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A cross-sectional study on the characteristics of fat and skeletal muscle mass and the risk of sarcopenia in Chinese elderly people

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ABSTRACT: Background Sarcopenia is a major health concern among the elderly over 60. Understanding the relationship between fat and skeletal muscle mass (SMM) and sarcopenia risk is crucial for its prevention and management.**Methods** This cross-sectional study involved the selection of 1523 participants from the baseline data of a health examination project for the elderly in Rugao and Dongtai City, Jiangsu Province, China, conducted between April and December 2024. The body composition parameters such as fat mass (FM) and SMM were measured by bioelectrical impedance analysis (BIA). **Results** Among the 1523 participants, the prevalence rates of sarcopenia among people aged 60 to 70, 71 to 80, and over 80 were 7.42%, 13.39%, and 46.15% respectively. The results of multivariate logistic regression showed that age, gender, body mass index (BMI), left calf circumference, FM and body fat percentage remained significantly associated with sarcopenia. Age was significantly positively correlated with the risk of sarcopenia ($P < 0.001$), BMI ($P < 0.001$) and FM ($P < 0.001$) were both significantly negatively correlated with the risk of sarcopenia. When age exceeded 79.90, age was significantly negatively correlated with BMI ($P < 0.001$). When age exceeded 73.43, it was significantly negatively correlated with FM ($P < 0.001$). In the age range above 80.00, age was significantly negatively correlated with body fat percentage ($P = 0.025$). In the age range below 82.00, age remained significantly negatively correlated with appendicular muscle mass ($P < 0.001$).**Conclusions** Among the elderly aged 60 and above, age, BMI, FM, body fat percentage and calf circumference were all independent influencing factors of sarcopenia. Detecting the body composition of the elderly is crucial for the early identification and intervention of sarcopenia.

Keywords Sarcopenia, aging, epidemiology, risk factors, BIA

1. Introduction

With the intensification of global population aging, the health issues of people over 60 years old have increasingly drawn attention. Among this group, changes in fat and skeletal muscle mass (SMM) have a

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profound impact on health. Sarcopenia is an age-related syndrome characterised by progressive and generalised loss of SMM and strength; it is a major contributor to the risk of physical frailty, functional impairment in older people, poor health-related quality of life, and premature death[1].

SMM is a key factor in maintaining the body's glucose homeostasis and is also an important biomarker for assessing metabolic health[2, 3]. In contrast, fat mass (FM) has been widely confirmed to be significantly associated with an increased risk of non-communicable diseases, including hypertension, hyperlipidemia, and insulin resistance[4]. It is reported that the prevalence of sarcopenia varies among different populations, ranging from 10% to 50%, and generally increases with age. Among people aged 80 and above, the prevalence exceeds 50%; it is even higher among elderly people living in nursing homes[5]. Among the elderly population, the development of sarcopenia may be masked by the relative stability of body weight, as the reduction in muscle mass is partially offset by an increase in fat content[6, 7]. Although sarcopenia has become a prominent focus in current research on elderly health, many questions remain concerning the age-related patterns of FM and SMM in the elderly aged 60 and over, as well as their relationship with sarcopenia risk. There may be significant differences among different age groups of the elderly in terms of the characteristics of changes in SMM, the pathogenesis of sarcopenia, and related influencing factors.

Research shows that compared with traditional anthropometric methods, body composition measurement demonstrates higher accuracy in predicting health status, as it can precisely reflect the proportion differences between FM and fat-free mass[8]. However, achieving accurate body composition measurement in routine clinical practice still faces many challenges, especially for individuals with limited mobility. Bioelectrical impedance analysis (BIA) is a technique often incorporated in daily clinical practice to assess body composition, mainly to assess muscle mass and hydration[9]. It is a simple, rapid, inexpensive and non-invasive method for estimating a patient's body composition and is a recognized guideline for detecting muscle mass loss[10].

Accordingly, we utilized data from the epidemiological cross-sectional study on sarcopenia among the elderly in Jiangsu Province, China, to (1) depict the age distribution characteristics of FM and SMM in individuals aged 60 and above; (2) assess the risk factors associated with sarcopenia; and (3) determine the potential threshold effects of age, body mass index (BMI), FM, and body fat percentage on sarcopenia risk, so as to provide quantitative evidence for early identification and intervention.

2. Methods

2.1 Study participants

This cross-sectional study involved 1523 elderly participants aged 60 years and older who participated in a health check-up in Rugao City and Dongtai City, Jiangsu Province, from April to December 2024. The inclusion criteria were as follows: a. participants must be 60 years of age or older and permanent residents (> 1 year); b. they must be willing to participate in the study; c. they must provide written informed consent. Exclusion criteria: a. inability to communicate with the interviewer (due to mental or visual impairment, deafness, inability to speak, or being affected by

any acute psychological disorder); b. obviously disabled and required assistance to walk, unable to participate in handgrip strength and 6-meter walking speed test; c. sudden change in body composition (such as dehydration, edema). The research protocol has been approved by the local ethics committees (Dongtai People's Hospital, approval number: 2024-0221) (Nantong Center for Disease Control and Prevention, approval number: 2025002). All patients provided written informed consent prior to participation. All methods were conducted in accordance with relevant guidelines and regulations.

2.2 Data collection

The survey data were collected by trained personnel through face-to-face interviews. Information on age, gender, marital status, education, economic status, smoking history, and alcohol use history was recorded on paper questionnaires at the time of the interview. Trained researchers conducted measurements of weight, height, waist circumference and body composition.

2.3 Body composition and physical measurement

The ambient temperature was maintained at 25℃ and the equipment was kept in a horizontal position. All participants sat quietly for 15 minutes before the measurement to adapt to the ambient temperature, removed heavy clothing, shoes, socks and accessories, and thoroughly cleaned the dust and dirt on their palms and soles. During the measurement, both arms were required to hang naturally to avoid contact between the arms and the trunk as well as the inner sides of the legs. Body composition-including total body water, FM, body fat percentage, and appendicular skeletal muscle mass (ASM)-was then measured with an automatic BIA device (MC-780MA, Dongguan Balienda Health Equipment Co., Ltd., China). The instrument performs a self-check program each time it is started up and conducts zero-point calibration before each use. This instrument is registered with the National Medical Products Administration of China (Yue Medical Device Registration No. 20192070581).

Height and weight were measured automatically using the DST-500 device (Beijing Donghua Yuan Medical Equipment Co., Ltd., China), with an accuracy of 0.1 cm and 0.1 kg. All instruments were calibrated before the study began. Waist circumference was measured at the midpoint between the lower border of the last palpable rib and the top of the iliac crest at the end of a gentle exhalation, using a non-stretch, flexible measuring tape.

2.4 Handgrip strength and 6-meter walking speed measurement

Muscle strength was assessed by handgrip strength (JY-WLJ-2, Changzhou Jinyu Medical Equipment Co., Ltd., China). Participants sat on chairs and were evaluated using their dominant hand. The elbow was flexed to 90° alongside the trunk, and the wrist was held in slight extension. After the dynamometer was zero-calibrated, each hand was measured twice, and the highest value was recorded. Physical function was assessed by evaluating 6-meter walking speed. Participants

walked at their usual pace along a straight line for more than 8 meters, and the walking speed over the middle 6 meters was calculated; the average of two tests was used as the final value.

2.5 Ascertainment of sarcopenia status

The diagnostic criteria for sarcopenia followed the 2019 Asian Working Group for Sarcopenia (AWGS) guidelines[11]: a. muscle mass: ASM/height^2 (kg/m^2) < 7.0 kg/m^2 (male) or < 5.7 kg/m^2 (female) is considered low; b. muscle strength: handgrip strength < 28 kg (male) or < 18 kg (female) is considered low; c. body function: 6-meter walking speed < 1.0 m/s is considered impaired physical function. When an individual exhibited both low muscle mass and diminished muscle strength or reduced physical performance, a diagnosis of sarcopenia was established.

2.6 Statistical analysis

Continuous variable data were presented as mean ± standard deviation (SD) and median (interquartile range, IQR), while categorical variables were expressed as percentages. One-way analysis of variance (ANOVA) or Kruskal-Wallis test and Pearson chi-square test were used to compare the differences in baseline characteristics among the three groups. Multivariate logistic regression analysis was conducted to identify independent factors significantly associated with sarcopenia after adjusting for potential confounding factors. Univariate and multiple logistic regression models were used to estimate crude and adjusted odds ratios (ORs), and 95% confidence interval (CI), respectively. Models were adjusted for age (model 2), and education level, monthly income (model 3), with model 1 without adjustment for any potential confounders. All models used sarcopenia (yes/no) as the dependent variable and ORs were estimated using the maximum likelihood method. Additionally, restricted cubic spline (RCS) regression was used to assess the relationship between sarcopenia risk and age or body composition. Piecewise logistic regression was employed to explore the potential threshold effects of age or body composition on sarcopenia. First, conventional logistic regression was used to test the relationships between age, BMI, FM, body fat percentage and sarcopenia, and then the segmented package in R software was used to identify possible breakpoint positions. The specific values of the breakpoints were determined based on model fit indices and statistical tests. When comparing the conventional logistic regression model with the piecewise logistic regression model, the likelihood ratio test (LRT) was used to determine whether the piecewise model was significantly better than the conventional model ($P < 0.05$). All statistical analyses were performed using R 4.2.2 software. The significance level was set at $P < 0.05$.

3. Results

3.1 Baseline characteristics

Table 1 presents the baseline characteristics of 1523 participants. Among them, there were 633 individuals aged 60 - 70, 747 aged 71 - 80, and 143 aged over 80, including 661 men and 862

women. The prevalence of sarcopenia in the three age groups was 7.42%, 13.39%, and 46.15%, respectively. Significant differences among age groups were observed in the prevalence of sarcopenia, marital status, education level, monthly income, physical examination indicators, muscle strength, physical function, and body composition ($P < 0.05$).

Table 1 Baseline characteristics of each group classified by different age groups.

Characteristic	Total (n = 1523)	60-70(n = 633)	71-80 (n = 747)	＞80 (n = 143)	*P*
Age					**<0.001**
Mean ± SD	72.55 ± 5.47	67.54 ± 1.84	74.66 ± 2.69	83.69 ± 2.64	
Median (Q1, Q3)	72.0 (68.0, 76.0)	68.0 (66.0, 69.0)	74.0 (72.0, 77.0)	83.0 (82.0, 85.0)	
Gender					0.229
Male	661 (43.40%)	259 (40.92%)	340 (45.52%)	62 (43.36%)	
Female	862 (56.60%)	374 (59.08%)	407 (54.48%)	81 (56.64%)	
Region					0.520
Rugao	689 (45.24%)	294 (46.45%)	336 (44.98%)	59 (41.26%)	
DongTai	834 (54.76%)	339 (53.55%)	411 (55.02%)	84 (58.74%)	
Sarcopenia					**<0.001**
Yes	213 (13.99%)	47 (7.42%)	100 (13.39%)	66 (46.15%)	
No	1310 (86.01%)	586 (92.58%)	647 (86.61%)	77 (53.85%)	
Marital status					**<0.001**
Unmarried	13 (0.85%)	7 (1.11%)	4 (0.54%)	2 (1.40%)	
Married	1289 (84.64%)	568 (89.73%)	634 (84.87%)	87 (60.84%)	
Divorced	95 (6.24%)	15 (2.37%)	54 (7.23%)	26 (18.18%)	
Widowed	126 (8.27%)	43 (6.79%)	55 (7.36%)	28 (19.58%)	
Education level					**<0.001**
Illiterate	403 (26.46%)	161 (25.43%)	188 (25.17%)	54 (37.76%)	
Primary School	481 (31.58%)	155 (24.49%)	288 (38.55%)	38 (26.57%)	
Middle School	363 (23.83%)	165 (26.07%)	165 (22.09%)	33 (23.08%)	
High school or above	276 (18.12%)	152 (24.01%)	106 (14.19%)	18 (12.59%)	
Previous occupation					0.203
Farmers	549 (36.05%)	229 (36.18%)	270 (36.14%)	50 (34.97%)	
Teachers/ Doctors	46 (3.02%)	17 (2.69%)	22 (2.95%)	7 (4.90%)	
Workers	707 (46.42%)	301 (47.55%)	340 (45.52%)	66 (46.15%)	
Civil servants	20 (1.31%)	2 (0.32%)	16 (2.14%)	2 (1.40%)	
Freelancers	30 (1.97%)	15 (2.37%)	12 (1.61%)	3 (2.10%)	
Others	171 (11.23%)	69 (10.90%)	87 (11.65%)	15 (10.49%)	
Monthly income (yuan)					**0.018**
＜2000	696 (45.70%)	294 (46.45%)	339 (45.38%)	63 (44.06%)	
2000~3999	536 (35.19%)	240 (37.91%)	256 (34.27%)	40 (27.97%)	
4000~5999	225 (14.77%)	82 (12.95%)	113 (15.13%)	30 (20.98%)	
6000~7999	32 (2.10%)	10 (1.58%)	18 (2.41%)	4 (2.80%)	
8000~9999	31 (2.04%)	6 (0.95%)	20 (2.68%)	5 (3.50%)	
≥10000	3 (0.20%)	1 (0.16%)	1 (0.13%)	1 (0.70%)	
Smoking					0.421
Yes	211 (13.85%)	93 (14.69%)	103 (13.79%)	15 (10.49%)	
No	1,312 (86.15%)	540 (85.31%)	644 (86.21%)	128 (89.51%)	
Alcohol use					0.473
Yes	610 (40.05%)	263 (41.55%)	295 (39.49%)	52 (36.36%)	
No	913 (59.95%)	370 (58.45%)	452 (60.51%)	91 (63.64%)	
Weight,kg					**<0.001**
Mean ± SD	64.77 ± 11.19	65.95 ± 11.43	65.07 ± 10.82	58.04 ± 9.63	
Median (Q1, Q3)	64 (57, 72)	66 (58, 73)	65 (57, 72)	57 (52, 64)	
Height, cm					**<0.001**
Mean ± SD	159.36 ± 9.20	159.85 ± 10.19	159.48 ± 8.41	156.59 ± 8.00	
Median (Q1, Q3)	159 (154, 165)	160 (155, 165)	159 (153, 165)	156 (151, 162)	
Body mass index (BMI), kg/m^2					**<0.001**
Mean ± SD	25.42 ± 3.67	25.72 ± 4.05	25.52 ± 3.35	23.59 ± 2.97	
Median (Q1, Q3)	25.2 (23.1, 27.5)	25.3 (23.3, 27.9)	25.3 (23.4, 27.6)	23.5 (21.6, 25.2)	

Characteristic	Total (n = 1523)	60-70(n = 633)	71-80 (n = 747)	＞80 (n = 143)	*P*
Waist circumference, cm					**0.002**
Mean ± SD	87.87 ± 9.95	87.69 ± 9.82	88.38 ± 9.33	86.05 ± 13.02	
Median (Q1, Q3)	88 (81, 94)	87 (81, 94)	88 (82, 94)	86 (79, 92)	
Hip circumference, cm					**<0.001**
Mean ± SD	96.20 ± 7.88	96.63 ± 7.40	96.38 ± 7.54	93.40 ± 10.64	
Median (Q1, Q3)	96 (91, 101)	96 (92, 101)	96 (92, 101)	94 (89, 99)	
Left thigh circumference, cm					**<0.001**
Mean ± SD	46.94 ± 4.49	47.63 ± 4.44	46.81 ± 4.41	44.63 ± 4.29	
Median (Q1, Q3)	47.0 (44.0, 50.0)	47.5 (45.0, 50.5)	47.0 (44.0, 50.0)	45.0 (41.0, 47.5)	
Right thigh circumference, cm					**<0.001**
Mean ± SD	47.15 ± 4.55	47.84 ± 4.51	47.02 ± 4.46	44.80 ± 4.34	
Median (Q1, Q3)	47.0 (44.0, 50.0)	47.8 (45.0, 50.6)	47.0 (44.0, 50.0)	45.0 (41.2, 47.5)	
Left calf circumference, cm					**<0.001**
Mean ± SD	35.00 ± 3.19	35.26 ± 3.18	35.03 ± 3.17	33.68 ± 3.05	
Median (Q1, Q3)	35.00 (33.00, 37.00)	35.00 (33.00, 37.00)	35.00 (33.00, 37.00)	33.50 (31.50, 35.50)	
Right calf circumference, cm					**<0.001**
Mean ± SD	35.02 ± 3.20	35.28 ± 3.10	35.03 ± 3.29	33.84 ± 2.97	
Median (Q1, Q3)	35.00 (33.00, 37.00)	35.00 (33.00, 37.00)	35.00 (33.00, 37.00)	33.70 (32.00, 36.00)	
Handgrip strength, kg					**<0.001**
Mean ± SD	25.92 ± 9.75	27.83 ± 10.09	25.14 ± 9.10	21.55 ± 9.54	
Median (Q1, Q3)	24 (19, 32)	26 (21, 34)	24 (19, 31)	20 (16, 25)	
6-meter walking speed, m/s					**<0.001**
Mean ± SD	1.00 ± 0.22	1.06 ± 0.20	0.99 ± 0.21	0.82 ± 0.20	
Median (Q1, Q3)	1.00 (0.86, 1.17)	1.00 (0.92, 1.20)	1.00 (0.86, 1.13)	0.86 (0.67, 0.96)	
Total body water, kg					**<0.001**
Mean ± SD	31.76 ± 5.56	32.40 ± 5.69	31.71 ± 5.38	29.20 ± 5.18	
Median (Q1, Q3)	31.0 (27.7, 35.3)	31.5 (28.2, 35.9)	31.0 (27.6, 35.1)	28.5 (25.6, 32.5)	
FM, kg					**<0.001**
Mean ± SD	20.24 ± 7.13	20.64 ± 7.47	20.52 ± 6.91	17.03 ± 5.81	
Median (Q1, Q3)	20 (15, 24)	20 (15, 25)	20 (16, 24)	16 (14, 21)	
Body fat percentage, %					**0.037**
Mean ± SD	31.24 ± 8.18	31.31 ± 8.58	31.52 ± 7.95	29.47 ± 7.35	
Median (Q1, Q3)	31 (26, 37)	31 (25, 37)	32 (26, 37)	30 (25, 34)	
Left arm muscle mass, kg					**<0.001**
Mean ± SD	2.21 ± 0.59	2.27 ± 0.64	2.21 ± 0.54	1.94 ± 0.51	
Median (Q1, Q3)	2.10 (1.80, 2.54)	2.15 (1.80, 2.60)	2.11 (1.80, 2.52)	1.90 (1.60, 2.30)	
Right arm muscle mass, kg					**<0.001**
Mean ± SD	2.26 ± 0.58	2.31 ± 0.59	2.27 ± 0.56	1.98 ± 0.52	
Median (Q1, Q3)	2.16 (1.82, 2.60)	2.20 (1.90, 2.70)	2.20 (1.83, 2.60)	1.93 (1.60, 2.31)	
Left leg muscle mass, kg					**<0.001**
Mean ± SD	6.52 ± 1.52	6.69 ± 1.49	6.51 ± 1.52	5.78 ± 1.42	
Median (Q1, Q3)	6.30 (5.37, 7.60)	6.39 (5.56, 7.80)	6.30 (5.33, 7.60)	5.51 (4.67, 6.84)	
Right leg muscle mass, kg					**<0.001**
Mean ± SD	6.58 ± 1.53	6.74 ± 1.50	6.59 ± 1.54	5.83 ± 1.44	
Median (Q1, Q3)	6.30 (5.40, 7.66)	6.39 (5.60, 7.90)	6.31 (5.40, 7.60)	5.53 (4.69, 6.89)	
ASM, kg					**<0.001**
Mean ± SD	17.57 ± 4.07	18.01 ± 4.06	17.58 ± 4.01	15.53 ± 3.78	
Median (Q1, Q3)	16.9 (14.4, 20.4)	17.2 (15.0, 21.1)	17.0 (14.5, 20.4)	14.6 (12.5, 18.2)	
ASMI, kg/m^2					**<0.001**
Mean ± SD	6.83 ± 1.06	6.95 ± 1.05	6.83 ± 1.03	6.27 ± 1.11	
Median (Q1, Q3)	6.74 (6.09, 7.51)	6.89 (6.24, 7.62)	6.73 (6.08, 7.53)	6.17 (5.49, 6.95)	
Trunk muscle mass, kg					**<0.001**
Mean ± SD	21.20 ± 4.31	21.53 ± 4.07	21.27 ± 4.46	19.37 ± 4.10	
Median (Q1, Q3)	20.8 (18.1, 24.0)	21.2 (18.5, 24.1)	20.7 (18.1, 24.1)	19.0 (16.4, 21.5)	
Basal metabolic rate, kcal					**<0.001**
Mean ± SD	1276.50 ± 193.32	1295.37 ± 195.00	1278.14 ± 188.88	1184.38 ± 183.73	
Median (Q1, Q3)	1261 (1139, 1404)	1274 (1157, 1426)	1267 (1142, 1402)	1184 (1079, 1309)	

Categorical variables are expressed as frequency (percent). Continuous variables are expressed as mean ± standard deviation and median (Q1: 1st Quartile, Q3: 3st Quartile). *P*: P-value, FM: fat mass, ASM: appendicular skeletal muscle mass, ASMI: appendicular skeletal muscle mass index, m: meter, cm: centimetre, kcal: kilocalorie, kg: kilogram, s: second.

3.2 Associations between sarcopenic and aging

Table 2 shows the OR and 95% CIs for sarcopenia stratified by age. In the unadjusted crude Model 1, the risk of sarcopenia was significantly increased in the 71 - 80 age group (OR: 1.93, 95% CI: 1.34 - 2.77, $P < 0.01$) and was even higher among those over 80 years old (OR: 10.69, 95% CI: 6.86 - 16.65, $P < 0.001$).

Table 2 Odds ratios and confidence intervals of sarcopenia by age category.

Age	Model1		Model2		Model3	
	OR (95%CI)	*P*	OR (95%CI)	*P*	OR (95%CI)	*P*
60-70	1.00 (Reference)		1.00 (Reference)		1.00 (Reference)	
71-80	1.93 (1.34 - 2.77)	<0.001	0.94 (0.53 - 1.68)	0.836	0.88 (0.49 - 1.59)	0.672
＞80	10.69 (6.86 - 16.65)	<0.001	2.19 (0.75 - 6.40)	0.153	1.88 (0.63 - 5.56)	0.255

OR: Odds Ratio, CI: Confidence Interval, *P*: P-value. Model 1: Crude. Mode 2: Adjust: age. Model 3: Adjust: age, marital status, education level, and monthly income.

3.3 Analysis of influencing factors of sarcopenia

The multivariate regression analysis showed that the risk of sarcopenia increased significantly with age (OR: 1.11, 95% CI: 1.07 - 1.15, $P < 0.001$) and decreased significantly with increases in BMI (OR: 0.63, 95% CI: 0.55 - 0.71, $P < 0.001$), FM (OR: 0.64, 95% CI: 0.56 - 0.73, $P < 0.001$), and left calf circumference (OR: 0.81, 95% CI: 0.71 - 0.94, $P = 0.005$). Compared with males, females had a markedly lower risk of sarcopenia (OR: 0.04, 95% CI: 0.02 - 0.09, $P < 0.001$). A higher body fat percentage was associated with an increased risk of sarcopenia (OR: 1.65, 95% CI: 1.49 - 1.83, $P < 0.001$) (Table 3).

Table 3 Univariate and multivariate analysis of influencing factors.

Variables	**Univariable**					**Multivariable**				
	β	S.E	Z	*P*	OR (95%CI)	β	S.E	Z	*P*	OR (95%CI)
Age	0.14	0.01	10.28	<0.001	1.15 (1.12 ~ 1.18)	0.10	0.02	5.72	<0.001	1.11 (1.07 ~ 1.15)
Gender										
Male					1.00 (Reference)					1.00 (Reference)
Female	-0.08	0.15	-0.53	0.596	0.92 (0.69 ~ 1.24)	-3.17	0.38	-8.38	<0.001	0.04 (0.02 ~ 0.09)
Marital status										
Unmarried					1.00 (Reference)					1.00 (Reference)
Married	-1.51	0.58	-2.61	0.009	0.22 (0.07 ~ 0.69)	-0.81	0.79	-1.03	0.302	0.44 (0.09 ~ 2.08)
Divorced	-0.51	0.61	-0.82	0.410	0.60 (0.18 ~ 2.01)	-0.54	0.87	-0.62	0.536	0.58 (0.11 ~ 3.21)
Widowed	-0.93	0.61	-1.51	0.130	0.40 (0.12 ~ 1.31)	-0.83	0.83	-0.99	0.321	0.44 (0.09 ~ 2.24)
Education level										
Illiterate					1.00 (Reference)					1.00 (Reference)
Primary School	-0.02	0.19	-0.10	0.919	0.98 (0.68 ~ 1.41)	-0.16	0.26	-0.61	0.543	0.85 (0.51 ~ 1.43)
Middle School	-0.24	0.21	-1.17	0.242	0.78 (0.52 ~ 1.18)	-0.22	0.31	-0.72	0.472	0.80 (0.43 ~ 1.47)
High school or above	-0.42	0.24	-1.76	0.078	0.66 (0.41 ~ 1.05)	-0.70	0.39	-1.77	0.076	0.50 (0.23 ~ 1.08)
Previous occupation										
Farmers					1.00 (Reference)					1.00 (Reference)
Teachers	-0.10	0.49	-0.21	0.836	0.90 (0.34 ~ 2.38)	0.30	0.83	0.36	0.716	1.35 (0.27 ~ 6.81)
Workers	0.05	0.16	0.32	0.752	1.05 (0.76 ~ 1.45)	-0.10	0.37	-0.29	0.776	0.90 (0.44 ~ 1.85)
Doctors	-12.72	360.38	-0.04	0.972	0.00 (0.00, 1.70 ×10^301)	-13.51	534.00	-0.03	0.980	0.00 (0.00 ~ Inf)
Civil servants	0.11	0.64	0.17	0.864	1.12 (0.32 ~ 3.90)	0.77	1.01	0.76	0.449	2.15 (0.30 ~ 15.61)

Variables	Univariable					Multivariable				
	β	S.E	Z	*P*	OR (95%CI)	β	S.E	Z	*P*	OR (95%CI)
Freelancers	0.23	0.51	0.46	0.643	1.26 (0.47 ~ 3.40)	-0.19	0.87	-0.22	0.825	0.82 (0.15 ~ 4.55)
Others	0.03	0.25	0.12	0.901	1.03 (0.63 ~ 1.69)	-0.29	0.41	-0.70	0.486	0.75 (0.33 ~ 1.68)
Monthly income (yuan)										
＜2000					1.00 (Reference)					1.00 (Reference)
2000~3999	0.06	0.17	0.37	0.709	1.06 (0.77 ~ 1.48)	0.22	0.34	0.65	0.514	1.25 (0.64 ~ 2.42)
4000~5999	0.42	0.20	2.06	0.039	1.53 (1.02 ~ 2.28)	0.39	0.40	0.96	0.335	1.47 (0.67 ~ 3.22)
6000~7999	-0.81	0.74	-1.10	0.271	0.44 (0.10 ~ 1.89)	-0.60	0.97	-0.62	0.534	0.55 (0.08 ~ 3.66)
8000~9999	-0.02	0.55	-0.03	0.978	0.98 (0.34 ~ 2.88)	-0.77	1.01	-0.76	0.447	0.46 (0.06 ~ 3.38)
≥10000	-12.67	509.65	-0.02	0.980	0.00 (0.00 ~ Inf)	-15.20	686.52	-0.02	0.982	0.00 (0.00 ~ Inf)
Smoking										
Yes					1.00 (Reference)					1.00 (Reference)
No	0.02	0.22	0.11	0.913	1.02 (0.67 ~ 1.56)	0.09	0.32	0.30	0.766	1.10 (0.59 ~ 2.04)
Alcohol use										
No					1.00 (Reference)					1.00 (Reference)
Yes	-0.12	0.15	-0.80	0.423	0.89 (0.66 ~ 1.19)	-0.00	0.22	-0.02	0.986	1.00 (0.65 ~ 1.54)
BMI	-0.36	0.03	-12.13	<0.001	0.70 (0.66 ~ 0.74)	-0.47	0.07	-7.01	<0.001	0.63 (0.55 ~ 0.71)
Waist circumference	-0.08	0.01	-9.14	<0.001	0.92 (0.91 ~ 0.94)	0.01	0.01	0.41	0.685	1.01 (0.98 ~ 1.03)
Hip circumference	-0.11	0.01	-8.89	<0.001	0.89 (0.87 ~ 0.92)	-0.01	0.02	-0.23	0.817	0.99 (0.95 ~ 1.04)
Left thigh circumference	-0.19	0.02	-10.02	<0.001	0.83 (0.80 ~ 0.86)	0.05	0.08	0.57	0.566	1.05 (0.90 ~ 1.22)
Right thigh circumference	-0.18	0.02	-9.97	<0.001	0.83 (0.80 ~ 0.86)	0.00	0.08	0.04	0.965	1.00 (0.86 ~ 1.17)
Left calf circumference	-0.32	0.03	-10.44	<0.001	0.72 (0.68 ~ 0.77)	-0.21	0.07	-2.80	0.005	0.81 (0.71 ~ 0.94)
Right calf circumference	-0.28	0.03	-9.45	<0.001	0.76 (0.71 ~ 0.80)	0.04	0.07	0.64	0.522	1.04 (0.92 ~ 1.19)
FM	-0.09	0.01	-7.36	<0.001	0.91 (0.89 ~ 0.94)	-0.45	0.07	-6.37	<0.001	0.64 (0.56 ~ 0.73)
Body fat percentage	-0.02	0.01	-1.66	0.096	0.99 (0.97 ~ 1.00)	0.50	0.05	9.65	<0.001	1.65 (1.49 ~ 1.83)

β: coefficient, S.E: standard error, Z: Z-score, *P*: P-value, OR: odds ratio, CI: confidence interval. BMI: body mass index, FM: fat mass, ASM: appendicular skeletal muscle mass, ASMI: appendicular skeletal muscle mass index.

3.4 Association between age, body composition indicators and sarcopenia

The RCS results are shown in Figure 1. The standard logistic regression model revealed that age was significantly positively associated with sarcopenia risk (OR: 1.15, 95% CI: 1.12 - 1.18, $P < 0.001$), whereas both BMI (OR: 0.70, 95% CI: 0.66 - 0.74, $P < 0.001$) and FM (OR: 0.91, 95% CI: 0.89 - 0.94, $P < 0.001$) were negatively associated with sarcopenia risk. In the piecewise logistic regression, age remained positively associated with sarcopenia risk above the cut-off of 65.70 years (OR: 1.15, 95% CI: 1.12 - 1.18, $P < 0.001$). BMI showed a negative association below 22.03 kg/m² (OR: 0.79, 95% CI: 0.66 - 0.95, $P = 0.014$) and a stronger negative association at or above 22.03 kg/m² (OR: 0.66, 95% CI: 0.59 - 0.73, $P < 0.001$). FM was negatively associated with sarcopenia risk when exceeding 9.81 kg (OR: 0.91, 95% CI: 0.89 - 0.94, $P < 0.001$). Likelihood-ratio tests indicated no significant improvement of the piecewise models over the standard model for age ($P = 0.905$), BMI ($P = 0.191$), or FM ($P = 0.998$) (Table 4).

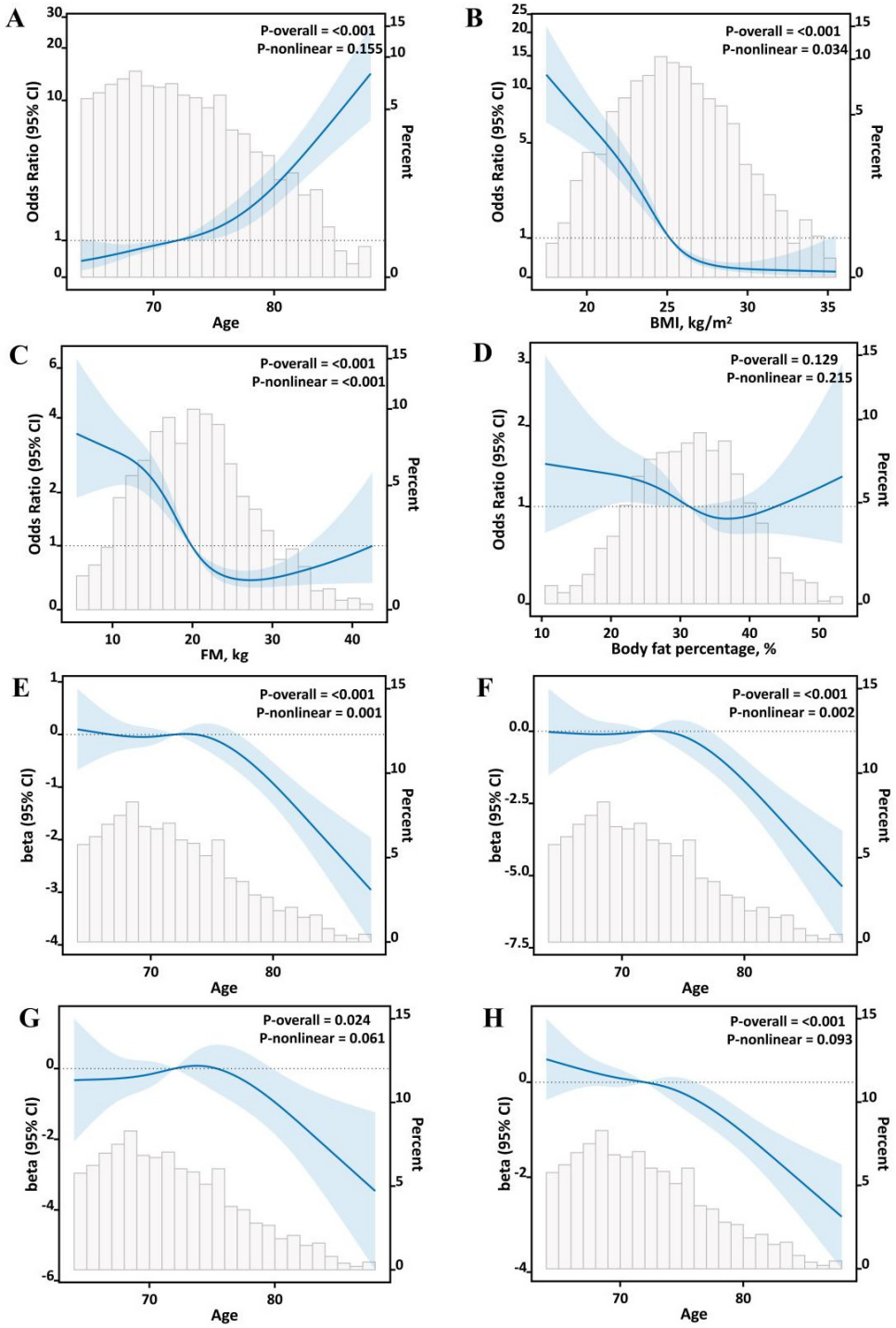

Figure 1. The nonlinear associations between age (A), BMI (B), FM (C), body fat percentage (D) and sarcopenia, and the nonlinear associations between BMI (E), FM (F), body fat percentage (G), ASM (H) and age. BMI: body mass index, FM: fat mass, ASM: appendicular skeletal muscle mass.

Table 4 Threshold effect analysis of age, BMI and FM on sarcopenia.

Variables		OR (95% CI)	*P*
	Fitting by standard Logistic regression model	1.15 (1.12, 1.18)	**<0.001**
	Fitting by piecewise Logistic regression model (Break-Point = 65.70)		
Age	< 65.70	1.40 (0.49, 3.95)	0.528
	≥ 65.70	1.15 (1.12, 1.18)	**<0.001**
	Log likelihood ratio		**0.905**
BMI, kg/m²	**Fitting by standard Logistic regression model**	0.70 (0.66, 0.74)	**<0.001**
	Fitting by piecewise Logistic regression model (Break-Point = 22.03)		

Variables		OR (95% CI)	*P*
	< 22.03	0.79 (0.66, 0.95)	**0.014**
	≥ 22.03	0.66 (0.59, 0.73)	<0.001
	Log likelihood ratio		0.191
	Fitting by standard Logistic regression model	0.91 (0.89, 0.94)	<0.001
	Fitting by piecewise Logistic regression model (Break-Point = 9.81)		
FM, kg	< 9.81	0.91 (0.71, 1.17)	0.452
	≥ 9.81	0.91 (0.89, 0.94)	<0.001
	Log likelihood ratio		0.998

OR: odds ratio, CI: confidence interval, *P*: P-value. BMI: body mass index, FM: fat mass.

Standard linear regression analysis showed that age was negatively associated with BMI (β: –0.088, 95% CI: –0.12 - –0.06, $P < 0.001$), FM (β: –0.156, 95% CI: –0.22 - –0.10, $P < 0.001$), and ASM (β: –0.113, 95% CI: –0.15 - –0.08, $P < 0.001$). The piecewise linear regression analysis indicated that when age exceeded 79.90 years, it was negatively associated with BMI (β: –0.368, 95% CI: –0.56 - –0.18, $P < 0.001$). When age exceeded 73.43 years, it was negatively associated with FM (β: –0.347, 95% CI: –0.50 - –0.20, $P < 0.001$). Above 80.00 years, age was negatively associated with body fat percentage (β: –0.486, 95% CI: –0.91 - –0.06, $P = 0.025$). Below 82.00 years, age remained negatively associated with ASM (β: –0.109, 95% CI: –0.15 - –0.06, $P < 0.001$). Likelihood-ratio tests indicated that the piecewise regression models for age ($P < 0.001$), FM ($P = 0.002$), and body fat percentage ($P = 0.048$) provided a better fit than the standard linear regression models (Table 5).

Table 5 Threshold effect analysis of age on BMI, FM, body fat percentage and ASM.

Variables		Beta (95% CI)	P
	Fitting by standard Linear regression model	-0.088 (-0.12, -0.06)	<0.001
	Fitting by piecewise Linear regression model (Break-Point = 79.90)		
BMI, kg/m2	Age < 79.90	-0.037 (-0.09, 0.01)	0.136
	Age ≥ 79.90	-0.368 (-0.56, -0.18)	<0.001
	Log likelihood ratio		<0.001
	Fitting by standard Linear regression model	-0.156 (-0.22, -0.10)	<0.001
	Fitting by piecewise Linear regression model (Break-Point = 73.43)		
FM, kg	Age < 73.43	0.063 (-0.11, 0.24)	0.482
	Age ≥ 73.434	-0.347 (-0.50, -0.20)	<0.001
	Log likelihood ratio		0.002
	Fitting by standard Linear regression model	-0.075 (-0.15, -0.00)	0.050
	Fitting by piecewise Linear regression model (Break-Point = 80.00)		
Body fat percentage, %	Age < 80.00	-0.002 (-0.11, 0.11)	0.971
	Age ≥ 80.00	-0.486 (-0.91, -0.06)	0.025
	Log likelihood ratio		0.048
	Fitting by standard Linear regression model	-0.113 (-0.15, -0.08)	<0.001
	Fitting by piecewise Linear regression model (Break-Point = 82.00)		
ASM, kg	Age < 82.00	-0.109 (-0.15, -0.06)	<0.001
	Age ≥ 82.00	-0.155 (-0.51, 0.20)	0.388
	Log likelihood ratio		0.938

OR: odds ratio, CI: confidence interval, *P*: P-value. BMI: body mass index, FM: fat mass, ASM: appendicular skeletal muscle mass.

4. Discussion

This study employed the BIA method to conduct a systematic assessment of the dynamic changes in ASM, FM, and total body water among elderly individuals of different age groups. The research findings indicated that the prevalence rates of sarcopenia in the 60 - 70 years old, 71 - 80 years old, and over 80 years old age groups were 7.42%, 13.39%, and 46.15% respectively, with significant differences among the groups ($P < 0.001$). There were significant statistical differences in the prevalence of sarcopenia, marital status, education level, and monthly income, physical examination indicators, muscle strength, physical function and body composition among different age groups ($P < 0.05$). The results of multivariate logistic regression analysis demonstrated that gender was an independent influencing factor significantly associated with sarcopenia. Compared with males, the risk of sarcopenia in females was significantly lower ($P < 0.001$). Chen et al.'s meta-analysis results indicated that the prevalence of sarcopenia among hospitalized elderly patients was higher than that among community-dwelling elderly individuals, and the prevalence of sarcopenia was higher in men than in women[12]. Liu et al.[13] investigated 4500 elderly people living in urban communities in China. The results showed that the prevalence of sarcopenia among men and women was 22.1% and 17.8%, respectively. A study in Poland indicated that the SMM of both men and women in the limbs began to decline from the age of 50, with a faster rate in men than in women[14]. Compared with studies in other regions of China, a survey of 316 elderly people in nursing homes in Suzhou, Jiangsu Province, found that the prevalence of sarcopenia was 30.4% in men and 27.9% in women. Additionally, high BMI and a diet containing meat, eggs, and dairy products were identified as protective factors[15]. In a study in the western region of China involving 4500 elderly people over the age of 50, the overall prevalence of sarcopenia was 16.7%, with 18.3% in men and 15.7% in women. The study also indicated that the occurrence of sarcopenia was closely related to factors such as advanced age, chronic diseases, and nutritional status[13]. The results of the above studies all showed that the prevalence of sarcopenia in elderly men is higher than that in women, which may be related to changes in testosterone levels and insulin-like growth factor-1 (IGF-1) levels in men[16]. In the early stages of aging, due to menopause and the decline in estrogen levels in the blood, women show a faster loss of muscle mass and strength compared to men; however, in the subsequent stages of aging, the decrease in IGF-1 and testosterone hormone levels in men leads to a significantly accelerated decline in muscle function and mass, thereby increasing the risk of sarcopenia[17]. The reported prevalence of sarcopenia in Asian countries ranges from 5.5% to 25.7%, with a majority of cases being male (5.1% - 21.0% in men vs. 4.1% - 16.3% in women)[18]. Due to the differences in diagnostic criteria, methods for detecting muscle mass and muscle strength, and population characteristics among various studies, the prevalence of sarcopenia varies in each study. Furthermore, the results indicated that an increase in FM and body fat percentage were independent influencing factors of sarcopenia, but the two were associated with sarcopenia risk in opposite directions. This reverse result is not contradictory but reflects the essential biological and statistical differences between FM and body fat percentage. Body fat percentage reflects the relative load of fat, while FM reflects the absolute fat reserve. The two point to different body composition phenotypes in the elderly population, which may be the reason for the opposite direction of association with the risk of sarcopenia. However, age is one of the main

risk factors for sarcopenia. This study analyzed the association between age and the risk of sarcopenia, and the results showed that compared with the elderly aged 60 - 70, the risk of sarcopenia was significantly increased in the 71 - 80 age group, and even higher in those over 80 years old in the crude model. In addition, the results of the segmented logistic regression analysis showed that age was significantly positively correlated with the risk of sarcopenia in the range above 65.70 ($P < 0.001$). Therefore, the factors that may lead to sarcopenia should be closely monitored and effectively intervened to delay its progression and minimize its impact on the prognosis of other diseases in the elderly.

As the largest amino acid reservoir in the human body, skeletal muscle maintains the balance between protein and free amino acids by regulating protein synthesis and degradation[19]. Protein homeostasis has a critical role in supporting a naturally long lifespan, and loss of proteostasis has been recognized as a key hallmark of ageing[20]. Muscle protein anabolism is mainly mediated by amino acids (especially branched-chain amino acids such as leucine), exercise, insulin and IGF-1, as well as hormones[21, 22]. They successively activate the phosphorylation of serine/threonine kinase - mammalian target of rapamycin (mTOR) pathway: after IGF-1 binds to IGF-1 receptor (IGFR), it recruits and phosphorylates insulin receptor substrate 1 (IRS-1), and then IRS-1 activates phosphatidylinositol 3-kinase (PI3K), which in turn activates protein kinase B (Akt). Ultimately, Akt promotes the activation of mTOR complex 1 (mTORC1) by inhibiting tuberous sclerosis complex 2 (TSC2). Akt inhibits glycogen synthase kinase 3 (GSK-3) and relieves the inhibition of RHEB by phosphorylating TSC2, thereby enhancing mTORC1[23-26]. mTORC1 then phosphorylates the downstream 70 kDa ribosomal protein S6 kinase (p70S6K1, Thr389) and eukaryotic translation initiation factor 4E binding protein-1 (4E-BP1, Thr37/46), relieving the inhibition of eukaryotic translation initiation factors eIF4B and accelerating translation initiation[27-30]. It can be seen from this that the IGF-1/PI3K/Akt/mTOR pathway is of great significance to protein synthesis. The reduction of protein synthesis in muscle cells is one of the main causes of sarcopenia, and the synthetic activity will decrease with aging[31]. In addition, the ubiquitin-proteasome system, the autophagy-lysosome system, the caspase system and the calpain system are the four major downstream components of protein degradation[32-36].The first three enzymes completely hydrolyze the substrate, while calpain modifies it at specific sites to regulate its activity[37]. In summary, during aging, the imbalance between synthesis and degradation leads to net protein loss and muscle atrophy. Therefore, maintaining or enhancing the protein synthesis capacity of elderly skeletal muscle is an effective approach to prevent and treat primary sarcopenia.

Age-related decline in physical performance is a major factor contributing to the loss of muscle mass and strength in the elderly[38, 39]. Exercise intervention has been proven to be one of the best methods for maintaining and enhancing SMM and strength, as well as preventing and treating sarcopenia. Studies have shown that resistance exercise can effectively promote protein synthesis in skeletal muscle and improve its energy metabolism function[40, 41]. Therefore, on the basis of adequate protein supplementation, resistance exercise has shown the most persistent effect in preventing the occurrence of sarcopenia in the elderly.

Particularly in progressive resistance training, as resistance gradually increases, muscle strength significantly improves, and this effect is considered to have important clinical significance[42, 43].

Muscle mass and strength exhibit dynamic changes throughout a person's life. From childhood, muscle mass grows rapidly and reaches its peak in early adulthood, then gradually decreases with age. Generally, men's muscle mass peaks around the age of 25, while women's peaks around 23[44]. During normal aging, humans lose an average of 3% to 8% of their muscle mass and strength each year starting from around 30 years old; after the age of 65, this rate of loss significantly accelerates, reaching 6% to 15% per year[45]. This study measured the height and weight of the research subjects to calculate their BMI values (the calculation formula is: BMI = weight (kg) / height² (m^2)). The research results showed that there was a significant statistical association between BMI and FM and the prevalence of sarcopenia. Specifically, as BMI ($P < 0.001$) and FM ($P < 0.001$) increased, the risk of sarcopenia significantly decreased. The results of the segmented logistic regression analysis showed that BMI was significantly negatively correlated with the risk of sarcopenia in the range below 22.03 kg/m^2 ($P = 0.014$); when BMI exceeded 22.03 kg/m^2, the negative correlation was more significant ($P < 0.001$). When FM was higher than 9.81 kg, it was significantly negatively correlated with the risk of sarcopenia ($P < 0.001$). The likelihood ratio test indicated that the piecewise model did not show significant improvement compared with the standard model, and the piecewise effect in the risk of sarcopenia could not be fully confirmed. The above results suggested that the reduction of BMI and FM in the elderly does not necessarily reduce the risk of sarcopenia, but may increase its prevalence. However, the specific mechanism by which low BMI and low FM lead to an increased prevalence of sarcopenia still requires further research. For elderly people with a lower BMI or a lower FM, more attention should be paid to their muscle mass status, and screening and preventive measures for sarcopenia should be carried out in a timely manner. As for the group with a higher FM, although their risk of sarcopenia is relatively low, they still need to pay attention to maintaining a healthy lifestyle to effectively prevent other chronic diseases related to obesity. Furthermore, the results of piecewise linear regression analysis indicated that when age exceeded 79.90, age was significantly negatively correlated with BMI ($P < 0.001$). When age exceeded 73.43, it was significantly negatively correlated with FM ($P < 0.001$). Meanwhile, within the age range of 60.00 - 82.00, age remained significantly negatively correlated with ASM ($P < 0.001$). The segmented model provided a better fit in terms of age ($P < 0.001$), FM ($P = 0.002$) and body fat percentage ($P = 0.048$), indicating that these critical points have high reliability in describing the impact of age on body composition. Therefore, to effectively delay and prevent the occurrence of sarcopenia, it is recommended to maximize muscle reserves during youth and maintain them until middle age; after entering old age, moderate exercise should be continuously carried out to reduce muscle loss, and weight stability should be maintained to further delay the development of sarcopenia[46, 47].

At present, the existing percentile curves of skeletal muscle mass mainly come from dual-energy X-ray absorptiometry (DXA) cohorts in Europe and America. The reference values of

BIA for large sample populations in Asia, especially in the developed eastern regions of China, are still blank. “Chinese Expert Consensus on Standardized Outpatient Management of Sarcopenia in the Elderly (2024)” [48] recommends the use of body composition analyzers, but lacks age- and gender-specific distribution data of fat mass and skeletal muscle mass based on the natural population over 60 years old, resulting in a lack of localized cut-off points for screening at the grassroots level. This study systematically explored the epidemiological characteristics of sarcopenia in the elderly aged 60 and above in Jiangsu Province, China, based on the latest diagnostic criteria released by AWGS in 2019. It was found that the prevalence of sarcopenia increased exponentially with age, and the age-specific prevalence range under the AWGS-2019 diagnosis in Jiangsu Province was provided. The relationship between the risk of sarcopenia and age or body composition was systematically depicted, revealing that for every additional year of age, the risk of sarcopenia increased by 15%, and this rate of increase remained consistent even after the age of 65.70, suggesting that the risk of sarcopenia accumulates linearly with age rather than simply accelerating exponentially. Additionally, the threshold effects of age, BMI, and FM on the risk of sarcopenia were precisely quantified through segmented regression, depicting the accelerated decline of physical measurement indicators with age in the elderly population of Jiangsu Province. This provides a reference baseline for the subsequent establishment of an age-body composition early warning model and offers a quantitative basis for formulating stratified screening and intervention strategies. Nevertheless, the cross-sectional study design is one of the main limitations of this study, which prevents us from determining the causal relationship and differentiating whether the decrease in BMI is due to natural aging or underlying diseases. Future studies should combine longitudinal weight trajectories with death registry data to clarify the etiological significance of the BMI inflection point at ≥79.9 years. Additionally, this study did not collect information on the comorbidity of chronic diseases among the subjects, thus making it impossible to assess the impact of common chronic diseases such as stroke, heart failure, and diabetes on the risk of sarcopenia. Previous research results have shown that the actual impact of chronic diseases on the prevalence of sarcopenia may have been systematically overestimated[49-51]. Future research will adopt larger sample size cohort studies or case-control designs, incorporating complete histories of chronic diseases and medication records, to further clarify their independent and interactive effects, and explore the causal relationship and reveal the underlying mechanisms of sarcopenia.

Globally, population aging is pushing age-related sarcopenia from a clinical finding to a public health risk. The prevalence of this condition among people over 60 exceeds 10%, and it increases exponentially with age, directly boosting the incidence and costs of falls, fractures, hospitalizations, and long-term care[52]. However, the current estimates of the true burden of disease in various countries' health systems are generally underestimated. This is due to internal factors (such as age and comorbidities), environmental conditions (such as urban-rural disparities), and inconsistent diagnostic criteria, which result in a large number of cases

going unrecorded and a lack of sustainable monitoring data[53, 54]. At the prevention level, intervention measures such as resistance training and high-protein diets have been proven to effectively slow down muscle loss in middle age and even old age[55]. However, current public health guidelines still remain at the level of expert consensus regarding the minimum effective protein dosage and exercise prescriptions, lacking mandatory standards. The accessibility of community fitness facilities and the awareness of sarcopenia among primary care medical staff are also uneven, making it difficult to implement interventions. In terms of regulation, although high-protein or vitamin D functional claims are allowed in the food and dietary supplement fields, the functional claim directory needs to be updated further and specific recommended intake levels for the elderly should be set. Overall, sarcopenia has evolved from a single clinical issue into a cross-sectoral public health challenge. The healthcare system needs to establish a unified diagnostic and early screening pathway, incorporate sarcopenia into the chronic disease management pathway, promote reimbursement for grassroots screening, exercise and nutritional interventions, and carry out public education to change the perception of irreversible aging. Only in this way can early prevention and treatment of sarcopenia be achieved in an aging society.

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Conflict of interest

The authors declare no conflicts of interest.

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