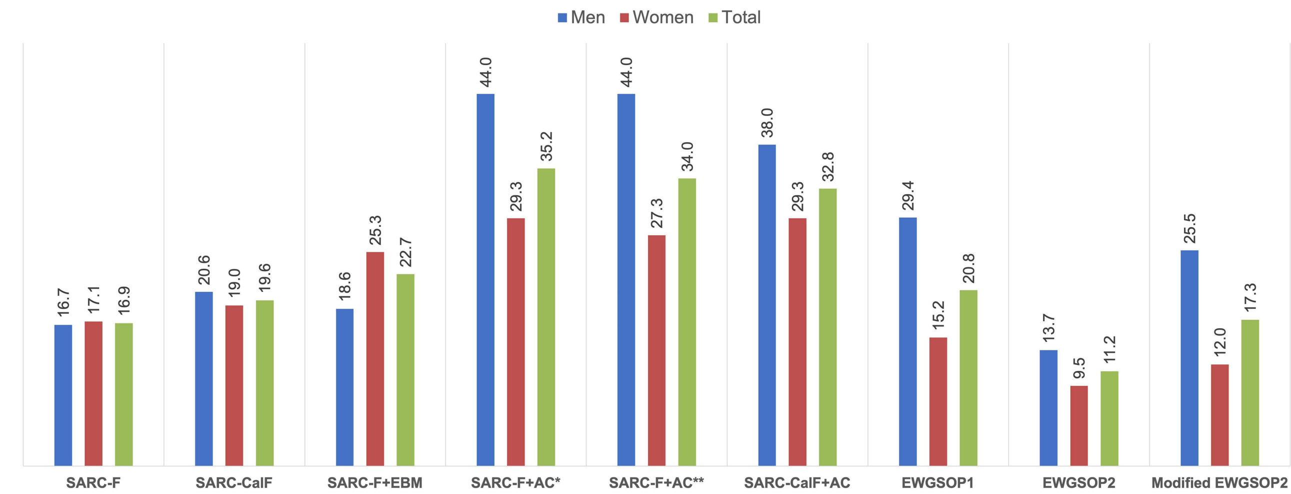



**Figure 1** Receiver Operating Characteristic Curves of Arm Circumference for Identifying Sarcopenia in Women (**A**) and in Men (**B**) according to EWGSOP1, EWGSOP2, and Modified EWGSOP2 Criteria.




*SARC-F+AC (version 1: ≥8 points); ** SARC-F+AC (version 2: ≥10 points).

**Figure 2** Prevalence of Sarcopenia Based on the SARC-F and Its Four Modified Versions and Three Sets of European Diagnostic Criteria of Sarcopenia.

persons with sarcopenia was found when EWGSOP1[21] criteria were used (n=54, including 30 men). The prevalence of sarcopenia diagnosed with various questionnaires in the total study sample and groups by sex are shown in Figure 2.

## Diagnostic Value of All Analyzed Questionnaires for Sarcopenia Screening

Table 4 shows the Se/Sp analyses and AUCs of the SARC-F, SARC-CalF, SARC-F+EBM, SARC-F+AC, and SARC-CalF+AC when using the EWGSOP1[21], EWGSOP2[1] and modified EWGSOP2[10] criteria as the reference standard. SARC-CalF+AC had the best Se and NPV against all used diagnostic criteria. SARC-CalF was the most specific tool

**Table 4** Sensitivity, Specificity, Positive and Negative Predictive Values, and Receiver Operating Curve Model of the SARC-F and Its Four Modified Versions Against EWGSOP1, EWGSOP2, and Modified EWGSOP2 Criteria of Sarcopenia in the Whole Study Population

| | Sensitivity (%) | Specificity (%) | PPV (%) | NPV (%) | AUC | p* |
|---|---|---|---|---|---|---|
| **EWGSOP1** | | | | | | |
| SARC-F (≥ 4 points) | 31.5 (19.52–45.55) | 86.9 (81.5–91.2) | 38.6 (27.1–51.6) | 82.9 (80.0–85.4) | 0.643 (0.557–0.728) | b, c, d, e |
| SARC-F+AC (version 1: ≥8 points) | 79.2 (65.89–89.16) | 76.6 (70.1–82.4) | 47.7 (40.6–54.9) | 93.2 (89.0–95.9) | 0.822 (0.751–0.892) | a |
| SARC-F+AC (version 2: ≥10 points) | 79.2 (65.89–89.16) | 78.2 (71.8–83.7) | 49.4 (42.0–56.8) | 93.3 (89.2–96.0) | | |
| SARC-CalF+AC (≥11 points) | 79.2 (65.89–89.16) | 79.7 (73.4–85.1) | 51.2 (43.5–58.9) | 93.5 (89.4–96.0) | 0.852 (0.786–0.919) | a, d, e |
| SARC-CalF (≥11 points) | 57.4 (43.21–70.77) | 90.3 (85.4–94.0) | 60.8 (49.1–71.4) | 89.0 (85.5–91.7) | 0.792 (0.714–0.870) | a, c |
| SARC-F+EBM (≥12 points) | 48.1 (34.34–62.16) | 84.0 (78.2–88.7) | 44.1 (34.2–54.5) | 86.1 (82.6–88.9) | 0.740 (0.664–0.816) | a, c |
| **EWGSOP2** | | | | | | |
| SARC-F (≥ 4 points) | 44.8 (26.5–64.3) | 86.6 (81.5–90.7) | 29.5 (20.0–41.4) | 92.6 (90.0–94.6) | 0.700 (0.590–0.811) | - |
| SARC-F+AC (version 1: ≥8 points) | 71.4 (51.3–86.8) | 69.4 (62.9–75.4) | 22.7 (17.8–28.6) | 95.1 (91.4–97.2) | 0.767 (0.655–0.879) | - |
| SARC-F+AC (version 2: ≥10 points) | 71.4 (51.3–86.8) | 70.7 (64.3–76.6) | 23.5 (18.4–29.6) | 95.2 (91.6–97.3) | | |
| SARC-CalF+AC (≥11 points) | 71.4 (51.3–86.8) | 72.1 (65.7–77.9) | 24.4 (19.1–30.7) | 95.2 (91.7–97.3) | 0.771 (0.656–0.887) | - |
| SARC-CalF (≥11 points) | 65.5 (45.7–82.1) | 86.1 (81.0–90.3) | 37.3 (28.1–47.4) | 95.2 (92.3–97.1) | 0.757 (0.640–0.874) | - |
| SARC-F+EBM (≥12 points) | 62.1 (42.3–79.3) | 82.3 (76.7–87.0) | 30.5 (22.8–39.5) | 94.5 (91.5–96.5) | 0.775 (0.674–0.875) | - |

(*Continued*)

**Table 4** (Continued).

| | Sensitivity (%) | Specificity (%) | PPV (%) | NPV (%) | AUC | p* |
|---|---|---|---|---|---|---|
| **Modified EWGSOP2** | | | | | | |
| SARC-F (≥ 4 points) | 37.8 (23.8–53.5) | 87.4 (82.3–91.6) | 38.6 (27.3–51.3) | 87.0 (84.2–89.5) | 0.678 (0.588–0.769) | b, c, d |
| SARC-F+AC (version 1: ≥8 points) | 75.0 (59.7–86.8) | 73.3 (66.7–79.2) | 37.5 (31.1–44.3) | 93.2 (89.1–95.8) | 0.799 (0.716–0.881) | a |
| SARC-F+AC (version 2: ≥10 points) | 75.0 (59.7–86.8) | 74.8 (68.3–80.5) | 38.8 (32.2–45.9) | 93.3 (89.3–95.9) | | |
| SARC-CalF+AC (≥11 points) | 77.3 (62.2–88.5) | 76.7 (70.3–82.3) | 41.5 (34.5–48.8) | 94.0 (90.1–96.5) | 0.820 (0.742–0.898) | a |
| SARC-CalF (≥11 points) | 57.8 (42.2–72.3) | 88.4 (83.3–92.3) | 51.0 (40.0–61.9) | 90.9 (87.6–93.4) | 0.778 (0.692–0.863) | a |
| SARC-F+EBM (≥12 points) | 51.1 (35.8–66.3) | 83.3 (77.6–88.0) | 39.0 (29.7–49.1) | 89.1 (85.7–91.7) | 0.746 (0.664–0.828) | - |

**Notes**: Data are presented with the 95% CI in parenthesis; *Significantly different ($p<0.05$) with: [a]SARC-F (≥ 4 points); [b]SARC-F+AC (version 1: ≥8 points) and SARC-F+AC (version 2: ≥10 points); [c]SARC-CalF+AC (≥11 points); [d]SARC-CalF (≥11 points); [e]SARC-F+EBM (≥12 points).

**Abbreviations**: PPV, positive predictive values; NPV, negative predictive values; AUC, area under the curve; EWGSOP1, the European Working Group on Sarcopenia in Older People; EWGSOP2, extended group for the European Working Group on Sarcopenia in Older People; AC, arm circumference.

against EWGSOP1[21] and modified EWGSOP2[10] criteria, while SARC-F and SARC-CalF had the highest Sp against EWGSOP2[1] criteria (86.6% and 86.1%, respectively).

Depending on the sarcopenia diagnostic criteria set used, the sensitivity of SARC-F, SARC-CalF, SARC-F+EBM, SARC-F+AC, and SARC-CalF+AC ranged 31.5–44.8%, 57.4–65.5%, 48.1–62.1%, 71.4–79.2% (for both versions), and 71.4–79.2%, respectively. The specificity ranged from 86.6–87.4%, 86.1–90.3%, 82.3–84.0%, 69.4–76.6% (version no.1), 70.7–78.2% (version no. 2), 72.1–79.7%, respectively. The AUC of SARC-F, SARC-CalF, SARC-F+EBM, SARC-F+AC, and SARC-CalF+AC ranged from 0.643–0.700, 0.757–0.792, 0.740–0.775, 0.767–0.812 (for both versions), and 0.771–0.852, respectively. Based on AUC, the diagnostic accuracy of all modified questionnaires was moderate, and low only for SARC-F. (Figure 3A–C) shows the ROC curves of SARC-F and its four modified versions against three sets of diagnostic criteria (EWGSOP1[21], EWGSOP2[1], and modified EWGSOP2[10]).

## Discussion

An ideal screening tool should combine high sensitivity (at least 80%) and reasonably high specificity.[6,15] High sensitivity is necessary for the efficient detection of affected subjects in a population. In contrast, high specificity reduces the number of false positive cases and helps to avoid unnecessary diagnostics and associated costs.[11,15] The sensitivity of SARC-F ranged from 31% to 45% in our analysis, depending on the applied diagnostic criteria. Our results demonstrate this questionnaire's lack of clinical utility and are consistent with previous findings indicating low to moderate sensitivity of SARC-F in diagnostics of sarcopenia.[6]

Four modified versions combining SARC-F items with various additional features were proposed to improve the diagnostic properties of this questionnaire. We analyzed these modified tools and found that all of them had higher sensitivity, NPV, and AUC than the original questionnaire, regardless of the used diagnostic criteria for sarcopenia (EWGSOP1[21], EWGSOP2[1], or modified EWGSOP2[10]). Similar results were found by Hax et al[11] in a group of 94 patients with systemic sclerosis (mean age 60.5±10.3 years, range 33–79). Hax et al[11] compared SARC-F with two modified versions (SARC-CalF and SARC-F+EBM) against EWGSOP2 criteria. They observed that SARC-F+EBM and SARC-CalF had better sensitivity, NPV, and AUC than SARC-F (SARC-F+EBM: 60%, 96.7%, and 0.832; SARC-CalF: 53.3%, 90.5% and 0.718; SARC-F: 40%, 87.7% and 0.588, respectively). However, different observations were made by Chen et al[12] in a group of 339 stable schizophrenic patients aged 50 years and older, who compared the same three tools against Asian diagnostic criteria for sarcopenia (ei, AWGS2019[24]). SARC-CalF had increased sensitivity but decreased specificity in comparison with SARC-F. In contrast, SARC-F+EBM had the highest specificity in both men and women, but its sensitivity and AUC were low in men (and not in women). This discrepancy may derive from a different health condition and the diverse age of the assessed populations. Subjects in our study were community-dwelling volunteers aged 60 and older (mean age 72.1±6.9 years), and none suffered from systemic sclerosis or schizophrenia.

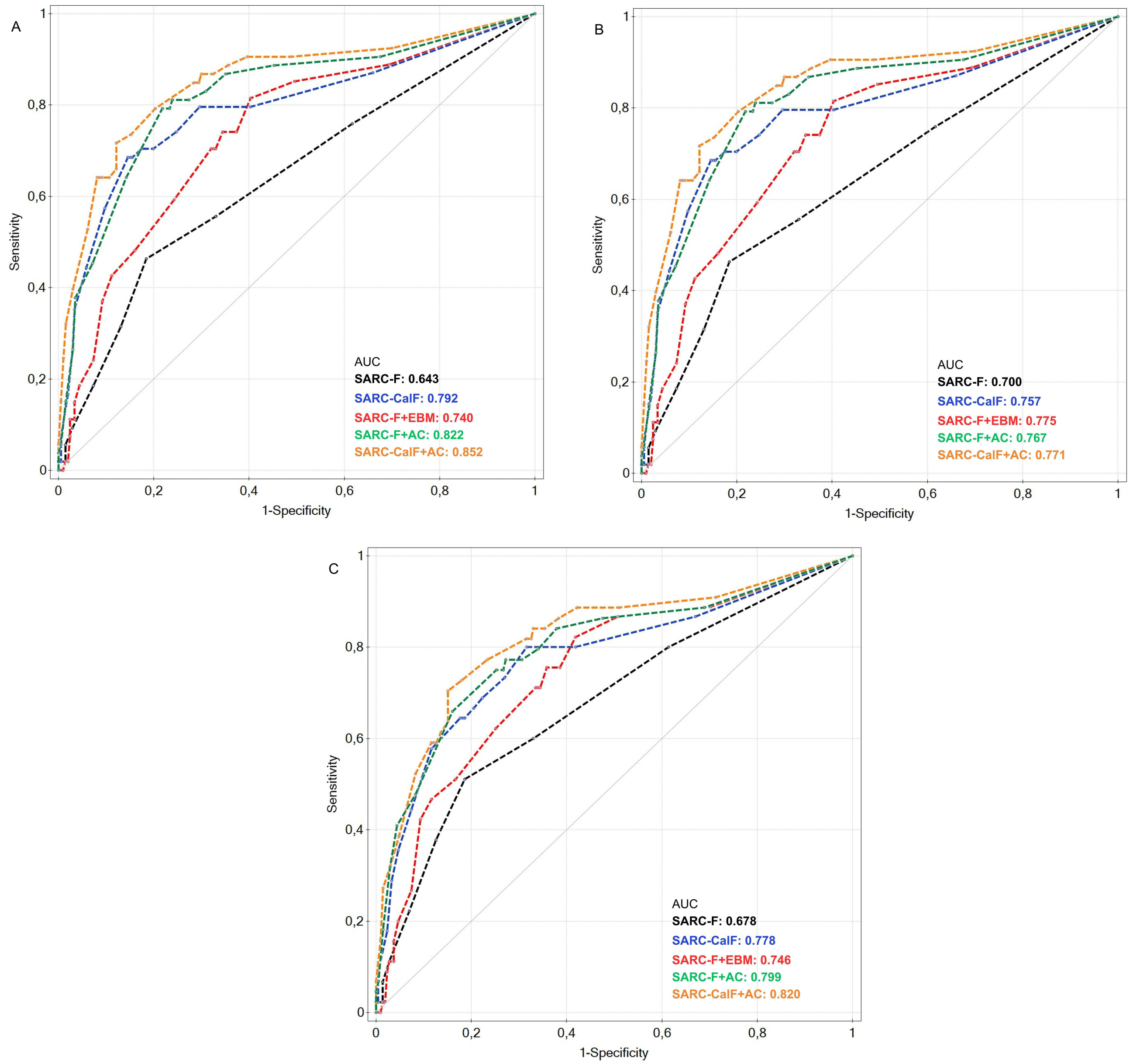



**Figure 3** The ROC Curves of SARC-F and Its Four Modified Versions (SARC-CalF, SARC-F+EBM, SARC-F+AC, SARC-CalF+AC) against EWGSOP1 (**A**), EWGSOP2 (**B**) and Modified EWGSOP2 criteria (**C**).

Our results are the best comparable with a recent analysis by Zhou et al,[15] who enrolled 401 volunteers aged at least 60 years and living in the community and used two sets of diagnostic criteria for sarcopenia: AWGS2019[24] and EWGSOP2[1]. They compared SARC-F with three modified versions: SARC-CalF, SARC-F+AC, and SARC-CalF+AC. We additionally assessed the fourth version: SARC-F+EBM. Zhou et al[15] observed very low sensitivity of the original SARC-F questionnaire (12.26% against AWGS2019 criteria[24] and 20.00% against EWGSOP2[1] criteria) but also very high specificity (>95% against both sets of diagnostic criteria). The SARC-CalF questionnaire had better sensitivity (47.17% against AWGS2019[24] criteria and 56.00% against EWGSOP2[1] criteria) while maintaining relatively high specificity (91.53% and 86.61%, respectively). The addition of arm circumference to both questionnaires notably increased their sensitivity (SARC-F+AC: 82.08% against AWGS2019[24] criteria and 70% against EWGSOP2[1] criteria; SARC-CalF+AC: 75.47% against AWGS2019[24] criteria and 80% against EWGSOP2[1] criteria), without an unacceptable drop in specificity (Sp >70% for both questionnaires). Similar results were found in our study: incorporation of arm circumference resulted in distinct improvement of SARC-F+AC and SARC-CalF+AC sensitivity in comparison with the original questionnaire (Se>70% against all used diagnostic criteria sets) while maintaining specificity ≥70% (regardless of the used diagnostic criteria set). These observations suggest that combining the SARC-F items with two anthropometric parameters (calf and arm circumference) enables more accurate identification of sarcopenia.

Anthropometric parameters, such as arm circumference, calf circumference, and body mass index, have been used for a long time in geriatric medicine to assess nutritional status. Studies conducted in the last decade suggest their usefulness in diagnosing sarcopenia, as mentioned in the introduction.[3,17–19] It should be emphasized that arm and calf circumference measurements are easily applicable in clinical practice, as they require only measuring tape, which is cheap, portable, and easy to use. Similarly, the calculation of BMI is an uncomplicated procedure, requiring only a scales and stadiometer.

The optimal cut-off points play a crucial role in the usefulness of anthropometric parameters in diagnosing sarcopenia. Cut-off points should be set to best differentiate subjects with and without this condition. Kim et al[25] noticed that many anthropometric parameters change with age, sex, ethnicity, and environment, which makes finding the standard cut-off points difficult. As national cut-off points for low CC have not been set, we used the most popular cut-off values used in the diagnostics of sarcopenia, proposed in 2016 by Barbosa-Silva et al[7] in the SARC-CalF tool: 33 cm for women and 34 cm for men. These cut-off points were also used in our previous papers[10,26] and some other European[27,28] studies. However, a lower and equal for both sexes threshold of 31 cm was assumed in most research performed in this region of the world.[29,30] Using uniform values of CC cut-off points for both sexes is controversial because men usually have higher calf circumferences than women.[18,30–32] In 2020, we compared the diagnostic performance of SARC-CalF against SARC-F using the CC cut-off point of 31 cm for both sexes and the CC cut-off point of 33 cm for women and 34 cm for men.[10] SARC-CalF with a CC cut-off point of 31 cm did not have higher sensitivity than the original SARC-F questionnaire (although its specificity and AUC were slightly better). In contrast, the application of 33/34 cm CC cut-off points resulted in nearly twice higher sensitivity while maintaining the specificity at the same level as the SARC-F tool. The SARC-CalF 33/34 cm had the best AUC among the studied questionnaires.[10]

To the best of our knowledge, the optimal arm circumference cut-off points for sarcopenia have not been assessed in the Central and Eastern Europe Caucasian population. As the cut-off threshold established by Zhou et al[15] in older Chinese people (28.4 cm in women and 29.5 cm in men) seemed inappropriate for our analysis, we decided to determine these thresholds in our study sample. The arm circumference cut-off points for sarcopenia established in our study were lower than in the Chinese study (25 cm in women and 27 cm in men). These cut-off points should be viewed cautiously, as our study sample was relatively small and not representative of the older Polish population. They should be verified in a larger group before a broader application.

It should be emphasized that some studies assessing the usefulness of anthropometric parameters in sarcopenia diagnostics used a midarm muscle circumference[32] or an arm circumference corrected by triceps skinfold thickness[19] instead of the arm circumference. This correction requires the assessment of skinfold thickness at the triceps with a caliper and using a conversion formula. We included in our analysis the results of studies using the arm circumference only.[3,15,17,18]

Our study has some limitations. Firstly, the sample comprises volunteers aged ≥60 years, and thus it is not representative of the total elderly population in Poland. Secondly, national cut-off points for low CC have not been determined in Poland. Therefore, we employed the most commonly used CC thresholds for sarcopenia (33 cm in women and 34 cm in men). We cannot be sure if these cut-off points are appropriate for the Polish population. Thirdly, we used the BIA method to assess ALM instead of computed tomography, magnetic resonance imaging, or dual X-ray analysis, which are considered more precise. However, the BIA method is much cheaper and safer (free of x-ray exposure). The analyzers are portable, which makes possible the assessment of elderly subjects at their living sites. Moreover, some international groups, such as EWGSOP1[21], EWGSOP2[1], and AWGS[24], recommended BIA as an alternative option for muscle measurement. Fourthly, the arm circumference cut-off points for diagnostics of sarcopenia determined in our study should be viewed with caution because they were established in a relatively small sample. Finally, as we enrolled community-dwelling elderly persons using a voluntary sampling method, a selection bias is likely because subjects with more severe sarcopenia were presumably less willing to participate. Therefore, generalization of our results to more frail populations, eg, nursing home residents, should be made with caution.

A strong point of our analysis is that it is the first assessment of the diagnostic performance of the SARC-F questionnaire and all its currently available modifications (SARC-CalF, SARC-F+EBM, SARC-F+AC, SARC-CalF +AC). To our knowledge, this was the first study demonstrating the diagnostic utility of incorporating two simple anthropometric measurements, ie, arm and calf circumference, with SARC-F for screening sarcopenia in community-dwelling older Europeans.

## Conclusion

Sarcopenia is a severe threat to healthy aging and should be routinely screened in elderly persons. The SARC-F questionnaire has low diagnostic accuracy, which limits its usefulness as a sarcopenia screening tool. Incorporating two simple anthropometric measurements, ie arm and calf circumference, notably improves the diagnostic performance of SARC-F. Based on our results, SARC-CalF+AC seems to be the best screening tool for sarcopenia screening in community-dwelling older adults. The diagnostic accuracy of this questionnaire should be confirmed in further studies, performed in various populations.

## Disclosure

The authors report no conflicts of interest in this work.

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