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RESEARCH

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Prevalence of sarcopenic obesity: comparison of different diagnostic criteria and exploration of optimal screening methods

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Abstract

Background and aims Despite concerns on the adverse health outcomes of sarcopenic obesity (SO), exploration regarding the applicability of different diagnostic criteria and the optimal screening methods is still lacking. This study aims to compare the prevalence and diagnostic agreement of SO under four diagnostic criteria in Chongming, Shanghai, China and assess the diagnostic value of nine screening methods for SO.

Methods The study population included older people aged ≥ 65 years. The Asian Working Group for Sarcopenia-2019 (AWGS-2019) was used to diagnose sarcopenia. Obesity was defined using percentage of body fat (PBF), percent of body fat exceeding the 60th percentile (60% PBF), body mass index (BMI) and waist circumference (WC). The four diagnostic criteria for SO were AWGS + PBF, AWGS + 60% PBF, AWGS + BMI and AWGS + WC. Nine screening methods were the sarcopenia questionnaire [the questionnaire with five items to screen for sarcopenia (SARC-F), the addition of calf circumference to the SARC-F (SARC-CalF), and the addition of elderly age and BMI to the SARC-F (SARC-F + EBM)] combined with commonly used obesity indicators. Cohen's kappa compared agreement between diagnostic criteria, whilst sensitivity, specificity, receiver operating characteristics (ROC) and area under the ROC curve (AUC) compared the diagnostic value of nine screening methods.

Results A total of 1407 older people were enrolled. The prevalence of SO ranged from 0.3 to 9.9%. The highest agreement between AWGS + 60% PBF and AWGS + PBF. When the AWGS + PBF was used as the 'gold standard' (due to its high agreement and high prevalence), SARC-CalF + PBF had the highest AUC value, and SARC-F + BMI had the highest sensitivity. The recommended cut-off values for SARC-F + BMI are SARC-F ≥ 1 score and BMI ≥ 19.845 kg/m^2, and the recommended cut-off values for SARC-CalF + PBF are SARC-CalF ≥ 5 score and PBF ≥ 34.55%.

Conclusion The prevalence of SO varied greatly amongst the four diagnostic criteria. AWGS + PBF is recommended for diagnosing SO in older people. SARC-F + BMI and SARC-CalF + PBF can be used as screening methods for SO.

Keywords Sarcopenic obesity, Prevalence, Diagnostic criteria, Screening method

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Introduction

Sarcopenic obesity (SO) is a clinical and functional syndrome where sarcopenia coexists with obesity [1]. According to the Asian Working Group for Sarcopenia-2019 (AWGS-2019), sarcopenia is characterised by ageing-induced skeletal muscle mass loss and decreased muscle strength and/or physical performance [2]. Sarcopenia and obesity synergistically accelerate muscle loss and fat gain due to common pathogenetic factors, including ageing, inflammation, insulin resistance and decreased physical activity [3, 4]. This vicious cycle exacerbates the adverse consequences of SO compared with either sarcopenia or obesity alone, with a predicted impact on 100 to 200 million people over the next 30 years [5]. Thus, early detection of SO is crucial for effectively preventing and treating adverse health outcomes in older people.

Although the European Society for Clinical Nutrition and Metabolism (ESPEN) and the European Association for the Study of Obesity (EASO) have proposed consensus on diagnostic criteria and screening methods for SO, these contents have not been widely accepted and applied globally, especially in Asia.A Canadian longitudinal study of individuals aged 65 and older found SO prevalence ranging from 0.1 to 85.3% in men and 0–80.4% in women using 29 diagnostic criteria [6]. In India, Pal et al. [7] investigated 111 older people aged ≥ 65 years using the diagnostic criteria of the European Working Group on Sarcopenia in Older People-2019 (EWGSOP-2019), which were combined with body mass index (BMI), waist circumference (WC) or percent of body fat (PBF) to describe SO; the prevalence percentages were 5.4%, 5.4% and 6.3%, respectively. A recent study on the relationship between different diagnostic criteria and the prevalence of SO noted that the highest prevalence of SO (7.9%) was observed when AWGS-2019 combined with visceral fat area (VFA) was used, followed by AWGS-2019 combined with WC (4.9%) and AWGS-2019 combined with PBF (4.5%); the SO prevalence was only 0.1% when AWGS-2019 combined with BMI was utilised [8]. The commonly used diagnostic criteria for sarcopenia include AWGS [9], EWGSOP [10], International Working Group on Sarcopenia (IWGS) [11] and Foundation for the National Institutes of Health (FNIH) [12]. Commonly used diagnostic criteria for obesity encompass BMI [13], PBF [14], percent of body fat exceeding the 60th percentile of the study sample (60% PBF) [15] and WC [13]. Different diagnostic criteria may differ in the accuracy of patient diagnosis, which contributes to the inconsistency in the mentioned diagnostic results. Therefore, a comparative evaluation of commonly used diagnostic criteria is essential to determine the most appropriate combination of diagnostic criteria for the given region.

Despite recent alarming concerns on the dangers of SO, no screening tools have been developed in Asia. In sarcopenia, muscle mass is commonly measured using dual-energy X-ray absorptiometry (DXA) and bioelectrical impedance analysis (BIA), which are not easily accessible and require professional measurement. Thus, simple questionnaires have been developed and validated for sarcopenia screening globally. The questionnaire with five items to screen for sarcopenia (SARC-F) was developed in 2013 as the first simple screening scale, which was recommended by AWGS-2019 and EWGSOP-2018. The addition of calf circumference to the SARC-F (SARC-CalF) significantly improves the screening accuracy of SARC-F for sarcopenia, with doubled sensitivity (from 33 to 66%) without effecting its specificity [16, 17]. Another prospective screening questionnaire is the addition of elderly age and BMI to the SARC-F (SARC-F + EBM) proposed by Kurita et al. in 2019 [18]. This approach introduces two sarcopenia risk factors (high age and low BMI) to the SARC-F screening questionnaire, although limited studies have explored its screening value. Obesity screening using PBF, BMI or WC was simple and widely used. Therefore, we explored the potential of combining the sarcopenia screening questionnaire with obesity screening variables as an initial screening method for SO. Diagnostic values [sensitivity, specificity, area under the receiver operating characteristics (ROC) curve (AUC) and optimal cut-off values] were explored to identify an ideal, practical and time-saving screening method suitable for use by professionals and non-professionals.

The lack of consistent diagnostic criteria and effective screening methods is a major limitation in the in-depth study of SO. To the best of our knowledge, no published study has compared the prevalence and diagnostic agreement of different diagnostic criteria in older people, and the diagnostic value of various screening methods of SO remains unexplored. Therefore, our study aimed to achieve the following objectives in the older population of suburban Shanghai: (1) compare the prevalence and diagnostic agreement of SO under four diagnostic criteria (AWGS + PBF, AWGS + 60% PBF, AWGS + BMI and AWGS + WC) to determine the most appropriate diagnostic criterion (the 'gold standard' of SO) in Chongming District, Shanghai; (2) evaluate the diagnostic value of nine SO screening methods (SARC-F + PBF, SARC-F + BMI, SARC-F + WC, SARC-CalF + PBF, SARC-CalF + BMI, SARC-CalF + WC, SARC-F + EBM + PBF, SARC-F + EBM + BMI and SARC-F + EBM + WC), which were analysed by ROC analysis with the 'gold standard' to determine the optimal screening method and the respective cut-off value for screening. We hope that our study contributes to a theoretical basis for the screening and

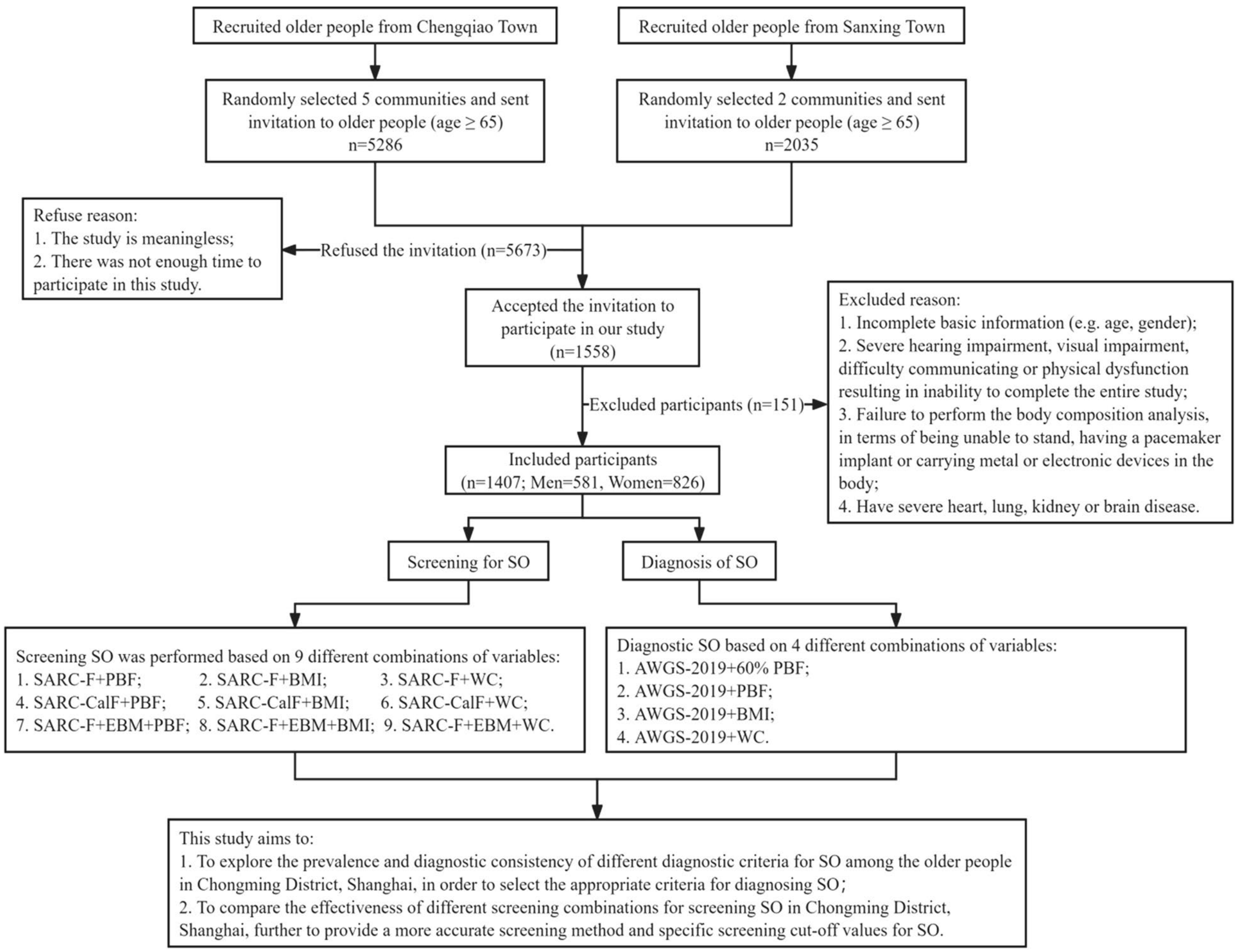

Fig. 1 Flow chart of this study

Abbreviations: SO, sarcopenic obesity; SARC-F, the questionnaire with five items to screen for sarcopenia; SARC-CalF, the addition of calf circumference to the SARC-F; SARC-F + EBM, the addition of elderly age and BMI to the SARC-F; PBF, percentage of body fat; BMI, body mass index; WC, waist circumference; AWGS-2019, Asian Working Group for Sarcopenia-2019

diagnosis of SO and ultimately promotes the prevention and treatment of SO in older communities.

Materials and methods

Study design and participants

This cross-sectional study was conducted in Chongming District, Shanghai, China from April 2021 to December 2021. We randomly selected two towns (Chengqiao town and Sanxing town) from 16 towns in Chongming District in proportion to age and gender. Seven communities were then selected from the two towns using a computer-generated random list, with five communities from Chengqiao town ($n = 5286$) and two communities from Sanxing town ($n = 2035$). The flowchart of this study is shown in Fig. 1.

The inclusion criteria were as follows: (1) age ≥ 65 years; (2) residing in Chengqiao town or Sanxing town, Chongming District; and (3) willingness to enrol in the study.

The exclusion criteria were as follows: (1) serious cognitive impairment, mental illness or other neurodegenerative diseases; (2) significant hearing impairment, visual impairment or communication barriers preventing the performance of instructions; and (3) physical disability or motor dysfunction resulting in the inability to walk, test handgrip strength (HS) and test gait speed (GS) over a distance of 6 m.

A total of 1558 participants were recruited in this study, all of whom were informed of the purpose and content of this study and signed the informed consent form. Complete data from 1407 participants were ultimately

Table 1 The variables and cut-off values for different diagnostic criteria

Variables	Reference	Cut-off points	
		Men	Women
Sarcopenia	AWGS-2019 [2]	ASMI < 7.0 kg/m^2 + HS < 28 kg; or ASMI < 7.0 kg/m^2 + GS < 1.0 m/s	ASMI < 5.7 kg/m^2 + HS < 18 kg; or ASMI < 5.7 kg/m^2 + GS < 1.0 m/s
60% PBF	Baumgartner et al. [15]	≥ 30.6%	≥ 36.8%
PBF	WHO [14]	≥ 25%	≥ 35%
BMI	China Blue Paper on Obesity Prevention and Control [13]	≥ 28 kg/m^2	≥ 28 kg/m^2
WC	China Blue Paper on Obesity Prevention and Control [13]	≥ 90 cm	≥ 85 cm

AWGS-2019 Asian Working Group for Sarcopenia-2019, *PBF* percentage of body fat, *BMI* body mass index, *WC* waist circumference *WHO* World Health Organisation

obtained for analysis in this study due to withdrawals for personal reasons or incomplete information. This study met the criteria of the Declaration of Helsinki, and the study protocol was approved by the Ethics Committee of Chongming Hospital Affiliated to Shanghai University of Medicine and Health Sciences (approval number: CMEC-2020-KT-42).

Definitions of SO

In this study, sarcopenia was defined in accordance with AWGS-2019 [9]: decreased muscle mass, diminished muscle strength and/or lower physical performance. The specific diagnostic cut-off values for sarcopenia and obesity are shown in Table 1.

Obesity is defined using four criteria: (1) 60% PBF of the study sample, as proposed by Baumgartner et al. [15]; (2) PBF according to the World Health Organisation [14]; (3) BMI as per the China Blue Paper on Obesity Prevention and Control [13]; and (4) WC as per the China Blue Paper on Obesity Prevention and Control [13].

Following the European Society for Clinical Nutrition and Metabolism and European Association for the Study of Obesity Consensus Statement [1], SO was defined as the co-occurrence of sarcopenia and obesity. Therefore, this study considered four combinations of SO: AWGS + 60% PBF, AWGS + PBF, AWGS + BMI and AWGS + WC.

Assessments of sarcopenia

The researchers strictly followed the standardised assessment methods described in AWGS-2019 [9] to measure muscle mass, muscle strength and physical performance.

Muscle mass

Muscle mass was expressed as the appendicular skeletal muscle mass index (ASMI). The sum of appendicular skeletal muscle mass (ASM) of upper and lower limbs was measured by BIA (Inbody720, Korea), with the unit in kg. The measurement protocol included specific requirements: participants were to be measured on an empty stomach and refrained from exercise or physical activity before the test. Participants stood on the examination table without shoes, with their feet shoulder-width apart and the angle between the trunk and upper limbs kept at 15°. They remained stationary during the test until the BIA indicated the end of the measurement. The formula for ASMI calculation is ASM/height^2, with the unit in kg/m^2.

Muscle strength

Muscle strength was expressed as dominant HS, which was measured using a handheld grip dynamometer (Jamar Plus + Digital Hand Dynamometer; IL, USA). The test protocol included certain requirements: participants maintained a standing position with the upper arm close to the body, elbow flexed at 90° and used their dominant hand to squeeze the dynamometer with maximum force for at least 5 s. Three consecutive measurements were conducted, with each test interval of 1 min, and the highest value was utilised as the final test result with the unit in kg.

Physical performance

Physical performance was expressed as GS over a distance of 6 m. The measurement protocol included the following requirements: participants walked the 6 m at their normal GS, and the test was performed twice. The average speed was then recorded with the unit in m/s.

Assessments of obesity

60% PBF and PBF

PBF was directly measured using BIA. In this study, the cut-off values for 60% PBF were ≥ 30.6% and ≥ 36.8% for men and women, respectively.

BMI

The formula for calculating BMI is weight (kg)/height^2 (m^2).

WC

WC was recorded in cm. The measurement process involved researchers using a soft tape to measure the narrowest circumference between the lowest rib and the iliac crest of the participants.

Table 2 The variables and cut-off values for the different screening methods

Variables	Cut-off values	
	Men	Women
SARC-F + PBF	SARC-F ≥ 4 and PBF ≥ 25%	SARC-F ≥ 4 and PBF ≥ 35%
SARC-F + BMI	SARC-F ≥ 4 and BMI ≥ 28 kg/m^2	SARC-F ≥ 4 and BMI ≥ 28 kg/m^2
SARC-F + WC	SARC-F ≥ 4 and WC ≥ 90 cm	SARC-F ≥ 4 and WC ≥ 85 cm
SARC-CalF + PBF	SARC-CalF ≥ 11 and PBF ≥ 25%	SARC-CalF ≥ 11 and PBF ≥ 35%
SARC-CalF + BMI	SARC-CalF ≥ 11 and BMI ≥ 28 kg/m^2	SARC-CalF ≥ 11 and BMI ≥ 28 kg/m^2
SARC-CalF + WC	SARC-CalF ≥ 11 and WC ≥ 90 cm	SARC-CalF ≥ 11 and WC ≥ 85 cm
SARC-F + EBM + PBF	SARC-F + EBM ≥ 12 and PBF ≥ 25%	SARC-F + EBM ≥ 12 and PBF ≥ 35%
SARC-F + EBM + BMI	SARC-F + EBM ≥ 12 and BMI ≥ 28 kg/m^2	SARC-F + EBM ≥ 12 and BMI ≥ 28 kg/m^2
SARC-F + EBM + WC	SARC-F + EBM ≥ 12 and WC ≥ 90 cm	SARC-F + EBM ≥ 12 and WC ≥ 85 cm

SARC-F the questionnaire with five items to screen for sarcopenia, *SARC-CalF* the addition of calf circumference to the *SARC-F*, *SARC-F + EBM* the addition of elderly age and *BMI* to the *SARC-F*, *PBF* percentage of body fat, *BMI* body mass index, *WC* waist circumference

Screening for SO

Nine combinations of SO screening methods were considered in this study, and detailed combination variables and cut-off values are shown in Table 2.

SARC-F questionnaire

The SARC-F screening scale was developed by Malmstrom and Morley in 2013 [19]. It consists of five items: muscle strength, assisted walking, chair rise, stair climbing and the number of falls. Each item scores from 0 to 2, with a maximum score of 10. An overall score of ≥ 4 indicates a positive screening result for sarcopenia.

SARC-CalF questionnaire

The SARC-CalF screening scale was developed by Barbosa-Silva et al. in 2016 [16]. It incorporates the measurement of calf circumference to the SARC-F. Researchers used a soft tape to measure the maximum circumference of the dominant calf whilst participants were in a standing position. The score is 0 when the calf circumference is > 34 cm for men and > 33 cm for women. The score is 10 when the calf circumference is ≤ 34 cm for men and ≤ 33 cm for women. The maximum score on the SARC-CalF screening scale is 20, and a total score of ≥ 11 indicates a positive screening result for sarcopenia.

SARC-F + EBM questionnaire

The SARC-F + EBM scale was developed by Kurita N et al. in 2019 [18]. It comprises seven items. The first five items mirror those in SARC-F, the sixth item is scored based on age (age ≥ 75 years scores 10, age < 75 years scores 0) and the seventh item is scored according to BMI (BMI ≤ 21 kg/m^2 scores 10, BMI > 21 kg/m^2 scores 0). The maximum score of SARC-F + EBM is 30, and a score of ≥ 12 indicates a positive screening result for sarcopenia.

Statistical analysis

The data were statistically analysed using SPSS 26.0 software (IBM, USA). The Shapiro–Wilk test was used to test the normality of the distribution of continuous data. Continuous data with a normal distribution were expressed as mean ± standard deviation, whilst non-normally distributed continuous data were presented as median (P25, P75). Categorical data were reported as frequencies (percentage). For comparing differences between groups, the independent sample t-test was used for measurement data meeting normal distribution, the Mann–Whitney U test was utilised for non-normally distributed measurement data and the Pearson chi-square test or continuity corrected chi-square test was employed for categorical data.

The overlap of SO defined by four different diagnostic criteria was represented by a Venn diagram. Cohen's kappa test was used to compare the consistency of the different diagnostic methods. Kappa = 0.0–0.20 means slight agreement, Kappa = 0.21–0.40 means fair agreement, Kappa = 0.41–0.60 means moderate agreement, Kappa = 0.61–0.80 means substantial agreement and Kappa = 0.81–1 means nearly perfect agreement [20].

Sensitivity, specificity, ROC, AUC and 95% confidence interval (CI) were calculated for the screening methods. When AUC > 0.5, values of AUC closer to 1 indicate better diagnostic accuracy. Specifically, AUC > 0.9 indicates high accuracy, AUC = 0.7–0.9 indicates moderate accuracy and AUC = 0.5–0.7 indicates low accuracy [21]. The differences between the various ROC curves were compared using the DeLong method. For intergroup comparison and graphing of ROC curves, we used GraphPad Prism 9.0 (GraphPad, La Jollar, CA, USA). $P < 0.05$ indicates a statistically significant difference for all two-sided tests.

Table 3 Baseline characteristics of the included subjects

Characteristics	Total ($n=1407$)	Men ($n=581$)	Women ($n=826$)
Age (years), mean ± SD	71.91 ± 5.59	72.53 ± 5.70	71.48 ± 5.47
Height (m), mean ± SD	1.60 ± 0.08	1.67 ± 0.06	1.56 ± 0.06
Weight (kg), mean ± SD	63.47 ± 10.63	68.78 ± 10.35	59.73 ± 9.13
BMI (kg/m^2), mean ± SD	24.65 ± 3.32	24.79 ± 3.32	24.55 ± 3.32
ASMI (kg/m^2), mean ± SD	6.79 ± 0.97	7.47 ± 0.82	6.30 ± 0.75
HS (kg), mean ± SD	27.92 ± 9.98	35.70 ± 8.87	22.45 ± 6.48
GS (m/s), mean ± SD	0.87 ± 0.48	0.90 ± 0.51	0.85 ± 0.45
PBF (%), mean ± SD	32.55 ± 6.76	28.74 ± 6.02	35.23 ± 5.92
WC (cm), mean ± SD	88.35 ± 9.59	90.08 ± 9.29	87.13 ± 9.61
Calf circumference (cm), mean ± SD	33.99 ± 3.17	34.71 ± 2.93	33.48 ± 3.24
SARC-F (score), *M* (*P*25, *P*75)	0.00 (0.00, 1.00)	0.00 (0.00, 1.00)	0.00 (0.00, 1.00)
SARC-CalF (score), *M* (*P*25, *P*75)	2.00 (0.00, 10.00)	1.00 (0.00, 10.00)	3.00 (0.00, 10.00)
SARC-F + EBM (score), *M* (*P*25, *P*75)	1.00 (0.00, 10.00)	1.00 (0.00, 10.00)	1.00 (0.00, 10.00)

BMI body mass index, *ASMI* appendicular skeletal muscle index, *HS* handgrip strength, *GS* gait speed, *PBF* percentage of body fat, *WC* waist circumference, *SARC-F* the questionnaire with five items to screen for sarcopenia, *SARC*-CalF the addition of calf circumference to the *SARC-F*, *SARC-F + EBM* the addition of elderly age and *BMI* to the *SARC-F*

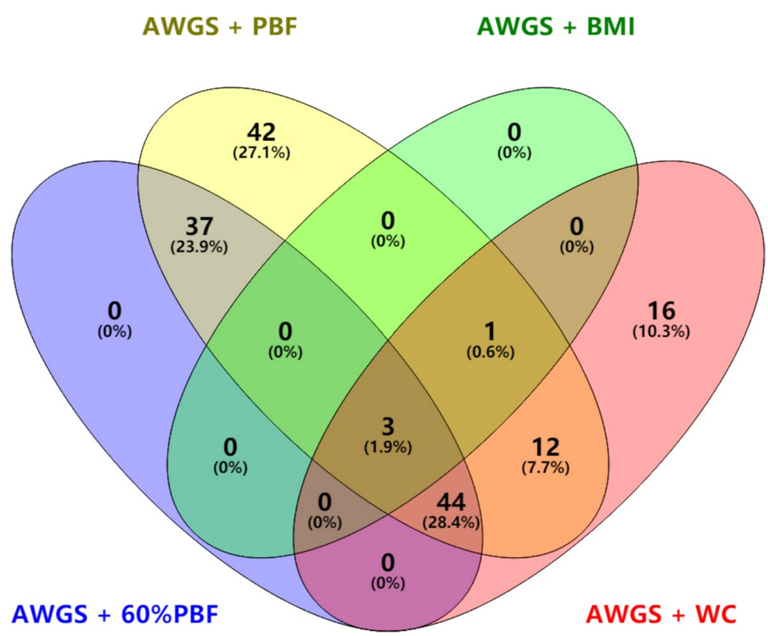

Fig. 2 The overlap of SO defined by different diagnostic criteria

Abbreviations: AWGS, Asian Working Group for Sarcopenia; PBF, percentage of body fat; BMI, body mass index; WC, waist circumference

Results

Characteristics of participants

In this study, 1407 participants were included, with 581 men and 826 women. The participants' age ranged from 65 to 95 years, with an overall mean age of 71.91 ± 5.59 years. Their overall height was 1.60 ± 0.08 m, weight was 63.47 ± 10.63 kg and BMI was 24.65 ± 3.32 kg/m^2. The median SARC-F screening scale score was 0.00 (0.00, 1.00), the median SARC-CalF screening scale score was 2.00 (0.00, 10.00) and the median SARC-F + EBM screening scale score was 1.00 (0.00, 10.00). Table 3 shows the detailed baseline information of the included participants.

Table 4 The prevalence of different diagnostic criteria and the case-finding of screening methods

Variables		Total (*n* = 1407)	Men (*n* = 581)	Women (*n* = 826)
AWGS + 60% PBF	SO	84 (6.0)	44 (7.6)	40 (4.8)
	Non-SO	1323 (94.0)	537 (92.4)	786 (95.2)
AWGS + PBF	SO	139 (9.9)	80 (13.8)	59 (7.1)
	Non-SO	1268 (90.1)	501 (86.2)	767 (92.9)
AWGS + BMI	SO	4 (0.3)	3 (0.5)	1 (0.1)
	Non-SO	1403 (99.7)	578 (99.5)	825 (99.9)
AWGS + WC	SO	76 (5.4)	32 (5.5)	44 (5.3)
	Non-SO	1331 (94.6)	549 (94.5)	782 (94.7)
SARC-F + PBF	SO	42 (3.0)	16 (2.8)	26 (3.1)
	Non-SO	1365 (97.0)	565 (97.2)	800 (96.9)
SARC-F + BMI	SO	13 (0.9)	4 (0.7)	9 (1.1)
	Non-SO	1394 (99.1)	577 (99.3)	817 (98.9)
SARC-F + WC	SO	32 (2.3)	9 (1.5)	23 (2.8)
	Non-SO	1375 (97.7)	572 (98.5)	803 (97.2)
SARC-CalF + PBF	SO	159 (11.3)	74 (12.7)	85 (10.3)
	Non-SO	1248 (88.7)	507 (87.3)	741 (89.7)
SARC-CalF + BMI	SO	17 (1.2)	9 (1.5)	8 (1.0)
	Non-SO	1390 (98.8)	572 (98.5)	818 (99.0)
SARC-CalF + WC	SO	115 (8.2)	40 (6.9)	75 (9.1)
	Non-SO	1292 (91.8)	541 (93.1)	751 (90.9)
SARC-F + EBM + PBF	SO	113 (8.0)	54 (9.3)	59 (7.1)
	Non-SO	1294 (92.0)	527 (90.7)	767 (92.9)
SARC-F + EBM + BMI	SO	20 (1.4)	8 (1.4)	12 (1.5)
	Non-SO	1387 (98.6)	573 (98.6)	814 (98.5)
SARC-F + EBM + WC	SO	92 (6.5)	31 (5.3)	61 (7.4)
	Non-SO	1315 (93.5)	550 (94.7)	765 (92.6)

SO sarcopenic obesity, *AWGS* Asian Working Group for Sarcopenia, *PBF* percentage of body fat, *BMI* body mass index, *WC* waist circumference, *SARC-F* the questionnaire with five items to screen for sarcopenia, SARC-CalF the addition of calf circumference to the SARC-F, *SARC-F + EBM* the addition of elderly age and *BMI* to the *SARC-F*

Table 5 The kappa values and magnitudes between different diagnostic criteria

SO diagnostic criteria		Total		
		Cohen's kappa	*P* value	Magnitude
AWGS + 60% PBF	AWGS + PBF	0.734	< 0.001	substantial
AWGS + 60% PBF	AWGS + BMI	0.063	< 0.001	slight
AWGS + 60% PBF	AWGS + WC	0.563	< 0.001	moderate
AWGS + PBF	AWGS + BMI	0.051	< 0.001	slight
AWGS + PBF	AWGS + WC	0.525	< 0.001	moderate
AWGS + BMI	AWGS + WC	0.095	< 0.001	slight

SO sarcopenic obesity, *AWGS* Asian Working Group for Sarcopenia, *PBF* percentage of body fat, *BMI* body mass index, WC waist circumference

Prevalence of SO under different diagnostic criteria

As shown in Table 4, the highest prevalence (9.9%) of SO was observed with the AWGS + PBF method for diagnosis. By contrast, the prevalence of SO diagnosed by the AWGS + BMI method, which was only confirmed in 3 men and 1 woman, was lower (0.3%) than that of the three other diagnostic criteria. The prevalence percentages of SO diagnosed by AWGS + 60% PBF and AWGS + WC methods were 6.0% and 5.4%, respectively. The overlap of the different diagnostic criteria used to identify SO is shown in Fig. 2. Among older people diagnosed with SO (meeting at least one diagnostic criterion, $n = 155$), only three (1.9%) participants met all four diagnostic criteria mentioned above.

Agreement of different SO diagnostic methods

In general, the agreement amongst the four diagnostic methods ranged from slight to substantial (Table 5). The AWGS + 60% PBF method had the strongest agreement with the AWGS + PBF method, with a substantial magnitude (Kappa = 0.734, $P < 0.001$). Conversely, the AWGS + PBF method had the weakest agreement with the AWGS + BMI method, with a slight magnitude (Kappa = 0.051, $P < 0.001$).

Case-finding of SO under different screening methods

The overall identification rate for SO ranged from 0.9 to 11.3% across the nine screening combinations (Table 4). The SARC-F + BMI screening method identified the fewest participants at risk of SO ($n = 13$, including 4 men and 9 women), whilst SARC-CalF + PBF identified the most participants at risk of SO ($n = 159$, including 74 men and 85 women).

Diagnostic value of SO screening methods

Table 6 shows the sensitivity, specificity, AUC, Youden index and optimal cut-off values for the nine screening methods used to identify SO in the entire study population, with the four SO diagnostic criteria serving as reference standards. The results of the nine screening methods are summarised as follows: SARC-F + PBF (sensitivity 61.2–100%/ specificity 59.2–72.3%/ AUC 0.665–0.842), SARC-F + BMI (sensitivity 42.9–100%/ specificity 45.1–83.8%/ AUC 0.657–0.936), SARC-F + WC (sensitivity 42.9–100%/ specificity 42.9–84.7%/ AUC 0.636–0.945), SARC-CalF + PBF (sensitivity 71.1–83.5%/ specificity 66.3–93.4%/ AUC 0.785–0.863), SARC-CalF + BMI (sensitivity 77.4–100%/ specificity 54.4–93.5%/ AUC 0.729–0.972), SARC-CalF + WC (sensitivity 71.9–100%/ specificity 70.7–91.8%/ AUC 0.742–0.958), SARC-F + EBM + PBF (sensitivity 57.9–86.9%/ specificity 60.6–86.5%/ AUC 0.708–0.797), SARC-F + EBM + BMI (sensitivity 57.6–100%/ specificity 57.6–85.2%/ AUC

Table 6 The sensitivity, specificity, AUC, Yordon Index and optimal cut-off values of the nine screening methods against four SO diagnostic criteria

	Sensitivity (%)	Specificity (%)	AUC (95% CI)	Youden Index	optimal cut-off value
AWGS + 60% PBF					
SARC-F + PBF	66.7	72.3	0.763 (0.716–0.809)	0.39	/
SARC-F	44	79.3	0.627 (0.558–0.695)	0.233	1.5
PBF	100	38.6	0.746 (0.701–0.790)	0.386	30.55
SARC-F + BMI	42.9	83.8	0.657 (0.598–0.716)[a]	0.267	/
SARC-F	44	79.3	0.627 (0.558–0.695)	0.233	1.5
BMI	96.4	16.9	0.450 (0.406–0.495)	0.133	21.35
SARC-F + WC	42.9	84.7	0.636 (0.572–0.699)[a]	0.276	/
SARC-F	44	79.3	0.627 (0.558–0.695)	0.233	1.5
WC	88.1	30.5	0.521 (0.474–0.568)	0.186	83.45
SARC-CalF + PBF	82.1	70.4	0.827 (0.782–0.873)[a, b,c]	0.525	/
SARC-CalF	81	56.4	0.716 (0.663–0.770)	0.374	4.5
PBF	100	38.6	0.746 (0.701–0.790)	0.386	30.55
SARC-CalF + BMI	77.4	66.1	0.729 (0.670–0.799)[b, c,d]	0.435	/
SARC-CalF	81	56.4	0.716 (0.663–0.770)	0.374	4.5
BMI	96.4	16.9	0.450 (0.406–0.495)	0.133	21.35
SARC-CalF + WC	75	74.1	0.749 (0.691–0.808)[b, c,d, e]	0.491	/
SARC-CalF	81	56.4	0.716 (0.663–0.770)	0.374	4.5
WC	88.1	30.5	0.521 (0.474–0.568)	0.186	83.45
SARC-F + EBM + PBF	86.9	63.6	0.797 (0.756–0.838)[a, b,c, e]	0.505	/
SARC-F + EBM	70.2	62.1	0.675 (0.619–0.732)	0.323	2.5
PBF	100	38.6	0.746 (0.701–0.790)	0.386	30.55
SARC-F + EBM + BMI	61.9	71.8	0.658 (0.599–0.717)[a, d,f, g]	0.337	/
SARC-F + EBM	70.2	62.1	0.675 (0.619–0.732)	0.323	2.5
BMI	96.4	16.9	0.450 (0.406–0.495)	0.133	21.35
SARC-F + EBM + WC	60.7	74.5	0.662 (0.605–0.720)[a, d,f, g]	0.352	/
SARC-F + EBM	70.2	62.1	0.675 (0.619–0.732)	0.323	2.5
WC	88.1	30.5	0.521 (0.474–0.568)	0.186	83.45
AWGS + PBF					
SARC-F + PBF	61.2	63.2	0.665 (0.617–0.712)	0.244	/
SARC-F	54	67	0.625 (0.572–0.677)	0.21	0.5
PBF	59	60.7	0.608 (0.562–0.655)	0.197	34.55
SARC-F + BMI	88.5	45.1	0.714 (0.675–0.735)	0.336	/
SARC-F	54	67	0.625 (0.572–0.677)	0.21	0.5
BMI	97.1	7.4	0.347 (0.308–0.385)	0.045	19.845
SARC-F + WC	46	79	0.658 (0.611–0.705)[b]	0.25	/
SARC-F	54	67	0.625 (0.572–0.677)	0.21	0.5
WC	99.3	4.1	0.433 (0.389–0.477)	0.034	71.25
SARC-CalF + PBF	83.5	66.3	0.785 (0.742–0.828)[a, b,c]	0.498	/
SARC-CalF	83.5	58.3	0.741 (0.701–0.782)	0.418	4.5
PBF	59	60.7	0.608 (0.562–0.655)	0.197	34.55
SARC-CalF + BMI	87.8	54.4	0.750 (0.714–0.785)[a, b,c, d]	0.422	/
SARC-CalF	83.5	58.3	0.741 (0.701–0.782)	0.418	4.5
BMI	97.1	7.4	0.347 (0.308–0.385)	0.045	19.845
SARC-CalF + WC	71.9	70.7	0.742 (0.697–0.787)[a, c,d]	0.426	/
SARC-CalF	83.5	58.3	0.741 (0.701–0.782)	0.418	4.5
WC	99.3	4.1	0.433 (0.389–0.477)	0.034	71.25

Table 6 (continued)

	Sensitivity (%)	Specificity (%)	AUC (95% CI)	Youden Index	optimal cut-off value
SARC-F + EBM + PBF	72.7	60.6	0.708 (0.663–0.754)[d]	0.333	/
SARC-F + EBM	71.9	56	0.672 (0.625–0.720)	0.279	1.5
PBF	59	60.7	0.608 (0.562–0.655)	0.197	34.55
SARC-F + EBM + BMI	57.6	76.7	0.705 (0.666–0.744)[d, e]	0.343	/
SARC-F + EBM	71.9	56	0.672 (0.625–0.720)	0.279	1.5
BMI	97.1	7.4	0.347 (0.308–0.385)	0.045	19.845
SARC-F + EBM + WC	74.1	57.1	0.688 (0.645–0.732)[d, e]	0.312	/
SARC-F + EBM	71.9	56	0.672 (0.625–0.720)	0.279	1.5
WC	99.3	4.1	0.433 (0.389–0.477)	0.034	71.25
AWGS + BMI					
SARC-F + PBF	100	59.2	0.842 (0.680-1.000)	0.592	/
SARC-F	75	78	0.786 (0.503-1.000)	0.53	1.5
PBF	75	88.9	0.797 (0.535-1.000)	0.639	40.45
SARC-F + BMI	100	80.1	0.936 (0.857-1.000)	0.801	/
SARC-F	75	78	0.786 (0.503-1.000)	0.53	1.5
BMI	100	89.8	0.939 (0.901–0.976)	0.898	28.73
SARC-F + WC	100	81.6	0.945 (0.873-1.000)	0.816	/
SARC-F	75	78	0.786 (0.503-1.000)	0.53	1.5
WC	100	89.1	0.937 (0.906–0.967)	0.891	99.95
SARC-CalF + PBF	75	93.4	0.863 (0.706-1.000)	0.684	/
SARC-CalF	100	53.2	0.664 (0.512–0.816)	0.532	3.5
PBF	75	88.9	0.797 (0.535-1.000)	0.639	40.45
SARC-CalF + BMI	100	93.5	0.972 (0.948–0.996)	0.935	/
SARC-CalF	100	53.2	0.664 (0.512–0.816)	0.532	3.5
BMI	100	89.8	0.939 (0.901–0.976)	0.898	28.73
SARC-CalF + WC	100	91.8	0.958 (0.929–0.986)	0.918	/
SARC-CalF	100	53.2	0.664 (0.512–0.816)	0.532	3.5
WC	100	89.1	0.937 (0.906–0.967)	0.891	99.95
SARC-F + EBM + PBF	75	86.5	0.785 (0.517-1.000)	0.615	/
SARC-F + EBM	75	53.3	0.591 (0.332–0.851)	0.283	1.5
PBF	75	88.9	0.797 (0.535-1.000)	0.639	40.45
SARC-F + EBM + BMI	100	85.2	0.933 (0.877–0.989)	0.852	/
SARC-F + EBM	75	53.3	0.591 (0.332–0.851)	0.283	1.5
BMI	100	89.8	0.939 (0.901–0.976)	0.898	28.73
SARC-F + EBM + WC	100	86.7	0.935 (0.892–0.979)	0.867	/
SARC-F + EBM	75	53.3	0.591 (0.332–0.851)	0.283	1.5
WC	100	89.1	0.937 (0.906–0.967)	0.891	99.95
AWGS + WC					
SARC-F + PBF	73.7	60.3	0.702 (0.642–0.762)	0.34	/
SARC-F	61.8	66.4	0.661 (0.594–0.728)	0.282	0.5
PBF	64.5	58.7	0.639 (0.573–0.705)	0.232	34.35
SARC-F + BMI	56.6	77.5	0.717 (0.662–0.772)	0.341	/
SARC-F	61.8	66.4	0.661 (0.594–0.728)	0.282	0.5
BMI	89.5	11.8	0.395 (0.338–0.453)	0.013	20.68
SARC-F + WC	93.4	42.9	0.725 (0.677–0.774)	0.363	/
SARC-F	61.8	66.4	0.661 (0.594–0.728)	0.282	0.5
WC	85.5	52.1	0.657 (0.620–0.695)	0.376	88.55
SARC-CalF + PBF	71.1	82	0.799 (0.746–0.852)[a, b,c]	0.531	/

Table 6 (continued)

	Sensitivity (%)	Specificity (%)	AUC (95% CI)	Youden Index	optimal cut-off value
SARC-CalF	93.4	49.1	0.758 (0.710–0.805)	0.425	1.5
PBF	64.5	58.7	0.639 (0.573–0.705)	0.232	34.35
SARC-CalF + BMI	86.8	56.5	0.754 (0.702–0.805)[d]	0.433	/
SARC-CalF	93.4	49.1	0.758 (0.710–0.805)	0.425	1.5
BMI	89.5	11.8	0.395 (0.338–0.453)	0.013	20.68
SARC-CalF + WC	82.9	82.1	0.844 (0.794–0.893)[a, b,c, d,e]	0.65	/
SARC-CalF	93.4	49.1	0.758 (0.710–0.805)	0.425	1.5
WC	85.5	52.1	0.657 (0.620–0.695)	0.376	88.55
SARC-F + EBM + PBF	57.9	81	0.734 (0.674–0.795)[d, f]	0.389	/
SARC-F + EBM	78.9	55.1	0.707 (0.647–0.767)	0.34	1.5
PBF	64.5	58.7	0.639 (0.573–0.705)	0.232	34.35
SARC-F + EBM + BMI	78.9	57.6	0.727 (0.673–0.781)[f]	0.365	/
SARC-F + EBM	78.9	55.1	0.707 (0.647–0.767)	0.34	1.5
BMI	89.5	11.8	0.395 (0.338–0.453)	0.013	20.68
SARC-F + EBM + WC	63.2	80.2	0.755 (0.705–0.804)[f]	0.434	/
SARC-F + EBM	78.9	55.1	0.707 (0.647–0.767)	0.34	1.5
WC	85.5	52.1	0.657 (0.620–0.695)	0.376	88.55

AUC the area under the curve, *AWGS* Asian Working Group for Sarcopenia, *PBF* percentage of body fat, *BMI* body mass index, *WC* waist circumference, *SARC-F* the questionnaire with five items to screen for sarcopenia, *SARC-CalF* the addition of calf circumference to the *SARC-F SARC-F + EBM* the addition of elderly age and *BMI* to the *SARC-F*

[a] Significantly different with SARC-F + PBF ($p < 0.05$)

[b] Significantly different with SARC-F + BMI ($p < 0.05$)

[c] Significantly different with SARC-F + WC ($p < 0.05$)

[d] Significantly different with SARC-CalF + PBF ($p < 0.05$)

[e] Significantly different with SARC-CalF + BMI ($p < 0.05$)

[f] Significantly different with SARC-CalF + WC ($p < 0.05$)

[g] Significantly different with SARC-F + EBM + PBF ($p < 0.05$)

[h] Significantly different with SARC-F + EBM + BMI ($p < 0.05$)

[i] Significantly different with SARC-F + EBM + WC ($p < 0.05$)

0.658–0.933) and SARC-F + EBM + WC (sensitivity 60.7–100%/ specificity 57.1–86.7%/ AUC 0.662–0.935).

Based on the comparison of prevalence and agreement amongst different diagnostic criteria mentioned above, the AWGS + 60% PBF method and the AWGS + PBF method had substantial diagnostic agreement, with the highest prevalence of SO diagnosed by the AWGS + PBF method. Considering the lack of multicentre, large-scale PBF data, clinical workers and related researchers may use the AWGS + PBF method for SO diagnosis. Therefore, we further comprehensively explored the diagnostic value of the nine screening methods using the AWGS + PBF method as the 'gold standard'.

The ROC curves of SARC-F + PBF, SARC-F + BMI, SARC-F + WC, SARC-CalF + PBF, SARC-CalF + BMI, SARC-CalF + WC, SARC-F + EBM + PBF, SARC-F + EBM + BMI and SARC-F + EBM + WC are shown in Fig. 3, with AWGS + PBF as the 'gold standard'. SARC-F + BMI had the highest sensitivity (88.5%) and the lowest specificity (45.1%). Conversely, SARC-F + WC had the lowest sensitivity (46%) and the highest specificity (79%). SARC-CalF + PBF yielded the highest AUC at 0.785 (95% CI 0.742–0.828). Further comparison of the ROC curves using the Delong method revealed that SARC-CalF + PBF significantly differed from all eight other screening methods. This finding suggests that SARC-CalF + PBF outperformed the other screening methods for SO detection. The sensitivity and specificity of SARC-CalF combined with PBF for SO prediction were 83.5% and 66.3%, respectively. The Youden index of SARC-CalF was 0.418, with an optimal cut-off value of 4.5 score, a sensitivity of 83.5% and a specificity of 58.3%. The Youden index of PBF was 0.197, with an optimal cut-off value of 34.55%, a sensitivity of 59% and a specificity of 60.7%.

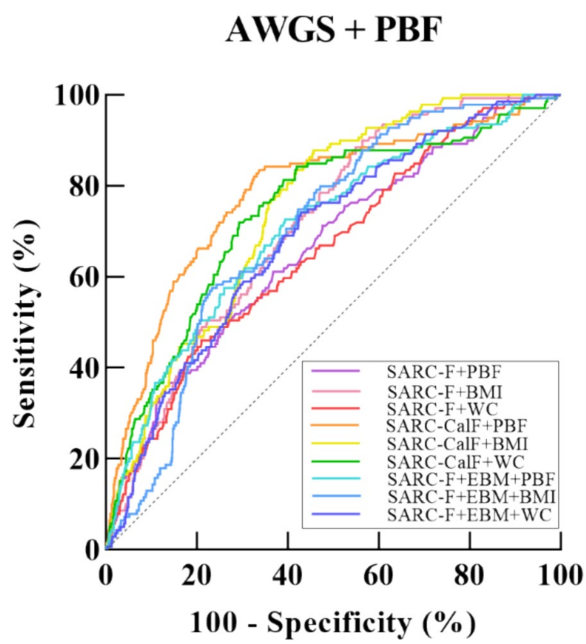

Fig. 3 The ROC curves of SARC-F + PBF, SARC-F + BMI, SARC-F + WC, SARC-CalF + PBF, SARC-CalF + BMI, SARC-CalF + WC, SARC-F + EBM + PBF, SARC-F + EBM + BMI, SARC-F + EBM + WC against AWGS + PBF criteria

Abbreviations: SARC-F, the questionnaire with five items to screen for sarcopenia; SARC-CalF, the addition of calf circumference to the SARC-F; SARC-F + EBM, the addition of elderly age and BMI to the SARC-F; PBF, percentage of body fat; BMI, body mass index; WC, waist circumference; AWGS, Asian Working Group for Sarcopenia

Discussion

Our study indicated that (1) the prevalence of SO in older people in Chongming District, Shanghai, China ranged from 0.3 to 9.9% under the four diagnostic criteria, with the highest prevalence of SO diagnosed by the AWGS + PBF criteria. (2) The agreement amongst the four diagnostic criteria ranged from slight to substantial, with the highest agreement found between AWGS + 60% PBF and AWGS + PBF. (3) Using nine screening combinations, the overall identification rate of SO ranged from 0.9 to 11.3%. (4) When AWGS + PBF was used as the 'gold standard', the AUC value of SARC-CalF + PBF as a screening method for SO was significantly better than that of the other screening methods.

Different diagnostic criteria and cut-off values have major implications for the epidemiology of SO. Our results are similar to those of Mo et al. [8] and Fu et al. [22], who utilised AWGS-2019 to combine the four forms of obesity (BMI, WC, PBF and VFA), with SO prevalence values ranging from 0.1 to 7.9% and 1.7–8.0%, respectively, in the two studies. Notably, in the studies by Mo et al. [8] and Fu et al. [22], the lowest prevalence was defined by AWGS + BMI, which is consistent with our findings. BMI is one of the commonly used indicators for diagnosing obesity, with the advantage that it is not affected by gender, and calculating the height and weight of individuals will immediately determine whether they are obese. It is widely used in large-scale population surveys and screening for obesity rates because it is easy to make sense of, easy to calculate and cost effective. However, its inability to completely separate muscle from fat would likely determine a well-muscled person, rather than fat, as obese [23]. In fact, ageing is accompanied by changes in body composition, as evidenced by a gradual decrease in water content and muscle mass, whilst fat mass increases, which means that the body weight of some older people is maintained in a relatively stable state; as a result, BMI does not accurately reflect changes in body composition [3, 24]. When obesity was diagnosed by BMI ≥ 28 kg/m², the prevalence of SO in our study was nearly 0. Unlike other diagnostic criteria, it has a certain leakage rate and is not recommended as the primary SO diagnostic criterion for SO. On the contrary, PBF is the percentage of body fat mass versus total body mass, which fully reflects body fat content [14]. Several studies have also used 60% PBF as a diagnostic of obesity based on the cut-off value of PBF determined from specific study populations, which would make the diagnosis more targeted. The 60% PBF cut-off values in our study were ≥ 30.6% and ≥ 36.8% for men and women, respectively. The prevalence percentages of SO in our study using AWGS + PBF versus AWGS + 60% PBF were 9.9% and 6%, respectively. This result is similar to the findings of Ren et al. [25], who obtained prevalence percentages of 7.90% and 6.75%. However, when AWGS + PBF was the criteria, the prevalence of SO in our study (9.9%) was slightly higher than that reported by Ren et al. (7.9%). A possible reason may be that Ren et al. missed physical performance indicators, such as GS, during the diagnosis of sarcopenia, which may lead to omissions in the diagnosis of sarcopenia in the population [25]. When 60% PBF was the criterion for obesity, our prevalence of SO (6% overall, 7.6% in men and 4.8% in women) was slightly lower than that of the study by Ren et al. [25] (6.75% overall) and much higher than that of the study by Bahat et al. [26] (0.3% in men and 0.1% in women). These differences obviously emphasise the diagnostic cut-offs for sarcopenia, the diagnostic cut-offs for obesity and the study groups' dominant role. WC is strongly associated with the risk of cardiovascular disease, diabetes and other metabolic diseases and is a key indicator of centripetal obesity [27]. In men and women, those with normal BMI but with centripetal obesity have a higher risk of cardiovascular disease mortality rate than those with similar BMI but without centripetal obesity [28].

In our study, more individuals with SO were diagnosed with AWGS + PBF (9.9%) than with AWGS + WC (5.4%). The reason may be that body size and composition vary greatly amongst the older people, and fat is not only limited to the abdomen. Judging obesity based on WC alone may fail to comprehensively and accurately assess obesity risk. By contrast, PBF can provide a more accurate assessment.

In this study, we assessed the agreement amongst the four diagnostic criteria using Cohen's kappa. Cohen's kappa, which is a statistical measure of agreement between diagnoses, has a value between − 1 and 1; however, it is usually between 0 and 1 [20]. A higher value corresponds to a greater degree of agreement between the diagnostic criteria for confirming the diagnosis of older people with SO. Based on our results, the agreement was found to range from slight to substantial, with the strongest agreement between AWGS + 60% PBF and AWGS + PBF (Kappa = 0.734, $P < 0.001$) and the weakest agreement between AWGS + PBF and AWGS + BMI (Kappa = 0.051, $P < 0.001$). This result may be due to that AWGS + 60% PBF and AWGS + PBF considered whole-body fat accumulation in older people comprehensively, but AWGS + BMI was more dependent on height and weight, which resulted in a low number of diagnoses. In addition, the agreement of AWGS + BMI was slight regardless of comparison with either SO diagnostic criterion, which is consistent with that obtained in the study by Mo et al. [8]. Furthermore, we used a Venn diagram to visualise the overlap amongst the four different diagnostic criteria. The Venn diagram illustrates four elliptical regions representing the number of people with confirmed SO for each diagnostic criterion. We noted that only three older people met al.l four diagnostic criteria simultaneously diagnosed as SO. This result indicates a wide variation amongst the four diagnostic criteria and that only a few individuals met al.l the criteria simultaneously. As shown in a previous study [29], even if the prevalence was approximately the same, the overlap was very low, for which it was important to select SO diagnostic criteria that were appropriate for the study population.

The prevalence, kappa value and Venn diagram need to be considered comprehensively to select the most appropriate diagnostic criteria for SO. As mentioned above, in Chongming District, Shanghai, AWGS + PBF showed the highest prevalence of 9.9%, followed by AWGS + 60%PBF of 6%. The two diagnostic criteria not only showed the highest agreement but also had a high prevalence, which would imply that they could more accurately identify older people with SO. However, the choice of diagnostic criteria may be limited by regional factors and data resource constraints. In practical applications, a lack of multicentre and large-scale PBF data is prevalent, which may limit the use of 60% PBF. Therefore, we inferred that AWGS + PBF is the most suitable diagnostic criterion for SO in Chongming District, Shanghai, which is consistent with the conclusion of Ren et al. [25].

In addition, we evaluated the sensitivity, specificity and AUC of nine different screening methods to recommend suitable screening methods for the early identification of SO based on the most suitable criteria for the diagnosis of SO as the 'gold standard' for comparison and recommendation. We observed that SARC-F + BMI had the highest sensitivity (88.5%), which implies that this screening method captured SO-positive cases in older people well and reduced the likelihood of missed diagnoses. However, its specificity (45.1%) was the lowest amongst the nine screening methods, which may lead to a higher misdiagnosis rate and risk of overtreatment in which non-SO individuals are incorrectly diagnosed with SO. This finding also reaffirms previous research that BMI fails to consider changes in body composition in older people, who tend to lose muscle mass on ageing, which may result in a BMI in the normal range but actually have higher PBF [23]. By contrast, SARC-F + WC had the highest specificity (79%) and could exclude non-SO individuals more accurately, which reduced the likelihood of misdiagnosis. However, its sensitivity (46%) was low, and it may exclude SO individuals incorrectly. Therefore, the balance between sensitivity and specificity must be considered when choosing a suitable screening method. We calculated the AUC value by graphing the ROC curve, which is a comprehensive measure of sensitivity and specificity and a measure of the accuracy of a screening method, with a value between 0.5 and 1. A value closer to 1 means higher accuracy of the screening method is [21]. According to our results, SARC-CalF + PBF had the highest AUC value (0.785/ $P < 0.05$), which was significantly higher than those of the eight other screening methods. This result means that it had the best accuracy and discriminatory ability for SO identification overall. In the meantime, its AUC value was greater than 0.7, and its sensitivity (83.5%) and specificity (66.3%) were moderately higher amongst the nine screening methods, which qualifies it as an ideal screening tool [30]. Although SARC-CalF + PBF demonstrated the highest AUC values, a previous study emphasised that screening tools should have maximum sensitivity, and screening methods should be affordable, practical and time-saving for at-risk populations and be accessible to professionals and non-professionals [1]. Considering that PBF is usually measured by BIA [31], DXA [32] or skinfold thickness [33], specific equipment is required, and practitioners need to be properly trained. Therefore, this study supports the use of SARC-F + BMI and SARC-CalF + PBF as screening methods for SO in suburban older people. However, it preferentially recommends SARC-CalF + PBF, given that it has the highest AUC value and considering that it provides more reliable and accurate screening results. When SARC-F + BMI will be used as the screening method, the recommended cut-off values are SARC-F ≥ 1 score and BMI ≥ 19.845 kg/m². In the meantime, the recommended cut-off values are SARC-CalF ≥ 5 score and PBF ≥ 34.55% when SARC-CalF + PBF will be used as the screening method. Notably, the assessment of screening methods in this study was based on the most appropriate SO standard for the region as the 'gold standard.' However, variations may exist across regions and populations, which result in differences in the efficacy of screening methods. Future studies could expand the sample size and consider studies in other regions and populations to validate and optimise the efficacy of screening methods.

Our study has the following strengths. First, this study effectively improved the deficiencies in SO screening in suburban areas. Our findings provided an important reference value for early identification and intervention of SO. Secondly, our assessment was comprehensive in terms of exploring diagnostic criteria and screening methods, including Cohen's kappa test, graphing the Venn diagram, calculating sensitivity, specificity, AUC values and the Youden index. Such multidimensional assessment methods will help provide a comprehensive understanding of the advantages and disadvantages of various diagnostic criteria and screening methods and provide a reliable basis for clinical practice.

However, this study has some limitations. Firstly, only AWGS-2019 was used to determine sarcopenia because the population of this study was Chinese older people. Using other diagnostic criteria for sarcopenia (such as EWGSOP) as an element of the SO diagnostic criteria may lead to different results. Secondly, this study was conducted only in Chongming District, Shanghai. Thus, the results may have been affected by area-specific factors and population bias. Therefore, careful consideration must be given when spreading to other areas. Thirdly, although our findings suggest suitable diagnostic criteria, screening methods and cut-off values, their feasibility and generalisability in clinical practice still need to be further evaluated. More factors may be involved in practical application, such as cost effectiveness, medical resources and patient acceptance, which requires more in-depth research. Lastly, this study is a cross-sectional one that only provides data at a specific time point. We believe that future studies could have a longer longitudinal follow-up to assess the effects of screening methods and cut-off values in long-term prognosis and prediction to better understand the impact of screening methods on the dynamics of SO.

Conclusion

AWGS + PBF may be used by clinicians and researchers to diagnose SO. When SARC-F + BMI is used as the screening method, the recommended cut-off values are SARC-F ≥ 1score and BMI ≥ 19.845 kg/m². In the meantime, the recommended cut-off values are SARC-CalF ≥ 5 score and PBF ≥ 34.55% when SARC-CalF + PBF is used as the screening method.

Abbreviations

SO	Sarcopenic Obesity
AWGS	Asian Working Group for Sarcopenia
PBF	Percentage of Body Fat
60% PBF	Percent of Body Fat Exceeding the 60th Percentile
BMI	Body Mass Index
WC	Waist Circumference
SARC-F	the Questionnaire with Five Items to Screen for Sarcopenia
SARC-CalF	the Addition of Calf Circumference to the SARC-F
SARC-F + EBM	the Addition of Elderly Age and BMI to the SARC-F
ROC	Receiver Operating Characteristics
AUC	Area Under the ROC Curve
EWGSOP	European Working Group on Sarcopenia in Older People
VFA	Visceral Fat Area
IWGS	International Working Group on Sarcopenia
FNIH	Foundation for the National Institutes of Health
DXA	Dual-Energy X-Ray Absorptiometry
BIA	Bioelectrical Impedance Analysis
HS	Handgrip Strength
GS	Gait Speed
WHO	World Health Organisation
ESPEN	European Society for Clinical Nutrition and Metabolism
EASO	European Association for the Study of Obesity
ASMI	Appendicular Skeletal Muscle Mass Index
ASM	Appendicular Skeletal Muscle Mass
CI	Confidence Interval

Supplementary Information

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Supplementary Material 1.

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Not applicable.

Authors' contributions

All authors meet criteria for authorship as stated in the Uniform Requirements for Manuscripts Submitted to Biomedical Journals. MZ, LW, XH, LM and YS contributed to the concept and design, data acquisition, data analysis and interpretation. MZ, LW and XH were responsible for drafting the manuscript and revising it critically. MZ, LW, XH, LM, YS and NC for final approval of the version to be published. NC had agreed to be accountable for all aspects of work.

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Availability of data and materials

The datasets generated during the present study will be available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The experimental design and recruitment methods were approved by the Ethics Committee of Chongming Hospital Affiliated to Shanghai University of Medicine and Health Sciences (approval number: CMEC-2020-KT-42) prior to the collection of the data reported in this study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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