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Research article

The relationship between thigh circumference and sarcopenia in Chinese community-dwelling elderly aged ≥60 years

Zhiwei Zhang, Qianwen Yang, Panpan He, Xiaoming Liu, Xuejiao Zeng, Xueqian Mao, Xueyi Jin, Ying Hu, Lipeng Jing *

Institute of Epidemiology and Statistics, School of Public Health, Lanzhou University, Lanzhou, Gansu Province, China

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ABSTRACT

Background: There has been a growing body of research demonstrating that thigh circumference is closely associated with the development of various chronic disease. However, limited evidence has been obtained regarding the relationship between thigh circumference and sarcopenia.
Objective: The aim of this study was to investigate the relationship between thigh circumference and sarcopenia, and explore the potential role of thigh circumference for sarcopenia screening among community-dwelling older adults.
Methods: The investigation was carried out in six rural communities located in northwestern China with participants aged ≥60 years old. We collected variables related to sarcopenia, including function, muscle mass, and strength. The thigh circumference was categorized into four groups based on quartiles, with the first quartile (≤46.65 cm); the second quartile (46.66–48.50 cm); the third quartile (48.51–50.55 cm); and the fourth quartile (>50.55 cm). The associations and screening effect were estimated with multivariate logistics regression and ROC curves.
Results: Of the 1000 participants aged 70.72 ± 4.68 years. Compared with the first quartile (≤46.65 cm), the odds ratios for the second, third, and fourth quartiles of thigh circumference were 0.465 (95%CI: 0.281–0.770, $p = 0.003$), 0.199 (95%CI: 0.097–0.407, $p < 0.001$), and 0.059 (95%CI: 0.016–0.220, $p < 0.001$), respectively. The regression results were consistent across different sexes. The AUC and cutoff values of thigh circumference for sarcopenia were 0.873 (95 % CI 0.836–0.909, $p < 0.001$) and 48.83 cm for men and 0.861 (95 % CI 0.822–0.900, $p < 0.001$) and 46.78 cm for women. There was a positive correlation between thigh circumference and skeletal muscle mass ($r = 0.747$, $p < 0.001$), hand grip strength ($r = 0.337$, $p < 0.001$), and gait speed ($r = 0.142$, $p < 0.001$), while a negative correlation was observed with five-times-sit-to-stand test ($r = -0.073$, $p = 0.021$).
Conclusion: There was a negative correlation between thigh circumference and sarcopenia, suggesting that thigh circumference may serve as a potential useful indicator for sarcopenia screening in the elderly.

* Corresponding author. Institute of Epidemiology and Statistics, School of Public Health, Lanzhou University, 199 Donggang West Road, Lanzhou, Gansu Province, 730000, China.
E-mail address: jinglp@lzu.edu.cn (L. Jing).

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1. Introduction

Sarcopenia is a geriatric syndrome characterized by decreased muscle strength and compromised muscle function [1]. The increased muscle loss with advanced age is primarily attributed to the significant decline in the function and performance of the neuromuscular system [2]. Sarcopenia can have detrimental effects on the well-being of the elderly and is intricately linked to adverse outcomes, including increased susceptibility to falls, greater frailty, and heightened mortality risk [3]. Current evidence indicates that the global prevalence of sarcopenia among individuals aged 60 years and older ranges from approximately 10 %–27 % [4]. In Chinese community-dwelling older adults, the prevalence of sarcopenia is estimated to be around 10.7 %–15.1 % in men and 8.9 %–13.4 % in women [5]. According to a study conducted in 2010, it is projected that the global population aged 60 and older will increase by 2 billion by 2050, with the number of individuals affected by sarcopenia reaching approximately 200 million [6]. The elevated incidence of sarcopenia will impose a substantial burden on family healthcare costs and public health expenditure at the societal level [7,8].

With advancing age, the risk of developing chronic diseases increases. A substantial body of research has indicated a significant correlation between various physical indicators and the development of chronic disease. For instance, waist-hip ratio (WHR) and body mass index (BMI) serve as valuable metrics for evaluating obesity, and excessive BMI and WHR are closely associated with the presence of frailty [9]. Elevated BMI and waist circumference are also associated with an increased risk of developing type 2 diabetes mellitus [10]. Similarly, calf circumference has been recognized as an important indicator for preliminary screening of sarcopenia in Asian communities [11].

In recent years, there has been a growing body of research focused on the correlation between thigh circumference and chronic diseases. Increased thigh circumference not only reduces the risk of metabolic diseases such as type 2 diabetes mellitus [12] and hypertension [13], but also predicts the risk of developing degenerative diseases such as dementia [14]. A prospective cohort study involving 2.7 million participants revealed that each 5 cm increment in thigh circumference was associated with an 18 % reduction in all-cause mortality [15]. There is a correlation between subcutaneous fat and thigh muscle mass with thigh circumference [16], and an abundance of muscle and subcutaneous adipose of thigh can better promote the stabilization of glucose and lipid metabolic functions [17,18]. Because abnormal glucose and lipid metabolism is a significant risk factor of sarcopenia [19,20]. Research has shown that, in addition to muscle atrophy, patients with sarcopenia also experience a decrease in the area of subcutaneous adipose in the thigh region, potentially leading to a decrease in thigh circumference [21]. Thus, thigh circumference appears to be a better indicator of overall health compared to previously studied body metrics. However, research on the relationship between thigh circumference and sarcopenia - a degenerative disease associated with aging - has been limited in recent years.

Currently, empirical evidence suggests that thigh circumference is a useful predictor of thigh muscle volume [22], and a significant association has been observed between thigh muscle volume or muscle thickness and grip strength as well as walking speed [23,24]. However, there is a paucity of studies investigating the relationship between thigh circumference and sarcopenia in Asia [25], with most of them being conducted among hospitalized patients or individuals with specific diseases, often characterized by relatively small sample sizes [26–28].

Given this background, this study aims to investigate the independent association between thigh circumference and sarcopenia, as well as to analyze the relationship between thigh circumference and the screening criteria for sarcopenia. Additionally, the study will determine the cutoff value of thigh circumference for screening sarcopenia and evaluate its predictive efficacy.

2. Methods

2.1. Study population

Our study was based on “Health Management Services for the Elderly”, which is part of “China’s National Basic Public Health Service Project (BPHS)” [29]. From March to May 2023, we investigated a total of 1417 individuals over 60 years of age from six rural communities in Jingyuan county, northwestern China. Of these, 1209 individuals completed the questionnaire, yielding a response rate of 85.32 %. After applying further exclusion criteria, 1000 participants were eventually included in this study. The inclusion criteria for this study were: (1) aged $\geq$60 years; (2) completed the hand grip strength (HGS), gait speed (GS), five-times-sit-to-stand (FTSTS), and InBody770 tests, and had measured thigh and calf circumferences; (3) local resident for five years or more; and (4) provided informed consent and willingness to participate in the study. The exclusion criteria were: (1) a history of mental illness such as schizophrenia, or impairment in communication such as cognitive, comprehension, and expression disorders; (2) chronically bedridden or had a disability that prevented them from taking measurements of relevant indicators; and (3) unwilling to cooperate with the investigation.

2.2. Assessment of sarcopenia

Participants were instructed to remove their coats and wear light clothing before individual index measurements were taken. Skeletal muscle mass (SMI, appendicular muscle mass (ASM)/height^2, kg/m^2) was measured using the InBody 770 (Biospace, Korea) instrument via bioelectrical impedance analysis (BIA). Participants stood barefoot on the foot electrodes of the device while firmly gripping the hand electrodes with extended arms, ensuring no contact with the upper body. Throughout the test, participants maintained a stable posture without swaying.

Hand grip strength (HGS)was assessed using a handgrip dynamometer (CAMRY, EH101). The investigator adjusted the meter handle to fit the participant’s palm, who stood upright and squeezed the dynamometer with maximum force without body movement.

Each hand was tested twice, with the maximum grip strengths from four attempts recorded.

Gait speed (GS) over 6 m was measured with participants starting with feet together and walking at their usual speed. The time to complete the distance was recorded twice, and the average was taken as the result. GS = walking distance in meters/completion time in seconds).

The five-times-sit-to-stand test (FTSTS) assessed participants' ability to stand up and sit down from a chair five times as quickly as possible. Participants sat in a chair with their backs straight, feet flat on the floor, arms and wrists crossed and held in front of their chests, and then subjects to stand up and sit down five times as fast as they could and recorded their time to complete the trial. The time taken for two trials was averaged for the final result.

Sarcopenia was defined using AWGS 2019 criteria [11], incorporating low muscle mass (SMI, male: <7.0 kg/m^2, female: <5.7 kg/m^2), low muscle strength (HGS, male: <28 kg, female: <18 kg), or impaired physical performance (GS < 1 m/s or FTSTS>12s). These criteria identified individuals meeting internationally recognized sarcopenia standards accurately.

2.3. Measurement

Prior to the measurements, participants were instructed to stand naturally with feet shoulder-width apart and distribute body weight evenly. They were asked to breathe naturally with relaxed abdomen and hips. A flexible, non-elastic tape measure was used horizontally without twisting or knotting.

To minimize clothing thickness influence, participants wore thin pants during thigh circumference. They stood upright with legs shoulder-width apart. The investigator positioned the tape measure around the thickest part of the upper thigh below the gluteal fold of the right thigh and recorded the horizontal circumference. Calf circumference was similarly measured at its thickest point.

During waist measurement, participants exposed their abdomen fully, and the tape measure was placed 1 cm above the navel. For hip measurement, participants stood with legs together, and the tape measure circled the fullest part of the buttocks. Height and weight measurements were taken using an infrared height and weight meter (LK-200, China). Using BMI (≥28 kg/m^2) [30] or waist circumference (≥90 cm for men, ≥85 cm for women) to define obesity [31].

All measurements were averaged from two readings, with a maximum allowable error of 0.1 cm. If error exceeded this, a third measurement was taken. Precision was ensured with measurements recorded to 0.01 cm.

2.4. Covariates

General demographic variables, including age (years), sex (male vs female), marital status (married or partnered vs not), education (early childhood, primary, lower secondary and upper secondary and above), and income (low vs high), were taken into consideration. Physical indicators such as body mass index (BMI), waist-to-hip ratio (WHR), and calf circumference were also included as covariates. Lifestyle habits, included daily steps, sleep duration, smoking (smokers vs never), alcohol drinking (drinkers vs never), and dietary preferences, were accounted for as well. Additionally, participants were asked about their history of falls and disease history. Frailty was defined following Fried's criteria [32]. with the presence of three or more of the following criteria: unintentional weight loss, self-reported exhaustion, weakness, slow walking speed, and low physical activity. The presence of one or two of these criteria indicates pre-frailty, while the absence of all criteria indicates a state of health.

Smoking and alcohol drinking were collected by aske participants if they had smoked and alcohol drank in the past. Smoking: Smoked in the past or currently have the habit of smoking; Never: Never smoked. Drinking: Drank in the past or currently have the habit of alcohol drinking; Never: Never drank.

Dietary preference information including taste preferences and the degree of dietary oiliness in daily meals. Taste preferences including five common tastes - sour, sweet, bitter, spicy and salty. We asked each participant about their preference for each taste and the extent of their preference. The categories are as follows: Dislike: Generally, do not eat foods with this taste; General: Indifferent to eating foods with this taste; Like: Will miss this taste if not consumed for a period of time. The degree of dietary oiliness: this was a subjective estimate of overall amount of oil intake. We would ask the participants about the amount of cooking oil used daily or the presence of floating oil on each dish or soup. The categories are as follows: Mild: Almost no oil used/no floating oil on the dish or soup; Slightly mild: A small amount of oil used/a little floating oil on the dish or soup; Slightly greasy: Some oil used/some floating oil on the dish or soup; Oily: A large amount of oil used/a significant amount of floating oil on the dish or soup.

2.5. Statistical analyses

Categorical variables were described using frequency N (%). Continuous variables are described by mean ± standard deviation (SD) when they satisfy a normal distribution. One-way analyses were used using Chi-square tests or Fisher's exact probability method and Independent-samples t-tests. We categorized thigh circumference into four groups based on quartiles: the first quartile (≤46.65 cm); the second quartile (46.66–48.50 cm); the third quartile (48.51–50.55 cm); and the fourth quartile (>50.55 cm). Additionally, we stratified the thigh circumference into sex-specific quartiles. Multiple logistic regression model was utilized to explore the association between thigh circumference quartile and sarcopenia, using the first quartile group as the reference. The odds ratio (OR) and its corresponding 95 % confidence interval (CI) were employed as the effect estimate to quantify the strength and direction of the relationship. We assessed subsequently the screening performance of thigh circumference in predicting sarcopenia using the area under the receiver operating characteristic (ROC) curve. Through this analysis, we determined the optimal cutoff value that maximized the sensitivity and specificity of thigh circumference in identifying individuals with sarcopenia. The Pearson correlation coefficient was utilized to examine the relationship between thigh circumference and variables, namely SMI, HGS, GS, and FTSTS. We adjusted for variables that previous studies have shown to be associated with sarcopenia or its related four diagnostic indicators (SMI, HGS, GS and FTSTS) in multiple logistics regression: age, sex, frailty, marital status, education, income, smoking, alcohol drinking, daily steps, dietary preferences, sleep duration, chronic diseases, falls, calf circumference, BMI and WHR. Finally, stratified analyses were conducted for age, gender, income, smoking alcohol drinking and obesity to ensure consistency of the results.

The data analysis in this study was performed using SPSS 27.0 software (IBM Corporation, Armonk, NY, United States), and ROC curves were generated using R 4.3.1 with the "proc" and "reportroc" package. Statistical significance was determined at a significance level of $p < 0.05$ for two-sided tests.

3. Results

3.1. Participants' characteristics

Our study involved 1000 participants aged 70.72 ± 4.68 years, including 406 male aged 71.25 ± 4.93 years and 594 female aged 70.36 ± 4.47 years ($p < 0.05$). According to the 2019 AWGS, sarcopenia was diagnosed in 185 participants (18.5 %, 95 % CI:16.1–20.9), with a higher prevalence among males at 22.2 % (95%CI: 18.2–26.3) compared to females at 16.0 % (95%CI: 13.0–18.9) ($p < 0.05$). Participants with sarcopenia exhibited a higher propensity towards older age, male gender, unmarried or non-partnered status, lower incomes, increased frailty, higher likelihood of smoking, and reduced daily step counts compared to those without sarcopenia ($p < 0.05$ for all; Table 1). Participants in the sarcopenic group not only had higher FTSTS, but also exhibited a higher propensity towards lower BMI, WHR, calf circumference, thigh circumference, SMI, HGS and GS compared to the non-sarcopenic group ($p < 0.001$ for all; Table 1). Upon dividing thigh circumference into quartile groups (≤46.65 cm, 46.66–48.50 cm, 48.51–50.55 cm and >50.55 cm), a decline in the prevalence of sarcopenia was observed with increasing thigh circumference, and demonstrating a similar trend for both male and female participants (Fig. 1).

3.2. Associations of thigh circumference with sarcopenia

In the multivariate adjusted model 4, compare to the first quantile (≤46.65 cm) of participants' thigh circumference, the ORs for the second (46.66–48.50 cm), third (48.51–50.55 cm), and fourth (>50.55 cm) quantile were 0.465 (95%CI: 0.281–0.770, $p = 0.003$), 0.199 (95%CI: 0.097–0.407, $p < 0.001$), and 0.059 (95%CI: 0.016–0.220, $p < 0.001$), respectively (Table 2). The thigh circumference was categorized into four groups based on sex-specific quartiles. Compared with the first quartile for male of thigh circumference, the ORs for second, third, and fourth quartile were 0.421 (95%CI: 0.180–0.946, $p = 0.037$), 0.040 (95%CI: 0.010–0.165, $p < 0.001$), and 0.021 (95%CI: 0.002–0.270, $p < 0.001$), respectively. Compared with the first quartile for female of thigh circumference, the ORs for second, third, and fourth quartile were 0.454 (95%CI: 0.221–0.933, $p = 0.032$), 0.261 (95%CI: 0.096–0.701, $p = 0.009$), and 0.075 (95%CI: 0.009–0.659, $p = 0.019$), respectively (Table 2). Both male and female participants, as well as the overall study participants, demonstrated a declining odds ratio with increasing thigh circumference (Table 2, Table S1). The trends in the results of the stratified analyses of the obesity and other factors (age, income, smoking and alcohol drinking) were also consistent with the aforementioned analyses (Table S2, Table S3).

ROC curves showed better screening for sarcopenia in thigh circumference compared to calf circumference and WHR, and the results were consistent across different sexes (Fig. 2(A–C)). AUCs for thigh circumference outperformed calf circumference in males (0.873 vs. 0.727) and females (0.861 vs. 0.743), respectively. The sensitivity and specificity were 0.718, 0.911 for males and 0.776, 0.789 for females. The derived ROC cutoffs were 48.83 cm in males and 46.78 cm in females (Table S4). The stratified analysis of other factors (age, income, smoking and alcohol drinking) of the ROC curve showed that all AUC values were greater than 0.800. The AUC values for the obese group and the non-obese group are 0.820 and 0.781, respectively ($p = 0.282$) (Fig. S1).

3.3. Associations of thigh circumference with SMI, HGS, GS and FTSTS

This study concurrently had examined the association between thigh circumference of participants and SMI, HGS, GS, and FTSTS. The findings had indicated a positive correlation between thigh circumference and SMI ($r = 0.747$, $p < 0.001$), HGS ($r = 0.337$, $p < 0.001$), and GS ($r = 0.142$, $p < 0.001$), while a negative correlation was observed with FTSTS ($r = -0.073$, $p = 0.021$) (Table 3).

4. Discussion

Our study primarily identified a negative association between increased thigh circumference and sarcopenia among elderly individuals aged 60 years and older in Chinese communities, irrespective of gender, after adjusting for potential confounding factors. Furthermore, the results of the receiver operating characteristic (ROC) curve analysis indicated that thigh circumference demonstrated favorable accuracy and predictive efficacy in screening for sarcopenia. This finding was attribute to the positive correlation observed between thigh circumference and muscle mass, muscle strength, and physical performance. Our research had warranted to confirm this inference by exploring the relationship between thigh circumference and SMI (Skeletal Muscle Index), HGS (Handgrip Strength), GS (Gait Speed), and FTSTS (Five Times Sit-to-Stand), and this finding were consistent with previous research results [22].

Thigh circumference can be a potential predictor of sarcopenia. The findings of this study were in line with previous research, indicating that increased thigh circumference can serve as a protective factor against sarcopenia [33]. Importantly, thigh

Table 1
Characteristics of the entire study population based on sarcopenia.

	Overall	Sarcopenia	No sarcopenia	p
N	1000	185	815	
Age (years)	70.72 (4.68)	73.28 (5.43)	70.14 (4.29)	**<0.001**
Sex (female)	594 (59.40 %)	95 (51.35 %)	499 (61.23 %)	**0.014**
Marital status (married or partnered)	758 (75.80 %)	125 (67.57 %)	633 (77.67 %)	**0.004**
Education				0.597
Early childhood*	489 (48.90 %)	83 (44.86 %)	406 (49.82 %)	
Primary	252 (25.20 %)	53 (28.65 %)	199 (24.42 %)	
Lower secondary	140 (14.00 %)	27 (14.59 %)	113 (13.87 %)	
Upper secondary and above	119 (11.90 %)	22 (11.89 %)	97 (11.90 %)	
Income (high)	361 (36.10 %)	54 (29.19 %)	307 (37.67 %)	**0.030**
Smoking (yes)	276 (27.60 %)	65 (35.14 %)	211 (25.89 %)	**0.011**
Alcohol drinking (yes)	150 (15.00 %)	30 (16.22 %)	120 (14.72 %)	0.608
Frailty				**<0.001**
Health	370 (37.00 %)	46 (24.86 %)	324 (39.75 %)	
Pre-frailty	555 (55.50 %)	112 (60.54 %)	443 (54.36 %)	
Frailty	75 (75.00 %)	27 (14.59 %)	48 (5.89 %)	
Daily steps				**0.010**
≤2000	204 (20.40 %)	55 (29.73 %)	149 (18.28 %)	
2001-4000	282 (28.20 %)	46 (24.86 %)	236 (28.96 %)	
4001-7000	289 (28.90 %)	51 (27.57 %)	238 (29.20 %)	
7001-10000	133 (13.30 %)	18 (9.73 %)	115 (14.11 %)	
10000≥	92 (92.00 %)	15 (8.11 %)	77 (9.45 %)	
The degree of dietary oiliness				0.450
Mild	81 (81.00 %)	11 (5.95 %)	70 (8.59 %)	
Slightly mild	235 (23.50 %)	49 (26.49 %)	186 (22.82 %)	
Slightly greasy	612 (61.20 %)	114 (61.62 %)	498 (61.10 %)	
Oily	72 (72.00 %)	11 (5.95 %)	61 (7.84 %)	
Sour				**0.018**
Dislike	271 (27.10 %)	45 (24.32 %)	226 (27.73 %)	
General	154 (15.40 %)	41 (22.16 %)	113 (13.87 %)	
Like	575 (57.50 %)	99 (53.51 %)	476 (58.40 %)	
Sweet				**0.018**
Dislike	327 (32.70 %)	53 (28.65 %)	274 (33.62 %)	
General	119 (11.90 %)	33 (17.84 %)	86 (10.55 %)	
Like	554 (55.40 %)	99 (53.51 %)	455 (55.83 %)	
Spicy				**0.042**
Dislike	378 (37.80 %)	84 (45.41 %)	294 (36.07 %)	
General	121 (12.10 %)	23 (12.43 %)	98 (12.02 %)	
Like	501 (50.10 %)	78 (42.16 %)	423 (51.90 %)	
Salty				0.330
Dislike	412 (41.20 %)	69 (37.30 %)	343 (42.09 %)	
General	203 (20.30 %)	44 (23.78 %)	159 (19.51 %)	
Like	385 (38.50 %)	72 (38.92 %)	313 (37.40 %)	
Bitter				0.880
Dislike	729 (72.90 %)	133 (71.89 %)	596 (73.13 %)	
General	124 (12.40 %)	25 (13.51 %)	99 (12.15 %)	
Like	147 (14.70 %)	27 (14.59 %)	120 (14.72 %)	
Sleep duration (hour)				**0.031**
<6h	310 (31.00 %)	63 (34.05 %)	247 (30.31 %)	
6–8h	478 (47.80 %)	73 (39.46 %)	405 (49.69 %)	
>8h	212 (21.20 %)	49 (26.49 %)	163 (20.00 %)	
Obesity	554 (55.4 %)	40 (21.62 %)	514 (3.07 %)	**<0.001**
Other diseases (yes)	943 (94.30 %)	170 (91.89 %)	773 (94.85 %)	0.118
Falls (yes)	154 (15.40 %)	29 (15.68 %)	125 (15.34 %)	0.908
Height (m)	1.59 (0.08)	1.57 (0.08)	1.59 (0.08)	**<0.001**
Weight (kg)	63.89 (10.34)	54.73 (7.48)	65.97 (9.76)	**<0.001**
BMI (kg/m^2)	25.27 (3.43)	22.29 (2.61)	25.94 (3.23)	**<0.001**
Waist circumference (cm)	87.53 (9.74)	80.08 (8.40)	89.22 (9.21)	**<0.001**
Hip circumference (cm)	96.94 (7.00)	91.64 (5.73)	98.14 (6.70)	**<0.001**
WHR	0.90 (0.07)	0.87 (0.07)	0.91 (0.06)	**<0.001**
Thigh circumference (cm)	48.69 (2.89)	45.97 (1.95)	49.31 (2.71)	**<0.001**
Calf circumference (cm)	34.21 (3.29)	32.18 (2.72)	34.67 (3.24)	**<0.001**
SMI (kg/m^2)	6.65 (0.88)	5.84 (0.70)	6.83 (0.81)	**<0.001**
HGS (kg)	25.99 (7.99)	23.26 (7.05)	26.61 (8.07)	**<0.001**
GS (m/s)	0.93 (0.21)	0.86 (0.20)	0.94 (0.21)	**<0.001**
FTSTS (s)	11.84 (4.70)	13.31 (5.48)	11.50 (4.44)	**<0.001**

Data are n (%) and mean SD, unless otherwise indicated.
Abbreviations: BMI, body mass index; WHR, waist-hip ratio; SMI, skeletal muscle index; HGS, hand grip strength; GS, 6 m gait speed; FTSTS, five-

times-sit-to-stand test.
*Less than primary' for educational attainment.

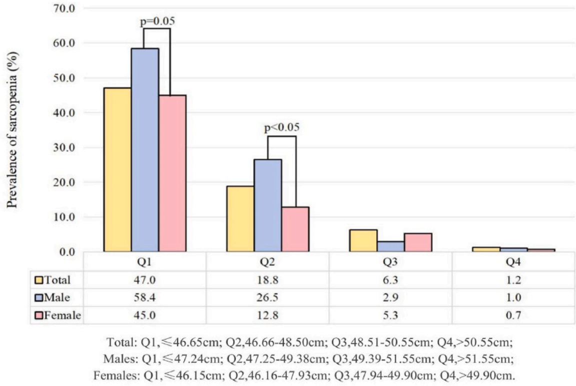

Fig. 1. Prevalence of sarcopenia based on grouping by thigh circumference. (total and by sex groups).

Table 2
Multiple logistic regression analysis of Thigh Circumference with sarcopenia.

Thigh circumference (cm)	N	Model 1		Model 2		Model 3		Model 4	
		OR (95%CI)	p	OR (95%CI)	p	OR (95%CI)	p	OR (95%CI)	p
Total									
≤46.65	253	Ref		Ref		Ref		Ref	
46.66–48.50	250	0.261 (0.174, 0.390)	**<0.001**	0.245 (0.159, 0.376)	**<0.001**	0.278 (0.176, 0.439)	**<0.001**	0.465 (0.281, 0.770)	**0.003**
48.51–50.55	254	0.076 (0.043, 0.133)	**<0.001**	0.061 (0.033, 0.111)	**<0.001**	0.084 (0.045, 0.158)	**<0.001**	0.199 (0.097, 0.407)	**<0.001**
> 50.55	243	0.014 (0.004, 0.045)	**<0.001**	0.011 (0.003, 0.036)	**<0.001**	0.016 (0.005, 0.053)	**<0.001**	0.059 (0.016, 0.220)	**<0.001**
Male									
≤47.24	101	Ref		Ref		Ref		Ref	
47.25–49.38	102	0.256 (0.142, 0.463)	**<0.001**	0.263 (0.144, 0.481)	**<0.001**	0.307 (0.151, 0.627)	**0.001**	0.421 (0.180, 0.946)	**0.037**
49.39–51.55	103	0.021 (0.006, 0.072)	**<0.001**	0.023 (0.007, 0.080)	**<0.001**	0.025 (0.007, 0.091)	**<0.001**	0.040 (0.010, 0.165)	**<0.001**
> 51.55	100	0.007 (0.001, 0.054)	**<0.001**	0.008 (0.001, 0.062)	**<0.001**	0.010 (0.001, 0.083)	**<0.001**	0.021 (0.002, 0.207)	**<0.001**
Female									
≤46.15	149	Ref		Ref		Ref		Ref	
46.16–47.93	148	0.180 (0.101, 0.322)	**<0.001**	0.198 (0.109, 0.358)	**<0.001**	0.223 (0.118, 0.424)	**<0.001**	0.454 (0.221, 0.933)	**0.032**
47.94–49.90	152	0.068 (0.031, 0.149)	**<0.001**	0.073 (0.033, 0.162)	**<0.001**	0.081 (0.035, 0.189)	**<0.001**	0.261 (0.096, 0.710)	**0.009**
> 49.90	145	0.008 (0.001, 0.062)	**<0.001**	0.011 (0.001, 0.079)	**<0.001**	0.016 (0.002, 0.120)	**<0.001**	0.075 (0.009, 0.659)	**0.019**

Abbreviations: OR, odds ratio; CI, confidence interval.
Model 1 unadjusted variables.
Model 2 adjusted for age, sex.
Model 3 adjusted for age, sex, frailty, marital status, education, income, smoking, alcohol drinking, daily steps, the degree of dietary oiliness, salty, bitter, sour, sweet, spicy, sleep duration, other diseases, falls, calf circumference.
Model 4 adjusted for age, sex, frailty, marital status, education, income, smoking, alcohol drinking, daily steps, the degree of dietary oiliness, salty, bitter, sour, sweet, spicy, sleep duration, other diseases, falls, calf circumference, BMI, WHR.
Note: The "sex" variable has not been adjusted for in models 2, 3 and 4, which are stratified between men and women.

circumference demonstrated predictive capabilities not only for thigh muscle mass [16], but also exhibited a strong positive correlation with overall skeletal muscle mass (SMI). The relationship between sarcopenia and aging had been well-established. A 10-year longitudinal study demonstrated that thigh circumference, similar to muscle atrophy, exhibits an increase in age-related loss [34]. Additionally, a Dutch study highlighted that thigh circumference was more closely associated with age-related muscle loss compared to calf circumference [35]. Our results also found that thigh circumference was also more accurate in screening for sarcopenia compared to calf circumference and WHR. These findings suggested that individuals with increased thigh circumference tend to

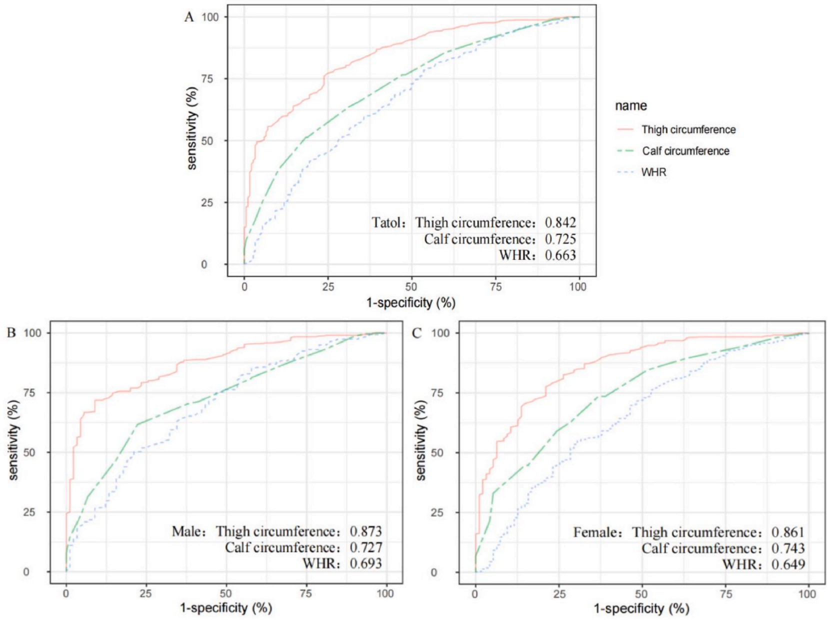

Fig. 2. ROC curve analysis of thigh circumference, calf circumference and WHR in screening sarcopenia. (A. Total B. Male C. Female).

Table 3
Correlation analysis of thigh circumference and SMI, HGS, GS and FTSTS.

	Total		Male		Female	
	r	p	r	p	r	p
SMI (kg/m^2)	0.747	<0.001	0.822	<0.001	0.758	<0.001
HGS (kg)	0.337	<0.001	0.300	<0.001	0.205	<0.001
GS (m/s)	0.142	<0.001	0.184	<0.001	0.036	0.378
FTSTS (s)	−0.073	0.021	−0.121	0.015	−0.035	0.392

Abbreviations: SMI, skeletal muscle index; HGS, hand grip strength; GS, 6 m gait speed; FTSTS, five-times-sit-to-stand test.

possess higher quality and strength in their skeletal muscles. Taking into account the age-related decline in thigh circumference, so it may serve as a valuable indicator for preliminary screening of sarcopenia among the elderly population. Certainly, the validation of thigh circumference's efficacy in screening for sarcopenia can be further elucidated in future cohort studies.

A strong correlation existed between thigh circumference and sarcopenia, which, in addition to the muscle mass of the thighs, may also be related to subcutaneous adipose. Therefore, we adjusted the covariates using BMI and WHR, two indicators that evaluate the distribution of obesity and fat in human body, and compare the diagnostic performance of thigh circumference between obese and non-obese participants. The results showed that although the ORs between thigh circumference and sarcopenia increased compared to the unadjusted BMI and WHR, thigh circumference remained a protective factor against sarcopenia, and its protective effect increased with the increase in thigh circumference, and there were no significant diagnostic differences between obese and non-obese participants. In addition, subcutaneous adipose in the thighs had been proposed as a protective factor against sarcopenia, along with muscle mass. A study conducted in Japan had indicated a possible correlation, showing that elderly and middle-aged people with low subcutaneous adipose in the thighs are more at risk for sarcopenia [21]which may because subcutaneous adipose was independently associated with better glucose and lipid levels compared to visceral adipose in middle-aged elderly populations [17].Lipid metabolism exerts a regulatory influence on skeletal muscle mass and function [19], while the perturbation of glucose metabolism is a pivotal factor contributing to the onset of sarcopenia [20].The mechanism may be that subcutaneous adipose can modulate glucose and lipid metabolism by secreting leptin and adiponectin through different feedback systems [36,37]. This is akin to how larger thigh circumference can contribute to a decreased risk of disease, as subcutaneous fat in this area releases adipokines that had beneficial effects on various metabolic processes in the body [13,38]. Building on these analyses, future studies could explore the potential link between glucose and lipid metabolism in specific parts of the body and the pathogenesis of sarcopenia.

The gender stratification analysis in our study revealed a stronger correlation between thigh circumference and skeletal muscle mass index (SMI) in men, along with a significant association between thigh circumference and grip strength (GS) as well as five times sit-to-stand test (FTSTS) compared to women. This phenomenon can be attributed to the higher muscle mass observed in men and their accelerated age-related decline in skeletal muscle mass and function compared to women. As a result, men were more prone to experiencing a decline in physical performance [39]. Moreover, unlike previous studies, the cutoff values for thigh circumference in males and females in this study were approximately 49 cm and 47 cm, respectively, which likely differed because the previous studies focused on hospitalized patients [26].

The strength of our study investigated six communities in northwestern China, which filled the population-based data gap on sarcopenia in low-income region. In addition, we conducted stratified analyses of multiple variables, and the results showed a certain degree of stability and consistency. However, this study also has some limitations. First, the design of our study limited the ability to make causal inferences, despite previous studies have shown that thigh circumference predicts thigh muscle mass. Second, although there were limitations to measuring skeletal muscle mass by bioelectrical impedance analysis (BIA) compared to dual-energy x-ray absorptiometry (DXA), the method was more suitable for large-scale community-based population surveys. Third, despite several physical indicators were measured, the data of subcutaneous adipose was not collected in this study which prohibited the further analysis of its role in the association of thigh circumference and sarcopenia. Fourth, the measurement of thigh circumference was based on the visual judgment by the investigators to locate the thickest part of the thigh introduces some measurement errors into the results despite we have taken various measures, including training for investigators and multiple measurements to minimize errors. Fifth, our study population was consisted of Chinese individuals, so the generalizability of the results may be limited. Finally, while this study adjusted confounders as many as possible, residual confounders cannot be eliminated.

5. Conclusion

In summary, our study revealed a significant association between increased thigh circumference and sarcopenia. In comparison to calf circumference, our study proposed thigh circumference as a valuable potential screening tool for early detection of sarcopenia in older adults.

CRediT authorship contribution statement

Zhiwei Zhang: Writing – original draft, Methodology, Investigation, Data curation. **Qianwen Yang:** Investigation. **Panpan He:** Investigation. **Xiaoming Liu:** Investigation. **Xuejiao Zeng:** Investigation. **Xueqian Mao:** Investigation. **Xueyi Jin:** Investigation. **Ying Hu:** Investigation. **Lipeng Jing:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Funding acquisition, Conceptualization.

Ethics statement

This study was reviewed and approved by the Ethics Committee of Lanzhou University with the approval number: IRB21010301, date of ethics approval Jan 3rd, 2021.

Data availability statement

Data will be made available on request.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e39322.

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