

Association between dietary patterns and sarcopenia among older adults aged 60 years and over in Haikou, China: a cross-sectional study

Ying Feng

Hainan Medical University

Ziyan Sun

Hainan Medical University

Rong Li

Hainan Medical University

Jingying Peng

Hainan Medical University

Yuxuan Fu

Hainan Medical University

Zhejia Liu

Hainan Medical University

Xiaozhi Zhang

Hainan Medical University

Zhuang Liu

The Third People's Hospital of Haikou City

Jinsheng Lu

Geriatric Hospital of Hainan

Chao Xu

The First Affiliated Hospital of Hainan University

Na Mo

The First Affiliated Hospital of Hainan University

Suyun Zhou

The First Affiliated Hospital of Hainan University

Xiao Liu

Hainan Sino-German Orthopaedic Hospital

Zhihong Zhang

zhihongzhang@hainmc.edu.cn

Hainan Medical University

Qi Wang

The First Affiliated Hospital of Hainan University

Research Article

Keywords: Dietary Pattern, Sarcopenia, The elderly, Factor analysis

Posted Date: October 23rd, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-11129141/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License. [Read Full License](#)

Additional Declarations: No competing interests reported.

Abstract

Objective

This study sought to examine the association between dietary patterns and sarcopenia in older adults aged 60 years and above in Haikou, China, utilizing a cross-sectional design.

Methods

A sample of 786 participants completed an online dietary questionnaire and underwent muscle mass assessments. Exploratory factor analysis was employed to identify distinct dietary patterns, while logistic regression analysis was conducted to evaluate the relationship between these dietary patterns and the risk of sarcopenia. Additionally, stratified analysis was performed to investigate potential variations in this association across different genders, age groups, and residential environments.

Results

The analysis identified four dietary patterns: the cereals, tubers, soya, and whole grains pattern; the high-sugar, fruit, and offal pattern; the poultry, eggs, and seafood pattern; and the high-vegetable pattern. Adherence to the 'grains, tubers, soya, and coarse grains' dietary pattern was found to be significantly inversely associated with the risk of sarcopenia (OR = 0.57, 95% CI: 0.38–0.86). In contrast, no significant association was observed between the other three dietary patterns and the risk of sarcopenia. In the stratified analysis indicating that women adhering to a dietary pattern characterized by grains, tubers, soya, and coarse grains (OR = 0.50; 95% CI: 0.29–0.87), individuals aged 70–79 years (OR = 0.43; 95% CI: 0.24–0.79), and non-hospitalized residents of towns and villages (OR = 0.49; 95% CI: 0.28–0.86) demonstrate a reduced risk of sarcopenia.

Conclusion

The findings suggest that the 'grains, tubers, soya, and coarse grains' dietary pattern is significantly inversely associated with sarcopenia risk, with this association being particularly notable among women, older adults aged 70–79, and rural township residents. Nonetheless, further validation through larger-scale, population-based studies is necessary to substantiate these conclusions.

1 Introduction

With the rapid advancement of economic development, the global aging of the population is accelerating at an unprecedented rate. According to data from the World Health Organization, the number of individuals aged 60 and over is projected to increase from 1.1 billion in 2023 to 2.1 billion by 2050 ^[1]. In China, the proportion of the population within this age group is anticipated to reach 23% by the end of 2025 ^[2]. According to United Nations criteria, China has already transitioned into a moderately aged society ^[3]. In Haikou, the percentage of individuals aged 60 and over has surpassed 18% and continues to rise ^[4], with health-related issues among the elderly becoming increasingly prominent.

Sarcopenia, a syndrome characterized by an age-related, progressive decline in muscle mass, strength, and function ^[5], exhibits a global prevalence ranging from 10% to 27%. In Asia, its prevalence varies between 7% and 35%. In China, the prevalence among community-dwelling older adults is approximately 15%, escalating to as high as 30% among hospitalized patients, and reaching 67% in individuals aged 80 and over ^[6–8]. Sarcopenia not only heightens the risk of falls and fractures but is also linked to an increased likelihood of cardiovascular and cerebrovascular diseases ^[9]. If not addressed, sarcopenia can elevate the risk of all-cause mortality by 1.38 to 1.71 times ^[10].

Nutritional factors are pivotal in the prevention and management of sarcopenia. Insufficient protein intake exacerbates muscle loss, whereas supplementation with whey protein or leucine has been shown to enhance lean body mass and physical function ^[11–13]. Additionally, the quality of carbohydrates may affect the risk of developing sarcopenia ^[14, 15]. Compared to individual nutrients, dietary patterns offer a more comprehensive understanding of the synergistic interactions among food components ^[16]. The Mediterranean dietary pattern is positively associated with greater muscle mass and improved physical function ^[17, 18], whereas the Western dietary pattern is linked to an increased risk of sarcopenia ^[17].

Nonetheless, a substantial portion of the current evidence is derived from Western populations and cannot be directly applied to older adults in China, who possess significantly different dietary and genetic backgrounds. There exist notable variations in dietary patterns among older adults across various regions of China ^[19, 20], with distinctive regional diets characterized by high salt intake, excessive meat consumption, and a predominance of refined grains ^[21, 22]. Hainan Province, as China's sole tropical island province, has reached a stage of moderate population aging and is celebrated as the 'Home of Longevity.' Its unique climate offers exceptional conditions for research into healthy aging. In Haikou, the provincial capital, the dietary patterns of older adults are both representative and culturally distinctive ^[4].

To date, research on sarcopenia in the Hainan region has been limited, primarily focusing on biochemical indicators or body composition analyses in hospitalized patients [23, 24]. The relationship between dietary patterns and indicators of sarcopenia and muscle function among older adults residing in communities and townships remains unexplored.

2 Materials and Methods

2.1 Questionnaire design

To accurately evaluate the dietary habits of study participants over the preceding three months, this study developed an online dietary questionnaire (accessible at http://www.yyjy365.org/ediet_hainan/public) tailored to the local specialty foods of Hainan. The questionnaire encompassed 76 food subcategories distributed across 10 principal categories: cereals and cereal products; tubers and tuber products; nuts; pulses and pulse products; vegetables; fruits; meat and meat products; dairy and egg products; seafood and aquatic products; and beverages. To facilitate precise dietary intake assessment, the study employed food images annotated with standard weights or volumes as references, requiring participants to individually report the frequency and portion sizes of each subcategory within all food categories. The reliability and validity of this questionnaire have been substantiated by prior research [25–27]. The survey data demonstrated a high level of concordance with the results from three-day dietary records, suggesting that the questionnaire is appropriate for large-scale population surveys.

2.2 Selection and exclusion criteria for study participants

This study was conducted from June 2024 to December 2025, involving the random selection of one community health service center from each of the four administrative districts of Haikou City, out of a total of four centers. Concurrently, hospitals within the jurisdiction were stratified based on their classification into Grade III Class A, Grade III, or Grade II, with one representative hospital randomly chosen from each stratum, resulting in a total of three hospitals. The towns and townships under their jurisdiction were stratified by geographical location, and one to two target towns or townships were randomly selected from each stratum. Subsequently, excluding the central village within each selected town or township, two to three administrative villages were randomly chosen from each. From these designated survey sites, participants aged 60 years or older, who had resided in Haikou City for more than one continuous year, were randomly selected. A total of 1,300 participants were recruited, among whom 843 completed the dietary questionnaire and various measurements. All participants provided written informed consent, and the study received approval from the Ethics Committee of Hainan Medical University. The survey procedures adhered to all pertinent guidelines and regulations.

The exclusion criteria for the study were as follows: (1) individuals classified as 'migratory,' who leave the island between March and October annually; (2) individuals diagnosed with severe mental disorders, including schizophrenia or depression; (3) individuals with Alzheimer's disease, significant memory impairment, or difficulties in recalling dietary history; (4) individuals unwilling to complete the questionnaire, provide a blood sample, or undergo body composition analysis; (5) individuals with communication difficulties; (6) individuals with limb deformities, restricted limb mobility, or loss of basic functional abilities; (7) individuals with metal implants or cardiac pacemakers; (8) individuals on long-term medication that affects muscle mass or body composition; (9) individuals who had undergone major surgery or experienced an infection within the preceding three months; (10) individuals with atypical energy intake levels, defined as males consuming more than 5,000 kcal (20,934 kJ) or less than 800 kcal (3,349 kJ), and females consuming more than 4,000 kcal (16,747 kJ) or less than 600 kcal (2,512 kJ) [28].

In accordance with the specified criteria, a total of 57 participants were excluded from the study, resulting in the inclusion of 786 participants for subsequent analysis (Fig. 1).

2.3 Dietary pattern assessment

Utilizing data from 21 food groups collected via a dietary questionnaire, we conducted a principal component analysis as a form of exploratory factor analysis. Factors with eigenvalues greater than 1 were extracted in line with the Kaiser criterion, and a varimax rotation was applied to simplify the factor structure and enhance interpretability. Dietary patterns were named based on the nutritional characteristics of the food groups within each factor.

2.4 Anthropometric measurements

Body composition data, including body mass index (BMI), macronutrient composition, appendicular skeletal muscle mass index (ASMI), body fat percentage, skeletal muscle mass, visceral fat area, and basal metabolic rate, were measured using a body composition analyzer (InBody S10). Participants were required to fast, remove outer clothing, metal jewelry, and electronic devices, and stand with their arms naturally hanging at an angle of approximately 15° from the torso, with legs apart.

Uniformly trained investigators assessed muscle-related indicators, including grip strength, calf circumference, 6-meter walking speed, and the time required to complete five sit-to-stand repetitions, following standardized procedures. Participants either stood naturally or sat with their upper bodies upright and arms hanging naturally at their sides. Grip strength was measured using a dynamometer, with participants holding the device in one hand; the grip strength of the dominant hand was recorded. Participants were instructed to exert maximum force on the dynamometer, with two measurements taken, and the higher value recorded to two decimal places. For calf circumference, participants stood with feet shoulder-width apart, and the circumference was measured at the thickest point using a soft tape measure, with results recorded to one decimal place. A 6-meter straight

line was marked on level ground, with start and finish points delineated perpendicularly. Participants were required to practice beforehand to familiarize themselves with the venue and procedure. During the test, participants walked from the starting point along the straight line at their normal walking speed, with the test concluding upon reaching the finish point. The results are recorded to two decimal places, and the walking speed over a distance of six meters is calculated. The participant is seated on a chair without armrests, approximately 46 centimeters above the floor, with the back of the chair positioned against the wall. The participant is instructed to cross their arms over their chest and perform the action of standing up and sitting down five times as quickly as possible. The time taken for this task is recorded, with the result rounded to two decimal places.

2.5 Sarcopenia assessment and diagnosis

$$ASMI^{[29]} = \frac{\text{Appendicular skeletal muscle mass}}{\text{Height}(m)^2}$$

1

ASMI (kg/m²): men aged 50–64 < 7.6, women < 5.7; men aged 65 and over < 7.0, women < 5.7

Grip strength (kg): men aged 50–64 < 34.0, women < 20.0; men aged 65 and over < 28.0, women < 18.0

5-repetition sit-to-stand test (s): aged 50–64 ≥ 10.0, aged 65 and over ≥ 12.0

6-meter walking speed (m/s): aged 50–64 ≥ 1.2, aged 65 and over ≥ 1.0

The diagnostic criteria employed in this study were derived from the 2025 Diagnostic Consensus of the Asian Sarcopenia Working Group. According to these criteria, sarcopenia is characterized by both ASMI and muscle strength, as measured by grip strength, falling below established thresholds. Possible sarcopenia is identified when either muscle mass or muscle strength is below the threshold. Individuals with normal muscle mass and strength, yet exhibiting risk factors such as being over 65 years of age (or aged 50–64 years with concerns regarding muscle health), limited mobility or functional decline, dysphagia or swallowing dysfunction, underweight status (BMI < 20 kg/m²) or recent weight loss (exceeding 2 kg within 6 months), acute or chronic wasting diseases, self-reported or clinically observed fatigue, or poor physical performance, are classified as being at high risk for sarcopenia. Conversely, individuals with normal muscle mass and strength and an absence of the aforementioned risk factors are considered to have good muscle health^[30].

2.6 Statistical analysis

Statistical analyses were conducted utilizing R 4.5.1. Exploratory factor analysis was employed to identify four distinct dietary patterns, which were subsequently categorized into quartiles (Q1–Q4) based on factor scores, with the Q4 group representing individuals most characteristic of a given dietary pattern. Within each dietary pattern, a higher factor score indicated a stronger inclination towards that pattern.

Variables exhibiting a normal distribution were statistically described as mean ± standard deviation, whereas variables with a skewed distribution were expressed as median (P_{25} , P_{75}). Participants were stratified according to dietary patterns, and depending on the variable type, one-way analysis of variance, chi-squared tests, or Kruskal–Wallis tests were utilized to examine differences in demographic characteristics (such as age, sex, educational attainment, and living environment), nutrient intake, and muscle-related indicators across groups.

Finally, bivariate correlation analysis was conducted to evaluate the association between dietary patterns and muscle function. Building upon existing literature and the findings from univariate analyses, we developed ordered logistic regression and linear regression models to perform association analyses. The baseline model was unadjusted, while Model 1 was adjusted for age, sex, educational attainment, and living environment. Model 2 expanded upon Model 1 by incorporating adjustments for BMI, smoking status, alcohol consumption, and energy intake. Model 3 further extended Model 2 by including adjustments for hypertension, hyperlipidemia, diabetes, coronary heart disease, and cerebrovascular disease. The significance threshold was established at $\alpha = 0.05$, with P -values less than 0.05 indicating statistical significance.

3 Results

The 175 food items included in the dietary questionnaire were categorized into 21 distinct food groups based on their nutritional characteristics. A factor analysis was conducted on the consumption data of these food groups, resulting in a Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy of 0.68 and a P -value of < 0.001 for Bartlett's test of sphericity, indicating the suitability of the data for factor analysis. Based on the eigenvalues and the scree plot, four principal dietary factors were extracted. After applying a variance-maximizing rotation, the variance explained by these four factors was 16.73%, 7.72%, 6.82%, and 6.25%, respectively, with a cumulative variance explanation of 37.52%. The corresponding eigenvalues were 3.51, 1.62, 1.43, and 1.31.

Utilizing an absolute factor loading threshold of ≥ 0.40 for the inclusion of food items, and considering the primary food compositions of each factor, four dietary patterns were identified: the cereals-tubers-soya-whole grains pattern (comprising whole grains, pulses, tubers, and soya products); the high sugar-fruit-offal pattern (including tropical high-sugar fruits, melons and gourds, and animal offal and blood products); the poultry-eggs-seafood pattern (encompassing poultry, eggs, and seafood); and the high-vegetable pattern (consisting primarily of vegetables). (Fig. 2a-2d)

In a cohort of 786 study participants, with an average age of 72.66 ± 7.30 years, the prevalence of sarcopenia was determined to be 30.66%. Participants were stratified into distinct dietary patterns according to their highest dietary pattern factor scores. Comparative analyses among the four dietary groups revealed statistically significant differences in variables such as age, BMI, living environment, total fat intake, dietary fiber intake, vitamin C intake, vitamin E intake, and polyunsaturated fatty acid intake (all $P < 0.05$) (Table 1).

Table 1
Basic characteristics of study participants across the four dietary patterns

Age, year	The cereals, tubers, soya, and whole grains pattern(n = 179)	The high-sugar, fruit, and offal pattern(n = 161)	The poultry, eggs, and seafood pattern(n = 199)	The high-vegetable pattern(n = 247)	P
	70.00(67.00,76.00)	71.00(67.00,77.00)	71.00(68.00,78.00)	73.00(68.00,78.00)	0.014
60–69, n(%)	80(44.69%)	63(39.13%)	82(41.21%)	70(28.34%)	
70–79, n(%)	67(37.43%)	69(42.86%)	84(42.21%)	127(51.42%)	
≥ 80, n(%)	32(17.88%)	29 (18.01%)	33(16.58%)	50(20.24%)	
Gender					0.948
Female, n(%)	99(55.31%)	92(57.14%)	111(55.78%)	143(57.89%)	
Male, n(%)	80(44.69%)	69(42.86%)	88(44.22%)	104(42.11%)	
Education					0.255
≤Primary school	106(59.22%)	86(53.42%)	126(63.32%)	144 (58.30%)	
Junior secondary school	35(19.55%)	30(18.63%)	34(17.09%)	40(16.19%)	
Senior secondary school	31(17.32%)	31(19.25%)	35(17.59%)	46 (18.62%)	
≥Bachelor's degree	7(3.91%)	14(8.70%)	4(2.01%)	17(6.88%)	
BMI, kg/m²	23.16 ± 3.53	23.38 ± 3.42	23.24 ± 3.60	22.73 ± 3.21	0.028
Living environment					<0.001
Township	107(59.78%)	81(50.31%)	89(44.72%)	155(62.75%)	
Community-dwelling	25(13.97%)	36(22.36%)	32(16.08%)	69(27.94%)	
Hospitalised	47(26.26%)	44(27.33%)	78(39.20%)	23(9.31%)	
Smoking					0.182
Yes, n(%)	24(13.41%)	25(15.53%)	43(21.61%)	42(17.00%)	
No, n(%)	155(86.59%)	136(84.47%)	156(78.39%)	205(83.00%)	
Drinking					0.486
Yes, n(%)	16(8.94%)	23(14.29%)	22(11.06%)	29(11.74%)	
No, n(%)	163(91.06%)	138(85.71%)	177(88.94%)	218(88.26%)	
Energy, kcal/day	1786.37(1447.78,2119.20)	1743.63(1479.93,2100.77)	1686.18(1454.42,2004.49)	1711.13(1457.77,2034.0)	0.395
Total protein, g/day	85.67(75.92,95.84)	87.54(78.21,99.82)	84.6(75.83,94.44)	86.99(77.41,96.15)	0.126
Total fat, g/day	56.36(47.54,63.30)	56.18(47.23,61.65)	59.11(50.58,69.76)	55.07(48.84,64.04)	0.015
Total carbohydrate, g/day	279.9(251.47,304.37)	280.31(256.16,303.57)	274.33(244.28,295.48)	282.4(253.37,301.93)	0.212
Fiber, g/day	10.47(8.27,13.76)	11.11(9.06,13.40)	10.10(7.86,12.73)	11.20(9.05,13.64)	0.002
Cholesterol, mg/day	167.58(137.15,210.38)	180.36(142.61,224.64)	183.63(148.83,224.42)	173.67(133.94,219.46)	0.150
Vitamin C, mg/day	102.56(75.54,150.76)	107.6(78.97,134.72)	91.73(69.03,127.21)	103.17(87.55,139.31)	0.001
Vitamin E, mg/day	42.80(34.68,49.88)	41.82(35.72,50.55)	44.80(38.50,54.51)	42.57(36.49,49.29)	0.026
PFA: Polyunsaturated Fatty Acids; ASMI: Appendicular Skeletal Muscle Mass Index.					

Age, year	The cereals, tubers, soya, and whole grains pattern(n = 179)	The high-sugar, fruit, and offal pattern(n = 161)	The poultry, eggs, and seafood pattern(n = 199)	The high-vegetable pattern(n = 247)	P
	70.00(67.00,76.00)	71.00(67.00,77.00)	71.00(68.00,78.00)	73.00(68.00,78.00)	0.014
Lsoleucine	3496.86(3110.89,3901.11)	3555.37(3161.88,4093.35)	3482.57(3063.26,3866.18)	3527.01(3154.18,4001.49)	0.202
Leucine	6801.15(6166.99,7570.77)	6914.16(6201.08,7953.41)	6781.51(6036.19,7520.87)	6880.33(6166.52,7703.59)	0.339
Valine	4300.87(3867.54,4739.20)	4431.19(3957.72,4927.53)	4271.45(3811.52,4730.57)	4314.01(3886.02,4820.06)	0.203
PFA, g/day	21.72(17.72,24.54)	21.48(16.81,24.36)	23.37(20.44,26.86)	21.87(17.47,24.83)	0.002
6-meter walking speed, m/s	0.76(0.60,0.95)	0.79(0.63,1.00)	0.81(0.60,0.95)	0.79(0.60,0.93)	0.368
5-repetition sit-to-stand test, s	13.54(11.50,18.65)	13.62(11.59,16.98)	13.98(11.65,18.04)	13.20(11.36,16.10)	0.625
Grip strength, kg	21.50(17.30,25.50)	21.60(17.35,26.85)	20.90(17.60,26.40)	20.20(16.40,24.10)	0.107
Left calf circumference, cm	32.00(30.00,35.00)	32.00(30.00,35.00)	32.00(30.00,35.00)	32.00(30.00,34.50)	0.629
Right calf circumference, cm	32.00(30.00,35.00)	32.00(30.00,35.00)	33.00(30.00,35.00)	32.00(30.00,35.00)	0.695
ASMI, kg/m²	6.40(5.80,7.20)	6.30(5.60,6.95)	6.40(5.70,7.20)	6.20(5.60,7.00)	0.155
Sarcopenia, n(%)	44(24.58%)	49(30.43%)	60(30.15%)	88(35.63%)	0.265
Possible sarcopenia, n(%)	73(40.78%)	65(40.37%)	71(35.68%)	91(36.84%)	
High risk of sarcopenia, n(%)	62(34.64%)	47(29.19%)	68(27.53%)	68(27.53%)	
Hypertension	62(34.64%)	60(37.27%)	71(35.70%)	81(32.80%)	0.816
Diabetes	35(19.55%)	23(14.29%)	46(23.10%)	39(15.80%)	0.108
Hyperlipidaemia	6(3.35%)	7(4.35%)	9(4.52%)	11(4.45%)	0.936
Coronary heart disease	5(2.79%)	7(4.35%)	13(6.53%)	6(2.43%)	0.127
Cerebrovascular disease	8(4.47%)	7(4.35%)	12(6.03%)	3(1.21%)	0.056
PFA: Polyunsaturated Fatty Acids; ASMI: Appendicular Skeletal Muscle Mass Index.					

The grain-tubers-soya-coarse grains dietary pattern demonstrated a negative correlation with both the time required to complete five sit-to-stand repetitions and the risk of sarcopenia, while showing a positive correlation with appendicular skeletal muscle mass index (ASMI). Conversely, the high-sugar fruit and visceral fat dietary pattern was negatively correlated solely with the time required for five sit-to-stand repetitions. The poultry, eggs, and seafood dietary pattern exhibited positive correlations with 6-meter walking speed, grip strength, ASMI, and calf circumference. In contrast, the high-vegetable dietary pattern was negatively correlated with 6-meter walking speed ($P < 0.05$) (Table 2).

Table 2
Correlation between factor scores of the four dietary patterns and muscle function indicators

Muscle function indicators	Dietary Pattern			
	The cereals, tubers, soya, and whole grains pattern	The high-sugar, fruit, and offal pattern	The poultry, eggs, and seafood pattern	The high-vegetable pattern
6-meter walking speed	-0.033	0.044	0.074*	-0.082*
5-repetition sit-to-stand test	-0.074*	-0.079*	-0.030	-0.049
Grip strength	0.043	0.041	0.079*	-0.057
ASMI	0.084*	0.010	0.096**	-0.044
Left calf circumference	0.043	-0.016	0.085*	-0.004
Right calf circumference	0.042	-0.018	0.084*	-0.024
Sarcopenia	-0.112**	-0.005	-0.050	0.019
*: $P < 0.05$; **: $P < 0.001$.				

Using the first percentile group of dietary patterns as a reference, and after adjusting for multiple factors, the risk of sarcopenia was found to be 43% lower in the fourth percentile group of the 'cereals, tubers, soya, and coarse grains' dietary pattern, indicating a significant inverse correlation with sarcopenia risk (Table 3).

Table 3
Logistic regression analysis of the association between dietary patterns and sarcopenia

Dietary Pattern	Q1	Q2	Q3	Q4
The cereals, tubers, soya and whole grains pattern				
Crude	Ref	1.00(0.69,1.45)	0.75(0.52,1.08)	0.59(0.41,0.85) **
Model 1	Ref	0.98(0.67,1.44)	0.82(0.57,1.19)	0.62(0.42,0.91) *
Model 2	Ref	0.97(0.65,1.44)	0.70(0.47,1.04)	0.58(0.39,0.88) **
Model 3	Ref	0.96(0.64,1.42)	0.69(0.46,1.02)	0.57(0.38,0.86) **
The high-sugar, fruit and offal pattern				
Crude	Ref	1.36(0.94,1.96)	1.05(0.73,1.52)	0.99(0.69,1.43)
Model 1	Ref	1.36(0.94,1.97)	1.07(0.74,1.54)	1.10(0.75,1.61)
Model 2	Ref	1.23(0.83,1.84)	1.13(0.77,1.69)	1.13(0.76,1.68)
Model 3	Ref	1.24(0.83,1.85)	1.14(0.76,1.69)	1.14(0.77,1.70)
The poultry, eggs, and seafood pattern				
Crude	Ref	1.34(0.93,1.93)	0.82(0.57,1.18)	0.91(0.63,1.31)
Model 1	Ref	1.51(1.03,2.22) *	0.92(0.62,1.37)	1.04(0.69,1.56)
Model 2	Ref	1.40(0.94,2.08)	0.78(0.52,1.17)	1.03(0.69,1.54)
Model 3	Ref	1.39(0.93,2.08)	0.77(0.51,1.15)	1.01(0.67,1.52)
The high-vegetable pattern				
Crude	Ref	1.15(0.80,1.66)	1.13(0.78,1.62)	1.07(0.75,1.55)
Model 1	Ref	1.19(0.82,1.74)	1.15(0.79,1.67)	1.20(0.82,1.75)
Model 2	Ref	1.20(0.81,1.78)	1.24(0.83,1.85)	1.24(0.84,1.85)
Model 3	Ref	1.38(0.86,1.90)	1.30(0.87,1.95)	1.28(0.86,1.91)
*: $P < 0.05$; **: $P < 0.01$;				
Model 1: adjusted for age, sex, educational level and living environment;				
Model 2: Model 1 plus adjustment for BMI, total energy intake, smoking and alcohol consumption;				

Model 3: Model 2 plus adjustment for hypertension, hyperlipidaemia, diabetes mellitus, coronary heart disease and cerebrovascular disease.

Stratified analyses further revealed that, when stratified by gender, women in the fourth quantile of this dietary pattern exhibited a significant inverse association with sarcopenia risk (OR = 0.50, 95% CI: 0.29–0.87). Similarly, in the stratification by place of residence, non-institutionalized township residents in the fourth quartile demonstrated a significant inverse association with sarcopenia risk (OR = 0.49, 95% CI: 0.29–0.87). Furthermore, age stratification indicated that adherence to this dietary pattern was significantly inversely associated with sarcopenia risk among older adults aged 70–79 years (OR = 0.43, 95% CI: 0.24–0.79) (Fig. 3–5).

4 Discussion

This study represents the inaugural online questionnaire survey aimed at examining the association between dietary patterns and the risk of sarcopenia among older adults in Haikou, China. Utilizing exploratory factor analysis, four principal dietary patterns were identified: the cereals, tubers, soya, and whole grains pattern; the high-sugar, fruit, and offal pattern; the poultry, eggs, and seafood pattern; and the high-vegetable pattern. The findings indicated that the 'grains, tubers, soya, and coarse grains' dietary pattern exhibited a significant negative correlation with the risk of sarcopenia, whereas the other three dietary patterns did not demonstrate any association with this risk. Notably, this negative correlation was particularly evident among women, older adults aged 70–79, and residents of townships and rural areas.

After adjusting for multiple confounding factors, it was determined that individuals in the fourth quartile of adherence to the 'grains, tubers, soya, and coarse grains' dietary pattern experienced a 43% reduction in the risk of sarcopenia compared to those in the first quartile. In addition to the dietary fiber and phytochemicals typically associated with the "grains, tubers, soy, and coarse grains" dietary pattern, tubers such as sweet potatoes, cassava, and yams, along with coix seeds and mountain rice, are abundant in resistant starch. These foods, characterized by their low glycemic index, are

frequently consumed in everyday diets and may offer protective benefits by modulating the gut microbiota and mitigating systemic chronic inflammation^[31, 32]. Research indicates that chronic inflammation is a critical mechanism contributing to the onset and progression of sarcopenia, which results in the deterioration of muscle mass and function by facilitating muscle protein breakdown and inhibiting muscle protein synthesis^[33, 34]. While single-source plant proteins, such as whole grains, are often considered "non-high-quality proteins" due to their deficiency in essential amino acids like lysine, this dietary pattern effectively combines whole grains—rich in methionine—with pulses—rich in lysine—to achieve protein complementarity and enhance the net utilization of protein^[35]. Soy and soy products serve as a primary source of high-quality plant protein, abundant in branched-chain amino acids and isoflavones. The consumption of soy protein contributes to the maintenance of muscle mass and strength in middle-aged and older adults^[36, 37]. This dietary pattern closely aligns with the Eastern Healthy Dietary Pattern^[21] and the Dietary Approaches to Stop Hypertension (DASH) diet^[38], both of which have demonstrated significant positive effects in the prevention of sarcopenia. Research involving American adults indicated that greater adherence to the DASH diet was significantly inversely correlated with the risk of sarcopenia, reducing this risk by 50%^[38]. Xu Song and colleagues reported that the Oriental Healthy Dietary Pattern was significantly inversely correlated with the risk of sarcopenia^[39], findings that are consistent with the results of our study.

Conversely, three other dietary patterns were found to have no significant association with sarcopenia. The 'high-sugar fruit and offal' pattern is characterized by a high intake of tropical high-sugar fruits, animal offal, and blood products. While animal offal is abundant in trace elements such as iron and zinc, which confer certain benefits for muscle function^[40], the diet also includes high-sugar fruits that may increase the glycaemic load. The pro-inflammatory and pro-oxidative components of this diet, including high sugar and cholesterol levels, may negate the protective effects of its micronutrients, leading to outcomes unrelated to sarcopenia. However, the specific mechanisms underlying these effects warrant further investigation. The 'low-meat, high-poultry, egg, and seafood' diet is characterized by a high intake of poultry, eggs, and seafood, which are excellent sources of high-quality animal protein and n-3 polyunsaturated fatty acids^[41]. Some studies suggest that adequate protein intake, particularly from high-quality animal sources, is crucial for maintaining muscle mass and function^[42, 43]. Given the low consumption of red meat in this diet, and despite current evidence linking excessive red meat intake to health risks^[44, 45], further research is needed to determine whether poultry can fully substitute for red meat in meeting the high protein requirements essential for muscle health. The high-vegetable diet prioritizes the intake of both dark and light-colored vegetables. Although vegetables are rich in antioxidants and vitamins, they generally contain low levels of protein. Adequate protein intake is crucial for maintaining muscle health; thus, merely increasing vegetable consumption without ensuring sufficient high-quality protein supplementation may not effectively prevent sarcopenia^[46].

Moreover, this study identified significant population heterogeneity in the negative association between the 'grains, tubers, soya, and coarse grains' dietary pattern and the risk of sarcopenia. This association was not consistently negative across all subgroups and was influenced by factors such as gender, age, and living environment. Specifically, the 'grains, tubers, soya, and coarse grains' dietary pattern was significantly negatively associated with sarcopenia risk only in women, with no significant association observed in men. Research has demonstrated that postmenopausal women experience a significant reduction in oestrogen levels. Given oestrogen's critical role in sustaining muscle mass and function, this reduction is identified as a primary contributor to the increased prevalence of sarcopenia in this demographic^[47–50]. Soya and its derivatives, integral to the 'grains, tubers, soya, and coarse grains' dietary pattern, are abundant in soya isoflavones. These phytoestrogens can partially activate oestrogen receptors, exerting mild oestrogen-like effects that may mitigate the deficit of endogenous oestrogen and consequently decelerate muscle degradation^[51–54]. Additionally, women typically exhibit a heightened awareness of health-related issues; thus, the consistent and prolonged intake of soya products may facilitate the accumulation of greater muscle reserves during early and middle adulthood^[55], potentially postponing the onset of sarcopenia. In terms of environmental factors, the 'grains, tubers, soya, and coarse grains' dietary pattern has been consistently associated with a stable negative correlation among non-hospitalised residents in urban and rural areas. The intake of animal protein among rural populations is comparatively limited. In contrast, the combination of cereals, tubers, and pulses, through the process of protein complementation, not only improves the overall quality of dietary protein but also provides a more abundant supply of amino acid substrates necessary for muscle synthesis^[56, 57]. Concurrently, residents of townships engage in relatively high-intensity physical labor. Research indicates that the oxidative stress and chronic inflammatory responses associated with such labor can be mitigated to some extent by the phenolic antioxidants and unsaturated fatty acids present in whole grains^[58, 59]. Within different age subgroups, a negative correlation between the dietary pattern characterized by 'grains, tubers, soya, and coarse grains' and the risk of sarcopenia was observed exclusively in older adults aged 70–79. For individuals aged 60–69, the bodily reserve capacity and compensatory ability remain relatively robust, resulting in a lower incidence of sarcopenia, at only 19.92%. The marginal effect of dietary patterns on muscle synthesis may be minimal, which could account for the difficulty in detecting a statistically significant association. The age range of 70 to 79 years represents a pivotal stage for muscle deterioration, marked by a rapid decrease in muscle mass and strength, during which nutritional interventions exert the most significant impact^[5]. By adhering to this dietary regimen, individuals within this demographic can effectively postpone the onset of sarcopenia through a consistent energy supply and the consumption of high-quality plant-based proteins and antioxidants. Prior research has corroborated that dietary interventions initiated around the age of 70 are most efficacious in preserving muscle function^[46, 60]. Conversely, for individuals aged 80 and above, the natural decline in muscle mass and strength becomes increasingly challenging to reverse; the cumulative effects of various age-related factors render dietary intervention alone insufficient to yield substantial outcomes^[61–63]. The very elderly exhibit elevated protein requirements; however, both actual intake and utilization efficiency diminish, thereby attenuating the protective effects of dietary patterns^[64].

The primary limitation of this study lies in its cross-sectional and retrospective design, which precludes the establishment of causal relationships between dietary factors and the associated diseases. In certain instances, the findings may even appear contradictory^[65]. Consequently, longitudinal

cohort studies are necessary to substantiate the relationships identified herein, and preliminary dietary interventions are essential to fully validate these associations. Moreover, considering China's extensive territory and substantial population, this study's focus on the elderly population in Haikou City, China, underscores the need for further research on the relationship between dietary patterns and associated diseases on a broader scale. Despite these limitations, the study has produced some valuable insights, notably the association between adherence to a diet rich in cereals, tubers, soy, and coarse grains and a reduced risk of sarcopenia.

5 Conclusion

This study identified a significant inverse relationship between the "grains, tubers, soya, and coarse grains" dietary pattern and the risk of sarcopenia. In contrast, the other three dietary patterns examined did not demonstrate any association with sarcopenia risk. Notably, this inverse association was particularly pronounced among women, individuals aged 70–79, and residents of towns and villages. However, due to the relatively small sample size of this study, the findings necessitate further corroboration and validation through large-scale, population-based studies. Additionally, further validation through dietary intervention studies is warranted.

Declarations

Disclosure of Interests. It is now necessary to declare any competing interests or to specifically state that the authors have no competing interests. Please place the statement with a third level heading in 9-point font size beneath the (optional) acknowledgments, for example: The authors have no competing interests to declare that are relevant to the content of this article. Or: Author A has received research grants from Company W. Author B has received a speaker honorarium from Company X and owns stock in Company Y. Author C is a member of committee Z.

Supplementary Information: None.

Acknowledgements: We wish to extend our heartfelt gratitude to Hainan Medical University, The First Affiliated Hospital of Hainan University, Hainan Sino-German Orthopaedic Hospital, the Third People's Hospital of Haikou, Hainan Geriatric Hospital, as well as the participants and data collectors involved in the study.

Authors' contributions: Z.-H.Z. and Q.W. conceptualized and designed the study; Y.F. and Z.-Y.S. executed the experiment and collected data; R.L., J.-Y.P., Y.-X.F., Z.-J.L. and X.-Z.Z. entered the data; Y.F., Z.-Y.S., Z.L. and J.-S.L. analyzed and interpreted the results; Y.F. and C.X. wrote the article; Z.-Y.S., N.M., S.-Y.Z. and X.L. revised the manuscript for important aspects; Z.-H.Z. and Q.W. obtained funds and supervised the project.

Funding: This research was supported by the Talent Project of Hainan Medical University (No. RZ2300002106), the Hainan Provincial Natural Science Foundation High-Level Talent Project (821RC1139), the Hainan Provincial Health Science and Technology Innovation Joint Project (WSJK2025MS203) and the Hainan Medical University College Students' Innovation and Entrepreneurship Training Program Project (S202511810014). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Data availability: There is all relevant data are available in this article.

Clinical trial number: Not applicable.

Declarations

Ethics approval: Ethical approval for this study was granted by the Ethics Committee of Hainan Medical University (HYLL-2024-698). All participants gave written informed consent before enrollment in the study, which was conducted in accordance with the principles of the Declaration of Helsinki.

Competing interests: The authors assert that the research was carried out without any commercial or financial affiliations that could be perceived as a possible conflict of interest.

Consent for publication: Not applicable.

Open Access: This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third-party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <https://creativecommons.org/licenses/by/4.0/>

References

1. World Health Organization. (2025) Ageing: Global population. World Health Organization. <https://www.who.int/news-room/questions-and-answers/item/population-ageing>. Accessed 2 Feb 2026.

2. National Bureau of Statistics of China. (2026) Statistical Communiqué of the People's Republic of China on the 2025 National Economic and Social Development. National Bureau of Statistics of China. https://www.stats.gov.cn/english/PressRelease/202602/t20260228_1962661.html. Accessed 1 March 2026.
3. Cox PR. The Aging of Populations and its Economic and Social Implications. Royal Stat Soc. 1958;121(2):253–4. <https://digitallibrary.un.org/record/3975472?v=pdf>.
4. Hainan Provincial Bureau of Statistics. (2026) Statistical Communiqué of Hainan Province on the 2025 National Economic and Social Development. Hainan Provincial Bureau of Statistics. <https://www.hainan.gov.cn/hainan/tjgb/202603/2117e9de79e840a0b92d2305d1a56445.shtml?ddtab=true>. Accessed 6 June 2026.
5. Cruz-Jentoft AJ, Sayer AA, Landi F, London. England), 14(2), 183–6. <https://doi.org/10.7861/clinmedicine.14-2-183>.
6. Meng S, He X, Fu X, Zhang X, Tong M, Li W, Zhang W, Shi X, Liu K. The prevalence of sarcopenia and risk factors in the older adult in China: a systematic review and meta-analysis. *Front Public Health*. 2024;12:1415398. <https://doi.org/10.3389/fpubh.2024.1415398>.
7. Chiu WC, Kao TW, Peng TC. Prevalence of sarcopenia in Asian older adults: A comparison of nine diagnostic criteria across different regions. *Exp Gerontol*. 2025;202:112721. <https://doi.org/10.1016/j.exger.2025.112721>.
8. Han YH, Kim M, Kim JH, Jeong HJ, Lim ST. New criteria of the Asian working group for sarcopenia: High prevalence of severe sarcopenia in hospitalized patients. *Medicine*. 2025;104(11):e41912. <https://doi.org/10.1097/md.00000000000041912>.
9. Gao K, Cao LF, Ma WZ, Gao YJ, Luo MS, Zhu J, Li T, Zhou D. Association between sarcopenia and cardiovascular disease among middle-aged and older adults: Findings from the China health and retirement longitudinal study. *EClinicalMedicine*. 2022;44:101264. <https://doi.org/10.1016/j.eclinm.2021.101264>.
10. Kong J, Li ST, Huang PD, Liu MH, Ren DJ. An empirical analysis on the association between sarcopenia and all-cause mortality in Chinese elderly residents. *Shanghai J Prev Med*. 2025;37(02):148–55. <http://dx.doi.org/10.19428/j.cnki.sjpm.2025.24400>.
11. Nasimi N, Sohrabi Z, Nunes EA, Sadeghi E, Jamshidi S, Gholami Z, Akbarzadeh M, Faghih S, Akhlaghi M, Phillips SM. (2023) Whey Protein Supplementation with or without Vitamin D on Sarcopenia-Related Measures: A Systematic Review and Meta-Analysis. *Advances in nutrition* (Bethesda, Md.), 14(4), 762–73. <https://doi.org/10.1016/j.advnut.2023.05.011>
12. Camajani E, Persichetti A, Watanabe M, Contini S, Vari M, Di Bernardo S, Faro M, Lubrano C, Gnessi L, Caprio M, Basciani S. Whey Protein, L-Leucine and Vitamin D Supplementation for Preserving Lean Mass during a Low-Calorie Diet in Sarcopenic Obese Women. *Nutrients*. 2022;14(9):1884. <https://doi.org/10.3390/nu14091884>.
13. Guo Y, Fu X, Hu Q, Chen L, Zuo H. The Effect of Leucine Supplementation on Sarcopenia-Related Measures in Older Adults: A Systematic Review and Meta-Analysis of 17 Randomized Controlled Trials. *Front Nutr*. 2022;9:929891. <https://doi.org/10.3389/fnut.2022.929891>.
14. Li S, Xiao M. (2026) Association between HEI-2020 and sarcopenia in US adults: A study based on the 2011–2018 NHANES data. *Nutrition research* (New York, N.Y.), 145, 102–111. <https://doi.org/10.1016/j.nutres.2025.12.003>
15. Kim JW, Yang SJ. Dietary Patterns, Kidney Function, and Sarcopenia in Chronic Kidney Disease. *Nutrients*. 2025;17(3):404. <https://doi.org/10.3390/nu17030404>.
16. Granic A, Sayer AA, Robinson SM. (2025) Nutrition in the prevention and treatment of skeletal muscle ageing and sarcopenia: a single nutrient, a whole food and a whole diet approach. *The Proceedings of the Nutrition Society*, 84(4), 340–355. <https://doi.org/10.1017/s0029665124007432>
17. Ruiz-Valenzuela RE, Artacho R, Ruiz-López MD, Molina-Montes E. Healthy Dietary Patterns and Risk of Sarcopenia in Adults Aged > 50 Years: A Systematic Review and Meta-Analysis Considering EWGSOP1 and EWGSOP2 Criteria. *Nutrients*. 2025;17(17):2764. <https://doi.org/10.3390/nu17172764>.
18. Robinson S, Granic A, Cruz-Jentoft AJ, Sayer AA. The role of nutrition in the prevention of sarcopenia. *Am J Clin Nutr*. 2023;118(5):852–64. <https://doi.org/10.1016/j.ajcnut.2023.08.015>.
19. Zhao FL. (2022) Dietary nutrition status of older adults aged 65 years and over in China and analysis of dietary factors associated with diabetes[D].
20. National Institute for Nutrition and Health Chinese Center for Disease Control and Prevention. (2021) Scientific Research Report on the Dietary Guidelines for Chinese Residents 2021. National Institute for Nutrition and Health, Chinese Center for Disease Control and Prevention. <https://www.chinanutri.cn/yyjkzpxt/yyjkkpzx/yytsg/zgjm/>. Accessed 15 July 2026.
21. Ma ZM, Hao XY, Wang DY, Wang XL, Sun YL, Li HY. (2023) Evolution and Distribution of Dietary Patterns in China and the Research Progress of Its Correlation with Health. *Science and Technology of Food Industry*, 2023, 44(10): 396 – 405. <http://dx.doi.org/10.13386/j.issn1002-0306.2022060202>
22. Qin ED, Wang J, Qin R, Liu H, Xiong HR, Liu J, Wang HY, Zhang L. Dietary Structure Analysis and Dietary Nutrition Recommendations in Different Regions of China. *Food Nutr China*. 2020;26(8):82–6. 10.3969/j.issn.1006-9577.2020.08.019.
23. He Y, Zhao Y, Yao Y, Yang S, Li J, Liu M, Chen X, Wang J, Zhu Q, Li X, Zhang F, Luan F. Cohort Profile: The China Hainan Centenarian Cohort Study (CHCCS). *Int J Epidemiol*. 2018;47(3):694–5. <https://doi.org/10.1093/ije/dyy017>.
24. Zhai X, Jiang F, Guan P, Feng GQ, Chen J, Fu WD, Zhong CR. Correlation between serum VIP levels and bone mineral density and sarcopenia in the elderly. *Chin J Osteoporos*. 2021;27(1):69–72. 10.3969/j.issn.1006-7108.2021.01.015.

25. Feng Y, Gu XB, Zhou M, Wang HL, Feng RN, Zhang ZH. Association between dietary glycine intake and the prevalence of hypertension, hyperlipidemia, overweight or obesity in rural northern China: a cross-sectional study. *Front Nutr.* 2024;11:1364309. <https://doi.org/10.3389/fnut.2024.1364309>.
26. Feng RN, Du SS, Chen Y, Li Z, Zhang YF, Sun CH, Jiang YS. An internet-based food frequency questionnaire for a large Chinese population. *Asia Pac J Clin Nutr.* 2016;25(4):841–8. <https://doi.org/10.6133/apjcn.092015.26>.
27. Li YC, Li CL, Qi JY, Huang LN, Shi D, Du SS, Liu LY, Feng RN, Sun CH. Relationships of Dietary Histidine and Obesity in Northern Chinese Adults, an Internet-Based Cross-Sectional Study. *Nutrients.* 2016;8(7):420. <https://doi.org/10.3390/nu8070420>.
28. Zhang H. (2020) Association between dietary patterns, body composition and physical fitness status among medical students[D].
29. Cheng KY, Chow SK, Hung VW, Wong CH, Wong RM, Tsang CS, Kwok T, Cheung WH. Diagnosis of sarcopenia by evaluating skeletal muscle mass by adjusted bioimpedance analysis validated with dual-energy X-ray absorptiometry. *J cachexia sarcopenia muscle.* 2021;12(6):2163–73. <https://doi.org/10.1002/jcsm.12825>.
30. Chen LK, Hsiao FY, Akishita M, Assantachai P, Lee WJ, Lim WS, Muangpaisan W, Kim M, Merchant RA, Peng LN, Tan MP, Won CW, Yamada M, Woo J, Arai H. A focus shift from sarcopenia to muscle health in the Asian Working Group for Sarcopenia 2025 Consensus Update. *Nat aging.* 2025;5(11):2164–75. <https://doi.org/10.1038/s43587-025-01004-y>.
31. Li S, Meng Y, Wang C, Suonan Z, Zhang X, Wu T, Dai Z, Zhang Y, Sharafeldin S, Zhang Y, Shen Q, Xue Y. Effect of structural characteristics of resistant starch prepared by various methods on microbial community and fermentative products. *Int J Biol Macromol.* 2024;254(Pt 1):127725. <https://doi.org/10.1016/j.ijbiomac.2023.127725>.
32. Wang Z, Gao M, Kan J, Cheng Q, Chen X, Tang C, Chen D, Zong S, Jin C. Resistant Starch from Purple Sweet Potatoes Alleviates Dextran Sulfate Sodium-Induced Colitis through Modulating the Homeostasis of the Gut Microbiota. *Foods (Basel Switzerland).* 2024;13(7):1028. <https://doi.org/10.3390/foods13071028>.
33. Dalle S, Rossmeislova L, Koppo K. The Role of Inflammation in Age-Related Sarcopenia. *Front Physiol.* 2017;8:1045. <https://doi.org/10.3389/fphys.2017.01045>.
34. Bano G, Trevisan C, Carraro S, Solmi M, Luchini C, Stubbs B, Manzato E, Sergi G, Veronese N. Inflammation and sarcopenia: A systematic review and meta-analysis. *Maturitas.* 2017;96:10–5. <https://doi.org/10.1016/j.maturitas.2016.11.006>.
35. Li C, Wang RH, Wang TY, Gu C, Zhang L, Meng D, Pan M, Yang R. The Whey-Plant Protein Heteroprotein Systems with Synergistic Properties and Versatile Applications. *J Agric Food Chem.* 2025;73(8):4440–54. <https://doi.org/10.1021/acs.jafc.4c10736>.
36. Mueller NT, Odegaard AO, Gross MD, Koh WP, Yu MC, Yuan JM, Pereira MA. Soy intake and risk of type 2 diabetes in Chinese Singaporeans. *Eur J Nutr.* 2012;51(8):1033–40. <https://doi.org/10.1007/s00394-011-0276-2>.
37. Yokoyama Y, Kitamura A, Seino S, Kim H, Obuchi S, Kawai H, Hirano H, Watanabe Y, Motokawa K, Narita M, Shinkai S. Association of nutrient-derived dietary patterns with sarcopenia and its components in community-dwelling older Japanese: a cross-sectional study. *Nutr J.* 2021;20(1):7. <https://doi.org/10.1186/s12937-021-00665-w>.
38. Zheng J, Chen X, Peng R, Li B, Lin Y, Cai X. DASH diet as a preventive strategy for sarcopenia: integrated observational and mendelian randomization analyses in US adults. *Nutr metabolism.* 2025;22(1):126. <https://doi.org/10.1186/s12986-025-01021-z>.
39. Xu S, Wang XN, Liu L, Han JJ, Li SQ, Meng G, Niu KJ, Gu YQ. Dietary patterns and sarcopenia in older adults: a cross-sectional study. *Chin J Health Manage.* 2021;15(3):290–8. 10.3760/cma.j.cn115624-20200730-00589.
40. van Dijk M, Dijk FJ, Hartog A, van Norren K, Verlaan S, van Helvoort A, Jaspers RT, Luiking Y. Reduced dietary intake of micronutrients with antioxidant properties negatively impacts muscle health in aged mice. *J cachexia sarcopenia muscle.* 2018;9(1):146–59. <https://doi.org/10.1002/jcsm.12237>.
41. Ibsen DB, Steur M, Imamura F, Overvad K, Schulze MB, Bendinelli B, Guevara M, Agudo A, Amiano P, Aune D, Barricarte A, Ericson U, Fagherazzi G, Franks PW, Freisling H, Quiros JR, Grioni S, Heath AK, Huybrechts I, Katze V, Wareham NJ. Replacement of Red and Processed Meat With Other Food Sources of Protein and the Risk of Type 2 Diabetes in European Populations: The EPIC-InterAct Study. *Diabetes Care.* 2020;43(11):2660–7. <https://doi.org/10.2337/dc20-1038>.
42. Bauer J, Biolo G, Cederholm T, Cesari M, Cruz-Jentoft AJ, Morley JE, Phillips S, Sieber C, Stehle P, Teta D, Visvanathan R, Volpi E, Boirie Y. Evidence-based recommendations for optimal dietary protein intake in older people: a position paper from the PROT-AGE Study Group. *J Am Med Dir Assoc.* 2013;14(8):542–59. <https://doi.org/10.1016/j.jamda.2013.05.021>.
43. Houston DK, Nicklas BJ, Ding J, Harris TB, Tylavsky FA, Newman AB, Lee JS, Sahyoun NR, Visser M, Kritchevsky SB, Health ABC, Study. Dietary protein intake is associated with lean mass change in older, community-dwelling adults: the Health, Aging, and Body Composition (Health ABC) Study. *Am J Clin Nutr.* 2008;87(1):150–5. <https://doi.org/10.1093/ajcn/87.1.150>.
44. Papier K, Fensom GK, Knuppel A, Appleby PN, Tong TYN, Schmidt JA, Travis RC, Key TJ, Perez-Cornago A. Meat consumption and risk of 25 common conditions: outcome-wide analyses in 475,000 men and women in the UK Biobank study. *BMC Med.* 2021;19(1):53. <https://doi.org/10.1186/s12916-021-01922-9>.
45. Li C, Bishop TRP, Imamura F, Sharp SJ, Pearce M, Brage S, Ong KK, Ahsan H, Bes-Rastrollo M, Beulens JWW, den Braver N, Byberg L, Canhada S, Chen Z, Chung HF, Cortés-Valencia A, Djousse L, Drouin-Chartier JP, Du H, Du S, Wareham NJ. Meat consumption and incident type 2 diabetes: an

- individual-participant federated meta-analysis of 1.97 million adults with 100 000 incident cases from 31 cohorts in 20 countries. *The lancet. Diabetes Endocrinol.* 2024;12(9):619–30. [https://doi.org/10.1016/s2213-8587\(24\)00179-7](https://doi.org/10.1016/s2213-8587(24)00179-7).
46. Chan R, Leung J, Woo J. A Prospective Cohort Study to Examine the Association Between Dietary Patterns and Sarcopenia in Chinese Community-Dwelling Older People in Hong Kong. *J Am Med Dir Assoc.* 2016;17(4):336–42. <https://doi.org/10.1016/j.jamda.2015.12.004>.
 47. Shrikhande L, Kedar K, Mounisa DC, Garg R, Agrawal P, Shrikhande A. Sarcopenia in Menopausal Women: Prevalence, Risk Factors, Hormonal Mechanisms, and Management Strategies. *J mid-life health.* 2025;16(4):367–70. https://doi.org/10.4103/jmh.jmh_134_25.
 48. Critchlow AJ, Hiam D, Williams R, Scott D, Lamon S. The role of estrogen in female skeletal muscle aging: A systematic review. *Maturitas.* 2023;178:107844. <https://doi.org/10.1016/j.maturitas.2023.107844>.
 49. Sipilä S, Törmäkangas T, Sillanpää E, Aukee P, Kujala UM, Kovanen V, Laakkonen EK. Muscle and bone mass in middle-aged women: role of menopausal status and physical activity. *J cachexia sarcopenia muscle.* 2020;11(3):698–709. <https://doi.org/10.1002/jcsm.12547>.
 50. Ikeda K, Horie-Inoue K, Inoue S. Functions of estrogen and estrogen receptor signaling on skeletal muscle. *J Steroid Biochem Mol Biol.* 2019;191:105375. <https://doi.org/10.1016/j.jsbmb.2019.105375>.
 51. Messina M. Soy and Health Update: Evaluation of the Clinical and Epidemiologic Literature. *Nutrients.* 2016;8(12):754. <https://doi.org/10.3390/nu8120754>.
 52. Soni M, Rahardjo TB, Soekardi R, Sulistyowati Y, Lestariningsih, Yesufu-Udechuku A, Irsan A, Hogervorst E. Phytoestrogens and cognitive function: a review. *Maturitas.* 2014;77(3):209–20. <https://doi.org/10.1016/j.maturitas.2013.12.010>.
 53. Intharuksa A, Arunotayanun W, Na Takuathung M, Chaichit S, Prasansuklab A, Chaikhong K, Sirichanchuen B, Chupradit S, Koonrunsesomboon N. Daidzein and Genistein: Natural Phytoestrogens with Potential Applications in Hormone Replacement Therapy. *Int J Mol Sci.* 2025;26(14):6973. <https://doi.org/10.3390/ijms26146973>.
 54. Hu Y, Hu Y, Li T, Shi R. Beyond Hormone Replacement: Multifaceted Effects of Phytoestrogens for Optimizing Kinesiological and Physiological Adaptations in Postmenopausal Women. *Clin Interv Aging.* 2025;20:1695–711. <https://doi.org/10.2147/cia.s539923>.
 55. Wardle J, Haase AM, Steptoe A, Nillapun M, Jonwutiwes K, Bellisle F. Gender differences in food choice: the contribution of health beliefs and dieting. *Annals Behav medicine: publication Soc Behav Med.* 2004;27(2):107–16. https://doi.org/10.1207/s15324796abm2702_5.
 56. Young VR, Pellett PL. Plant proteins in relation to human protein and amino acid nutrition. *Am J Clin Nutr.* 1994;59(5 Suppl):S1203–12. <https://doi.org/10.1093/ajcn/59.5.1203s>.
 57. van Vliet S, Burd NA, van Loon LJ. The Skeletal Muscle Anabolic Response to Plant- versus Animal-Based Protein Consumption. *J Nutr.* 2015;145(9):1981–91. <https://doi.org/10.3945/jn.114.204305>.
 58. Kalyani RR, Corriere M, Ferrucci L. Age-related and disease-related muscle loss: the effect of diabetes, obesity, and other diseases. *The lancet. Diabetes Endocrinol.* 2014;2(10):819–29. [https://doi.org/10.1016/s2213-8587\(14\)70034-8](https://doi.org/10.1016/s2213-8587(14)70034-8).
 59. Milesi G, Rangan A, Grafenauer S. Whole Grain Consumption and Inflammatory Markers: A Systematic Literature. *Rev Randomized Control Trials Nutrients.* 2022;14(2):374. <https://doi.org/10.3390/nu14020374>.
 60. Pu R, Jia S, Zhang X, Man Q, Yu D, Cai S, Song P, Zhang J. Association between dietary patterns and sarcopenia among community-dwelling older adults in five provinces of China: a cross-sectional study. *Front public health.* 2025;13:1556033. <https://doi.org/10.3389/fpubh.2025.1556033>.
 61. Pabla P, Jones EJ, Piasecki M, Phillips BE. (2024) Skeletal muscle dysfunction with advancing age. *Clinical science (London, England: 1979),* 138(14), 863–882. <https://doi.org/10.1042/cs20231197>
 62. Whaikid P, Piaseu N, Tantiprasoplap S, Krongthaeo S, Srisuk W, Jitwiriyatham T, Tantipongsirikul J, Subtema C. Prevalence and associated factors of sarcopenia risk and possible sarcopenia among older homeless adults in a home for destitute, Thailand: A cross-sectional study. *Belitung Nurs J.* 2025;11(6):714–21. <https://doi.org/10.33546/bnj.4166>.
 63. Todoroki H, Takayanagi T, Morikawa R, Asada Y, Hidaka S, Yoshino Y, Hiratsuka I, Shibata M, Wada A, Asai S, Ito A, Kamimura K, Fujiwara Y, Kuwata H, Hamamoto Y, Seino Y, Suzuki A. Effects of High-Protein Nutritional Guidance on Sarcopenia-Related Parameters in Individuals Aged ≥ 75 Years with Type 2 Diabetes: An Exploratory Single-Arm Pre-Post Intervention Study. *Nutrients.* 2025;17(21):3459. <https://doi.org/10.3390/nu17213459>.
 64. Beasley JM, Shikany JM, Thomson CA, Nutrition. 28(6), 684–90. <https://doi.org/10.1177/0884533613507607>
 65. Haftenberger M, Heuer T, Heidemann C, Kube F, Krems C, Mensink GB. Relative validation of a food frequency questionnaire for national health and nutrition monitoring. *Nutr J.* 2010;9:36. <https://doi.org/10.1186/1475-2891-9-36>.

Figures

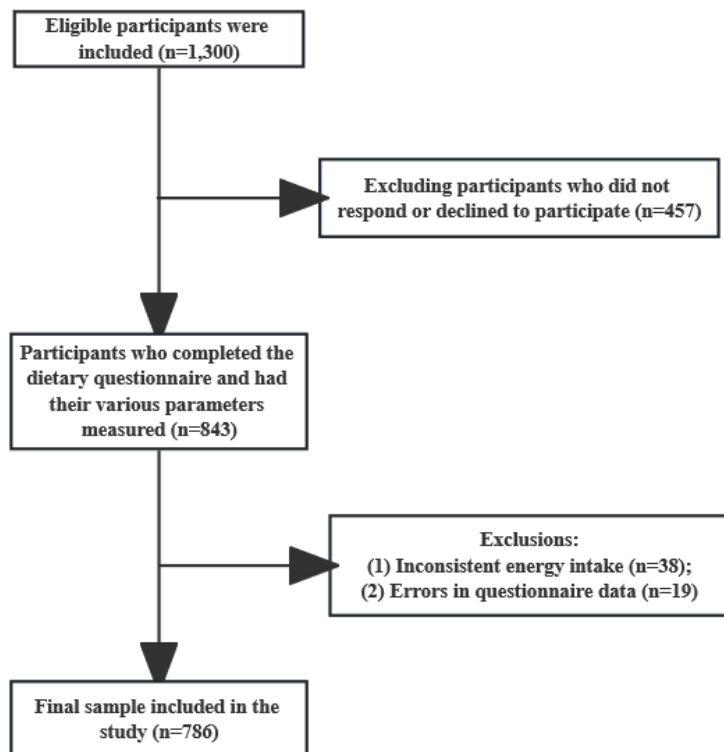


Figure 1

Flow chart of participant screening

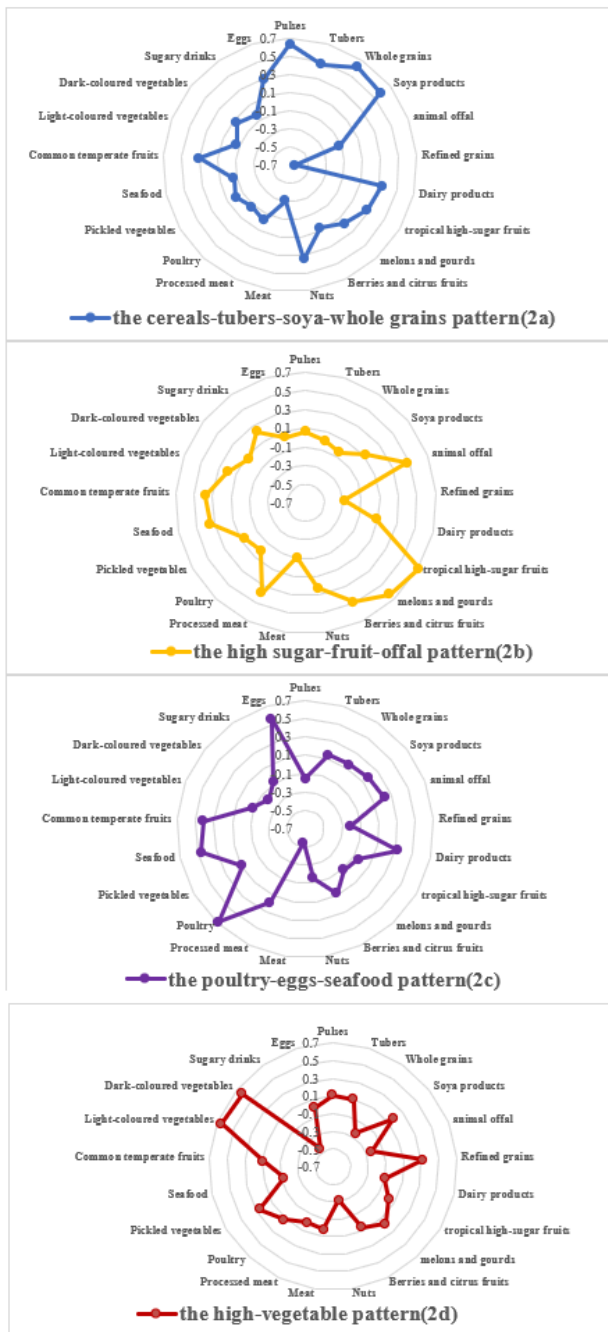


Figure 2

a-2d. Radar chart of factor loadings for the four dietary patterns

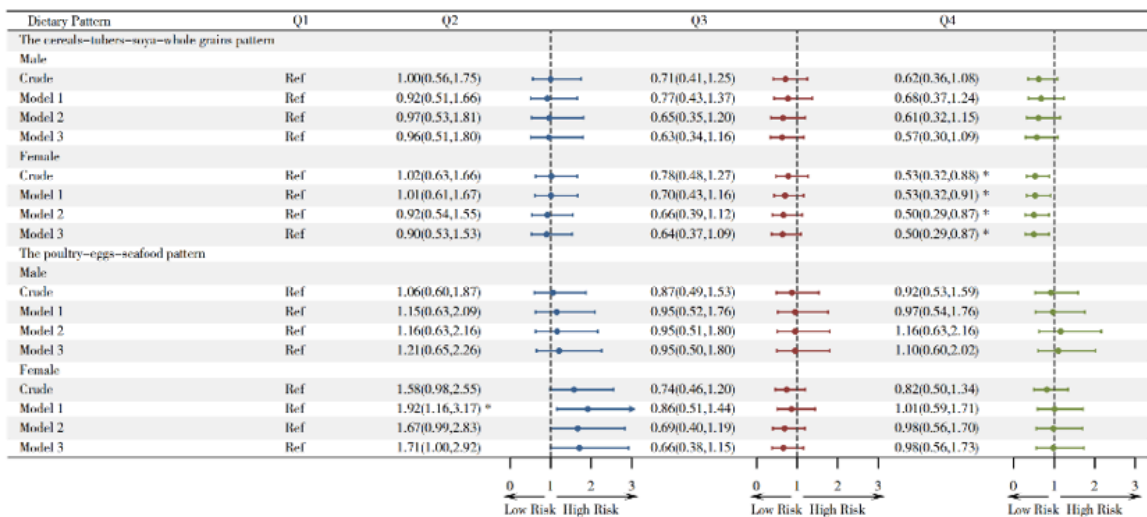


Figure 3

Forest plot of regression analysis for the association between sex and sarcopenia risk

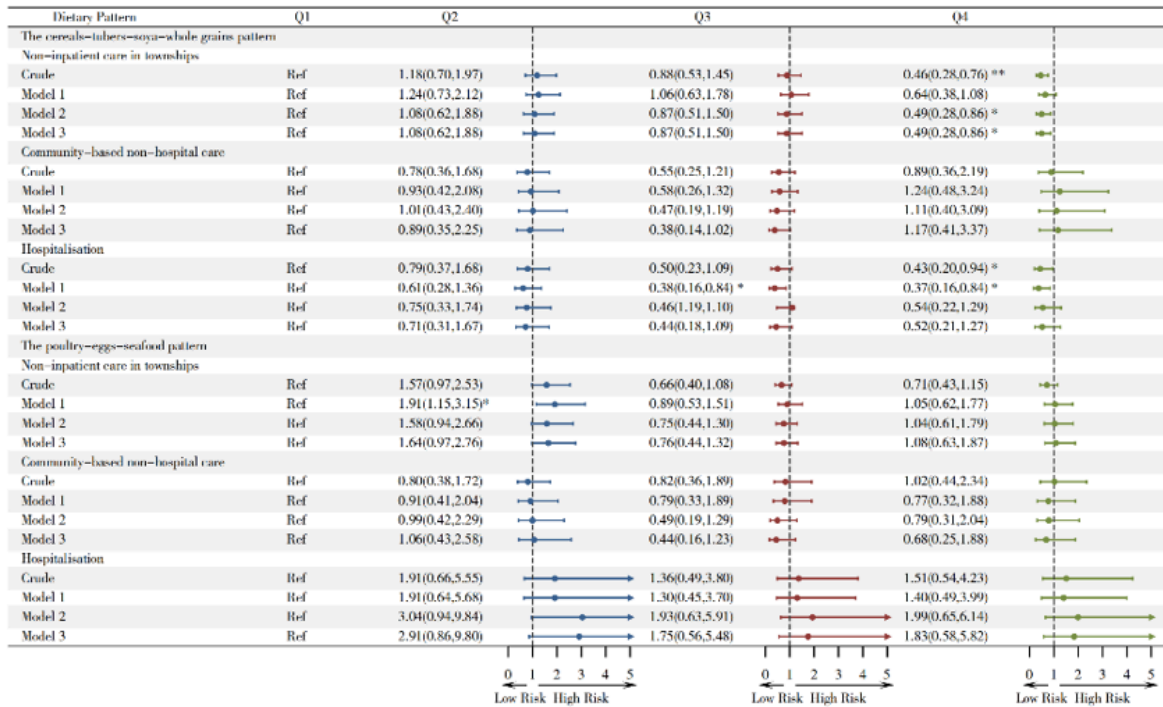


Figure 4

Forest plot of regression analysis for the association between living environment and sarcopenia

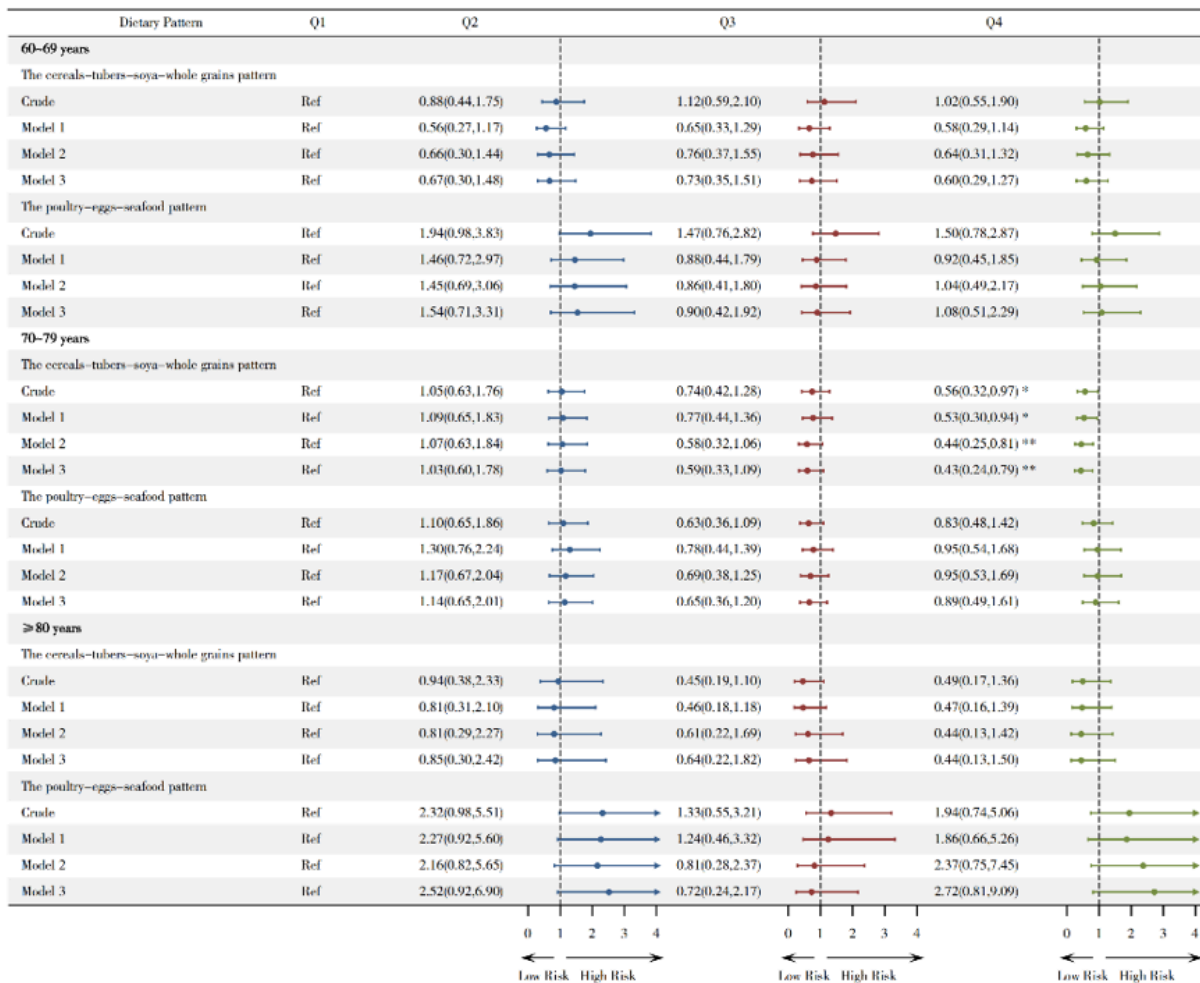


Figure 5

Forest plot of regression analysis for the association between age group and sarcopenia risk