Original Article

Validity of the modified versions of SARC-F+EBM for sarcopenia screening and diagnosis in China: the PPLSS study

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Background and Objectives: It is recommended by Asian Working Group for Sarcopenia to early identify people at risk for sarcopenia using simple screening tools like SARC-F. The modified version SARC-F+EBM showed higher diagnostic performance. However, this cut-off value of body mass index (BMI) remained uncertain to be used in Chinese population. In this study, we used appropriate BMI recommended for Chinese older population and further modified SARC-F+EBM by combining calf circumference. **Methods and Study Design:** Diagnostic tests were performed and the receiver operating characteristics analyses were conducted between the SARC-F, SARC-F+EBM (cut-off of BMI: $\leq$ 21 kg/m^2), SARC-F+EBM (CN) (cut-off of BMI: $\leq$ 22 kg/m^2), SARC-CalF and SARC-CalF+EBM (CN) (cut-off of BMI: $\leq$ 22 kg/m^2) in 1660 community-dwelling participants aged $\geq$ 65 years from China. **Results:** The participants had an average age of 71.7±5.1 years, of which 56.8% were women. All the modified models could enhance the areas under the receiver operating characteristic curve (AUC) of original SARC-F (all p<0.001). The SARC-F+EBM (CN) also showed a significantly higher sensitivity of 47.4% (p<0.001) and an AUC of 0.809 (p=0.005) than SARC-F+EBM. SARC-CalF+EBM (CN) was validated to be of great diagnostic value of the highest AUC of 0.88 among these sarcopenia screening tools, including SARC-F, SARC-CalF and SARC-F+EBM (CN) (all p<0.001). Using this study population as a reference, the optimal cut-off value of SARC-CalF+EBM (CN) is ≥12 points, with a sensitivity of 79.3% and a specificity of 80.7%. **Conclusions:** The SARC-F+EBM (CN) and SARC-CalF+EBM (CN) could enhance the diagnostic performance of SARC-F and SARC-F+EBM and are suitable sarcopenia screening tools for Chinese population.

Key Words: sarcopenia, SARC-F, diagnostic test, older, Chinese

INTRODUCTION

Sarcopenia, as a gerontology syndrome, is significantly associated with falls, fractures, all-cause mortality and other adverse outcomes[1] and affects nearly 15% of the population in Asia[2] and 9.2%-16.2% in China.[3] The Asian Working Group for sarcopenia (AWGS) developed consensus on the diagnosis and treatment of sarcopenia for the Asian population.[4] In the 2019 updated consensus of AWGS, it is recommended to early identify people at risk for sarcopenia and promote the case finding using simple screening tools such as SARC-F and SARC-CalF, especially in the community setting.[5]

SARC-F is a simple questionnaire first established by Malmstrom and Morley,[6] and was validated not only in Western countries but also in Asian population.[7, 8] We translated it into Chinese and conducted the cross-cultural adaptation and validation according to the standard methods of the European Union Geriatric Medicine Society Sarcopenia Special Interest Group.[9] The Chinese version of SARC-F was demonstrated to be of good reliability and diagnostic accuracy.[10]

However, SARC-F has low to moderate sensitivity and moderate to high specificity despite its good reliability, which has led to controversy over its clinical use.[7] Therefore, more screening tools were developed to promote the case finding, like the Ishii test and the mini Sarcopenia risk assessment questionnaire and so on.[11, 12] It is worth mentioning that the SARC-CalF made great progress by combining calf circumference measurement with the five questions of SARC-F13 and was also recommended by AWGS2019 consensus.[5]

The original SARC-F questions only focus on strength and physical performance. Kurita et al. established anoth-

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er modified SARC-F questionnaire called SARC-F+EBM, which additionally includes dimensions of aging and body composition.[14] Combined use of SARC-F, age and body mass index (BMI) showed higher sensitivity and diagnostic performance among Japanese and Poland population.[14, 15] In SARC-F+EBM, a BMI ≤ 21 kg/m^2 was considered to be underweight.[14] However, this cut-off value of BMI remained uncertain to be used in Chinese population because of the different ethnic backgrounds and social-economy factors.

In this study, we used the appropriate body mass index ≥22 kg/m^2 recommended for Chinese older population to adjust SARC-F+EBM.[16] We further modified SARC-F+EBM by combining calf circumference to improve its clinical use and diagnostic accuracy. By recruiting community-dwelling participants aged ≥65 from China, the diagnostic values of these SARC-F modified versions were validated to facilitate the use of sarcopenia screening and diagnosis tools in Chinese communities and to promote the early detection of sarcopenia.

METHODS

Study population and design

We used the cross-sectional data of the Peking Union Medical College Hospital Multicenter Prospective Longitudinal Sarcopenia Study (PPLSS) from April to October 2022 in the rural community of Beijing, China.[17] The study was approved by the Human Ethics Committee of the Peking Union Medical College Hospital (no. ZS-3462) and all participants in this study provided written informed consent.

Participants aged ≥ 65 years, with independent physical ability and normal cognitive function were included in the study. While participants who were suffering from infectious diseases, neuromuscular diseases, or had electronic devices or metal materials implanted in the body were excluded from the study.

Data collection

Through face-to-face interviews, trained investigators collected information by structured questionnaire and displayed anthropometry and body composition measurements. Data on several aspects associated with the participants were collected, including demographic characteristics, personal behavior, nutritional status and medical history. Chronological age was determined according to the date of interview and the date of birth on the citizen identity card. Nutritional status was assessed by Mini Nutritional Assessment-Short Form (MNA-SF).[18]

Body height was measured using a fixed stadiometer. Calf circumference was measured on the left leg in a seated position with the knee and ankle at right angles. Grip strength was measured by using an electronic hand dynamometer (CAMRY MODEL EH101, HaNDCReW) and was calculated by taking the maximum value of the two consecutive measurements in the dominant hand. Gait speed was measured by timing the participants' ability to walk 6 m at a normal pace.

Muscle mass was measured using a segmental multifrequency bioelectrical impedance analysis (M-BIA) instrument (H-Key350, Beijing Seehigher Technology Co., Ltd). At the same time, body weight was measured. The skeletal muscle mass index (SMI) was calculated by dividing the sum of total appendicular skeletal muscle mass in kilograms by body height in meters squared. BMI was calculated by dividing the body weight in kilograms by body height in meters squared.

Sarcopenia diagnosis criteria

Criteria recommended in AWGS2019 consensus were used to define sarcopenia.[5] Confirmed sarcopenia was defined as participants with reduced muscle mass (SMI M:<7.0 kg/m^2, F:<5.7 kg/m^2) and either low muscle strength (grip strength M:<28 kg, F:<18 kg) or low physical performance (gait speed <1.0 m/s). Possible sarcopenia was defined as participants with low muscle strength or low physical performance. Severe sarcopenia was defined as participants with reduced muscle mass, low muscle strength and low physical performance.

Sarcopenia screening tools

SARC-F questionnaire for sarcopenia self-screening consists of five simple questions, including strength, assistance with walking, rising from a chair, climbing stairs and falls.6 Each question scores 0-2 points according to the physical ability, constituting a total of 0-10 points. In this study, we used the SARC-F Chinese version,[10] which was well cross-cultural adapted and validated according to the standard methods of the European Union Geriatric Medicine Society Sarcopenia Special Interest Group.[9] The translation process included forward translation, expert panel, back-translation, pre-testing and cognitive interviewing to generate the final version. The Chinese version SARC-F questionnaire and the back-translated version were approved that the translation could express the original meaning by John Morley, one of the authors of the SARC-F questionnaire.

SARC-F+EBM added the age and BMI components into the SARC-F questionnaire, with age ≥75 scored 10 points and BMI ≤ 21 kg/m^2 scored 10 points, otherwise scored 0 points, constituting a total of 0-30 points. The cut-off value of SARC-F+EBM was ≥12 points.[14]

Using the Chinese recommended cut-off value of appropriate BMI for Chinese older population of ≥22 kg/m^2,[16] we modified the SARC-F questionnaire with the following models: 1) SARC-F+BM combined SARC-F and BMI (≤21 kg/m^2 scored 10 points, otherwise scored 0 points) with cut-off values of ≥9 points; 2) SARC-F+BM (CN) combined SARC-F and BMI (≤22 kg/m^2 scored 10 points, otherwise scored 0 points) with cut-off values of ≥9 points; 3) SARC-F+EBM (CN) combined SARC-F, age (≥75 years scored 10 points, otherwise scored 0 point) and BMI (≤22 kg/m^2 scored 10 points, otherwise scored 0 points) with cut-off values of ≥12 points.

The SARC-CalF questionnaire combined SARC-F and calf circumference measurement, with a score ≥11 indicating sarcopenia risk.[13] The calf circumference additionally scores 10 points with the cut-off values of ≤ 34 cm for men and ≤ 33 cm for women, otherwise scored 0 points.

We further modified SARC-CalF by adding age and BMI and established another model: 4) SARC-CalF+EBM (CN) combined SARC-CalF, age (≥75 years scored 10 points, otherwise scored 0 points) and BMI (≤ 22 kg/m^2 scored 10 points, otherwise scored 0 points).

Statistical analyses

The statistical analyses were performed by STATA/SE 16.0 Software (StataCorp., T.X., USA). Continuous variables were described as means ± SD, and the categorical variables were described as counts and percentages. Comparison between groups was conducted using Student's t-test, Mann–Whitney test or Chi-squared test as appropriate. Diagnostic tests were performed to validate the accuracy of the sarcopenia screening models, and displayed by sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV). The receiver operating characteristics (ROC) analyses were conducted and the areas under the receiver operating characteristic curve (AUC) were compared by Chi-squared test. Differences were considered significant at $p< 0.05$.

RESULTS

Basic characteristics

This study included 1677 participants meeting the criteria. After excluding 12 participants with unfinished SARC-F questionnaires and 5 participants with unfinished body composition measurements, a total of 1660 participants remained in the statistical analysis.

Table 1 shows the basic characteristics of these 1660 study participants. The participants had an average age of 71.7±5.1 years, of which 56.8% were women. According to AWGS2019 sarcopenia diagnosis criteria, the prevalence of sarcopenia was 16.0% with 266 participants positive. While the positive rates of possible and severe sarcopenia were 78.3% and 9.6%, respectively. The participants with sarcopenia tended to be man and smokers, with higher age, worse nutritional status, lower waist circumference, calf circumference or BMI. Besides, the scores of SARC-F, SARC-CalF, SARC-F+EBM, and other modified models of participants with sarcopenia were significantly higher than those without sarcopenia (all $p<0.001$).

Diagnostic value and ROC analysis

To explore the BMI cut-off value suitable for Chinese population, we validated models of SARC-F+BM, which means SARC-F combined with BMI ≥21 kg/m^2 or ≥22 kg/m^2. Table 2 shows the diagnostic values of modified SARC-F screening tools according to AWGS2019 sarcopenia diagnosis criteria. All the modified models could enhance the sensitivity, PPV, NPV and AUC of original SARC-F (all AUC $p<0.001$). Especially, SARC-F+BM (CN) shows significantly higher sensitivity ($p<0.001$) and AUC ($p=0.01$) than SARC-F+BM, as shown in Figure 1A. Similarly, after substituting the BMI cut-off value of SARC-F+EBM to ≥ 22 kg/m^2, the SARC-F+EBM (CN) also showed significantly higher sensitivity of 47.4% (^{p}<0.001) and AUC of 0.809 ($p=0.005$) than SARC-F+EBM, as shown in Figure 1B.

In Table 3, SARC-CalF+EBM (CN), the further modification of SARC-CalF, was validated to be of great diagnostic value of the highest AUC of 0.88 among these sarcopenia screening tools, including SARC-F, SARC-CalF and SARC-F+EBM (CN) (all $p<0.001$), as shown in Figure 2A. Using this study population as a reference, the optimal cut-off value of SARC-CalF+EBM (CN) is ≥12 points, with a sensitivity of 79.3%, a specificity of 80.7% and a Youden index of 0.60.

To validate the application of SARC-F+EBM (CN) and SARC-CalF+EBM (CN) in this population, their ROC analyses were displayed according to AWGS2019 confirmed sarcopenia, possible sarcopenia and severe sarcopenia criteria respectively, as shown in Table 3. Firstly, the tests of AUC between genders remained insignificant ($p>0.05$, except for SARC-F against possible sarcopenia), which means that both men and women could use the same screening tools and cut-off values without gender adjustment. For possible sarcopenia, the original SARC-F remained the highest AUC of 0.663 and significantly higher than SARC-CalF ($p=0.001$) and SARC-CalF+EBM (CN) ($p=0.007$). For severe sarcopenia, SARC-F+EBM (CN) could significantly improve the diagnostic accuracy of SARC-F (AUC $p<0.001$), while SARC-CalF+EBM (CN) could also significantly improve the diagnostic accuracy of SARC-CalF (AUC $p=0.045$), as shown in Figure 2B.

DISCUSSION

In this study, the SARC-F+EBM (CN), the modified version of SARC-F+EBM adapted to Chinese population, was validated to have good diagnostic accuracy of sarcopenia. Furthermore, SARC-CalF+EBM (CN) was established to improve the diagnostic accuracy of SARC-CalF and SARC-F+EBM (CN), and we obtained its optimal cut-off value of ≥12 points to guide its clinical use. The applications of SARC-F screening tools against AWGS2019 defined sarcopenia in different severities were validated in the thorough ROC analyses. For screening confirmed sarcopenia and severe sarcopenia, both men and women could use the same SARC-F screening tools and cut-off values without gender adjustment, and the SARC-CalF+EBM (CN) was the most recommended in the clinical practice of Chinese population, because of its excellent diagnostic accuracy and the balanced sensitivity and specificity.

Nowadays many studies used SARC-F positive as the substitute measurement of sarcopenia diagnosis to overcome the drawback of muscle mass and muscle strength measurements.[19, 20] However, our result showed the same low sensitivity of under 20% as previous studies of Chinese population.[21] The low sensitivity of SARC-F may contribute to the missed diagnosis of the cases, which may cause the bias of results. The SARC-F+EBM (CN) and SARC-CalF+EBM (CN) could improve the sarcopenia cases found in Chinese community for clinical use in the future.

SARC-F+EBM was established and validated in Japanese older men with musculoskeletal disease,[14] and it was well validated in the community-dwelling population of Poland later.[15] We demonstrated similar results that SARC-F+EBM had better diagnostic performance compared to the original questionnaire. However, our modification further included calf circumference, which is another simple anthropometry measurement as a good representative of muscle mass. This SARC-CalF+EBM (CN) showed the highest diagnosis performance among these screening tools.

Table 1. Basic characteristics

Characteristic	Man			Woman			Total			
	Sarcopenia (n=136)	No sarcopenia (n=581)	*p*	Sarcopenia (n=130)	No sarcopenia (n=813)	*p*	Total (n=1660)	Sarcopenia (n=266)	No sarcopenia (n=1394)	*p*
Age (year) (mean±SD)	75.3±5.9	71.0±4.7	<0.001	75.2±5.5	70.9±4.6	<0.001	71.7±5.1	75.3±5.7	71.0±4.7	<0.001
Smoking (n [%])	60 (44.1)	225 (38.7)	0.247	5 (3.9)	31 (3.8)	0.985	321 (19.3)	65 (24.4)	256 (18.4)	0.022
Drinking (n [%])	54 (39.7)	268 (46.1)	0.175	2 (1.5)	34 (4.2)	0.214	358 (21.6)	56 (21.1)	302 (21.7)	0.824
Hypertension (n [%])	54 (39.7)	291 (50.1)	0.029	66 (50.8)	462 (56.8)	0.196	873 (52.6)	120 (45.1)	753 (54)	0.008
Coronary heart disease (n [%])	6 (4.4)	39 (6.7)	0.432	21 (16.2)	82 (10.1)	0.039	148 (8.9)	27 (10.2)	121 (8.7)	0.441
Diabetes (n [%])	17 (12.5)	94 (16.2)	0.286	21 (16.2)	176 (21.7)	0.152	308 (18.6)	38 (14.3)	270 (19.4)	0.051
MNA-SF (n [%])										
Malnourished	5 (3.7)	2 (0.3)	<0.001	4 (3.0)	1 (0.1)	<0.001	12 (0.7)	9 (3.4)	3 (0.2)	<0.001
Malnutrition risk	63 (46.3)	68 (11.7)		58 (44.6)	138 (17.0)		327 (19.7)	121 (45.5)	206 (14.8)	
Normal	68 (50.0)	511 (88.0)		68 (52.3)	674 (82.9)		1321 (79.6)	136 (51.1)	1185 (85)	
Waist circumference (cm)(mean±SD)†	82.6±8.6	92.3±8.9	<0.001	82.3±8.3	91.3±9.3	<0.001	90.2±9.7	82.5±8.4	91.7±9.1	<0.001
Calf circumference (cm) (mean±SD)	32.6±1.9	36.4±2.5	<0.001	30.9±2.3	34.9±2.7	<0.001	34.9±3	31.8±2.3	35.5±2.7	<0.001
BMI (kg/m^2) (mean±SD)	21.6±2.7	25.4±3.0	<0.001	22.1±3.0	26.0±3.5	<0.001	25.1±3.5	21.9±2.9	25.8±3.3	<0.001
SMI (kg/m^2) (mean±SD)	6.5±0.4	7.9±0.7	<0.001	5.3±0.4	6.6±0.6	<0.001	6.9±1	5.9±0.7	7.1±0.9	<0.001
Grip (kg) (mean±SD)	20.3±5.8	26.0±6.3	<0.001	13.0±4.1	16.6±4.8	<0.001	19.9±7.1	16.8±6.2	20.5±7.2	<0.001
Low gait speed (n [%])‡	80 (58.8)	219 (37.7)	<0.001	100 (76.9)	463 (57.0)	<0.001	862 (51.9)	180 (67.7)	682 (48.9)	<0.001
SARC-F score (mean±SD)	1.2±1.9	0.4±1.0	<0.001	2.0±2.2	1.0±1.5	<0.001	0.9±1.5	1.6±2.1	0.7±1.3	<0.001
SARC-F+BM score (mean±SD)	5.5±5.1	1.0±2.6	<0.001	5.0±4.8	1.5±2.6	<0.001	1.9±3.4	5.2±5	1.3±2.6	<0.001
SARC-F+BM(CN) score (mean±SD)	7.1±5.3	1.7±3.5	<0.001	7.0±5.2	2.1±3.4	<0.001	2.7±4.2	7±5.2	1.9±3.4	<0.001
SARC-F+EBM score (mean±SD)	10.5±7.8	3.1±4.8	<0.001	10.4±6.5	3.5±5.1	<0.001	4.5±6	10.5±7.2	3.3±5	<0.001
SARC-F+EBM(CN) score (mean±SD)	12.1±7.8	3.8±5.3	<0.001	12.4±6.6	4.1±5.6	<0.001	5.3±6.5	12.3±7.2	3.9±5.5	<0.001
SARC-CalF score (mean±SD)	9.4±4.2	2.2±3.9	<0.001	10.5±3.8	3.5±4.7	<0.001	4.1±5.1	9.9±4	3±4.5	<0.001
SARC-CalF+EBM(CN) score (mean±SD)	20.3±9.3	5.5±7.3	<0.001	21.0±8.1	6.7±8.0	<0.001	8.5±9.5	20.6±8.7	6.2±7.7	<0.001

MNA-SF, Mini Nutritional Assessment-Short Form; SMI, skeletal muscle mass index.
†Missing value n=48.
‡Low gait speed: gait speed <1.0 m/s

Table 2. The diagnostic values of screening tools according to AWGS2019 confirmed sarcopenia

Screening tool †	Sensitivity (%) ‡	Specificity (%) ‡	PPV (%) ‡	NPV (%) ‡	AUC ‡	*p* for equal AUC		
						vs SARC-F	vs SARC-F+BM	vs SARC-F+EBM
SARC-F	16.9 (12.6-22)	94.1 (92.8-95.3)	35.4 (27.2-44.4)	85.6 (83.7-87.3)	0.625 (0.589-0.66)			
SARC-F+BM	36.8 (31-42.9)	94.5 (93.1-95.6)	56 (48.3-63.5)	88.7 (87-90.3)	0.752 (0.718-0.786)	<0.001		
SARC-F+BM(CN)	54.9 (48.7-61)	88.1 (86.3-89.7)	46.8 (41.2-52.5)	91.1 (89.4-92.6)	0.78 (0.747-0.812)	<0.001	0.01	
SARC-F+EBM	38.7 (32.8-44.9)	92.6 (91.1-93.9)	50 (43-57)	88.8 (87.1-90.4)	0.787 (0.756-0.817)	<0.001	0.008	
SARC-F+EBM(CN)	47.4 (41.2-53.6)	90.6 (88.9-92.1)	49 (42.8-55.3)	90 (88.3-91.5)	0.809 (0.78-0.838)	<0.001	<0.001	0.005

PPV, positive predictive value; NPV, negative predictive value; AUC, areas under the receiver operating characteristic curve.
†Cutoff points: SARC-F≥4, SARC-F+BM≥9, SARC-F+BM (CN) ≥9, SARC-F+EBM ≥12, SARC-F+EBM (CN) ≥12.
‡Data are presented with the 95% CI in parenthesis.

Table 3. The ROC analysis of screening tools according to AWGS2019 defined different stages of sarcopenia

	AUC			p_1†	p_2‡		
	Total	Man	Woman		vs SARC-F	vs SARC-F+EBM(CN)	vs SARC-CalF
Confirmed sarcopenia							
SARC-F	0.625 (0.589-0.66)	0.632 (0.585-0.679)	0.642 (0.591-0.693)	0.778			
SARC-F+EBM (CN)	0.809 (0.78-0.838)	0.796 (0.752-0.84)	0.829 (0.794-0.863)	0.252	<0.001		
SARC-CalF	0.847 (0.823-0.87)	0.865 (0.832-0.898)	0.847 (0.817-0.878)	0.442	<0.001	0.017	
SARC-CalF+EBM (CN)	0.88 (0.86-0.901)	0.882 (0.853-0.911)	0.886 (0.858-0.914)	0.848	<0.001	<0.001	<0.001
Possible sarcopenia							
SARC-F	0.663 (0.643-0.682)	0.612 (0.585-0.64)	0.7 (0.673-0.727)	<0.001			
SARC-F+EBM (CN)	0.651 (0.623-0.679)	0.622 (0.581-0.663)	0.676 (0.636-0.715)	0.064	0.388		
SARC-CalF	0.614 (0.585-0.644)	0.586 (0.544-0.628)	0.632 (0.591-0.674)	0.127	0.001	0.019	
SARC-CalF+EBM (CN)	0.621 (0.59-0.651)	0.6 (0.556-0.645)	0.636 (0.594-0.678)	0.253	0.007	0.001	0.482
Severe sarcopenia							
SARC-F	0.744 (0.704-0.784)	0.761 (0.702-0.821)	0.739 (0.685-0.794)	0.595			
SARC-F+EBM (CN)	0.846 (0.814-0.879)	0.847 (0.795-0.899)	0.848 (0.808-0.887)	0.984	<0.001		
SARC-CalF	0.863 (0.836-0.89)	0.862 (0.818-0.907)	0.87 (0.841-0.9)	0.767	<0.001	0.332	
SARC-CalF+EBM (CN)	0.883 (0.858-0.907)	0.879 (0.84-0.918)	0.888 (0.858-0.919)	0.717	<0.001	<0.001	0.045

AUC, areas under the receiver operating characteristic curve.
†p1 for equal AUC between genders.
‡p2 for equal total AUC between tools.

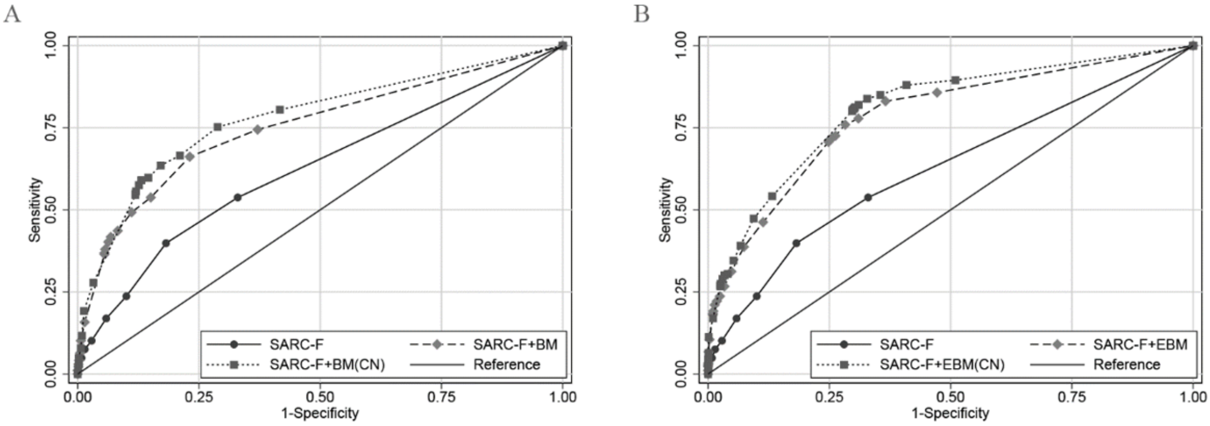

Figure 1. (A) The receiver operating characteristics curves of SARC-F, SARC-F+BM and SARC-F+BM (CN) against AWGS2019 confirmed sarcopenia. (B) The receiver operating characteristics curves of SARC-F, SARC-F+EBM and SARC-F+EBM (CN) against AWGS2019 confirmed sarcopenia.

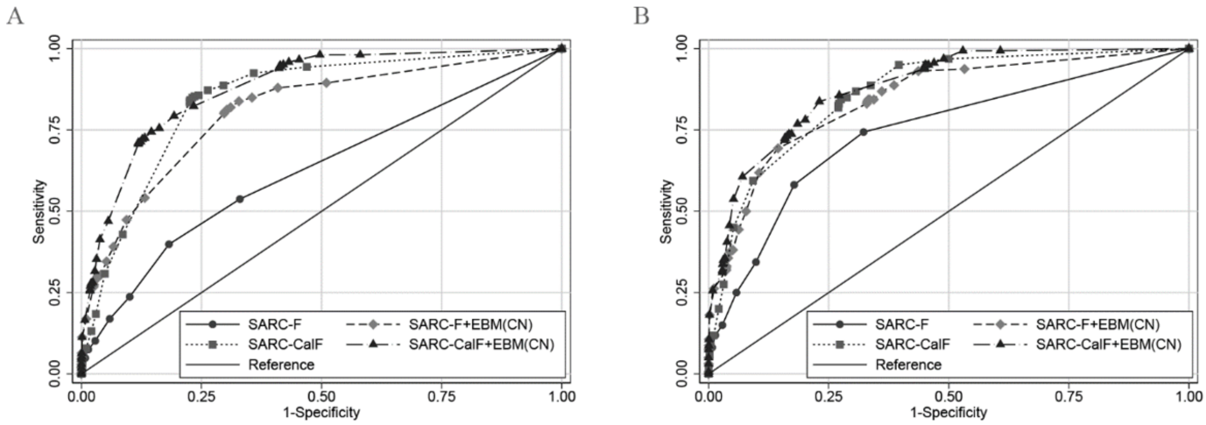

Figure 2. (A) The receiver operating characteristics curves of SARC-F, SARC-F+BM (CN), SARC-CalF and SARC-CalF+EBM (CN) against AWGS2019 confirmed sarcopenia. (B) The receiver operating characteristics curves of SARC-F, SARC-F+BM (CN), SARC-CalF and SARC-CalF+EBM (CN) against AWGS2019 severe sarcopenia.

For confirmed and severe sarcopenia, the SARC-F+EBM (CN) and SARC-CalF+EBM (CN) showed much higher diagnostic value than before, which means moderate to severe sarcopenia were easier to find by these tools. However, the original SARC-F was validated to be the best tool for finding possible sarcopenia, remaining the highest AUC of 0.663. Our results showed that the positive rate of possible sarcopenia (78.3%) in the study population was much higher than confirmed sarcopenia (16.0%). It is partly because in AWGS2019 diagnosis criteria, possible sarcopenia was defined as participants with low muscle strength or low physical performance, while the decline of muscle strength was reported to early appear than muscle mass.[22, 23] That suggests age, BMI, or calf circumference are not the beginning symptoms for finding sarcopenia in an early stage. Therefore, SARC-F and the modified screening tools are not suitable for screening possible sarcopenia. In the future, the case finding tools need further exploration by combining more sensitive measurements or early onset symptoms for the early detection and intervention of the risk population.

It is worth noting that SARC-F has the advantage of simplicity and time saving attributing to the five objective questions. This self-report instrument is of great importance for case finding and health education in the communities and primary health care systems. Likewise, age, BMI and calf circumference are indicators easy to get and measure. Therefore, SARC-F+EBM (CN) and SARC-CalF+EBM (CN) are especially suitable for the wide use in communities of China.

In this study, we adjusted the cut-off value of BMI in SARC-F+EBM according to the up-to-date recommendation of Chinese Nutrition Society for Chinese older population, especially for the oldest older population.[16] BMI is a simple index reflecting nutrition status. For the older population, low BMI was significantly associated with an increased likelihood of probable sarcopenia.[24] While the moderately higher BMI appeared protective effects on health and aging. Our former results showed, among the elderly population, the average age was 74.4 ± 9.93 and average BMI was 22.2 ± 3.08 in the participants with sarcopenia, and they were significantly different from those in the participants without sarcopenia (all p<0.01), respectively.[3] Recently, a study from West China established the BMI cut-off value of <25 kg/m^2 for the identification of sarcopenia.[25] However, the best range of BMI for sarcopenia screening and diagnosis should be further validated due to the conflicting effects of overweight and obesity.

Although establishing the screening tools suitable for Chinese population and improving the diagnostic performance of SARC-F+EBM and SARC-CalF, our study has some disadvantages. Firstly, this study population was from rural areas of northern China. The population from southern China or urban regions need to be included and more validation studies throughout the country are highly warranted. Secondly, the optimal SARC-CalF+EBM (CN) cut-off value of ≥12 points derived from this study population was equal to the one of SARC-F+EBM by Kurita et al.[14] It may cause by the study population that men with musculoskeletal disease may score higher in the SARC-F questionnaire. To confirm and finally determine the optimal cut-off value of SARC-CalF+EBM (CN), more large sample studies of Chinese population are needed.

The SARC-F+EBM (CN) and SARC-CalF+EBM (CN) could enhance the diagnostic performance of SARC-F and SARC-F+EBM and are suitable sarcopenia screening tools for Chinese population. More studies expanding sample size and settings to validate these screening and diagnosis tools are warranted.

CONFLICT OF INTEREST AND FUNDING DISCLOSURES

The authors declare no personal or financial conflicts of interest.

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