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Association between dietary knowledge and muscle mass in Chinese older adults: a cross-sectional and longitudinal study

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ABSTRACT

Objectives This study aims to explore the possible association between dietary knowledge and muscle mass in a Chinese population aged 60 years and above.

Design Cross-sectional and longitudinal studies.

Setting Data from the 2006 and 2011 China Health and Nutrition Survey (CHNS) were used for this study.

Participants A total of 1487 Chinese participants (44.38% males) aged 60 and above in the 2006 survey were included in the cross-sectional study. From the same study population, a total of 1023 participants (46.82% males) with normal muscle mass on the interview date of 2006 were included in the longitudinal study.

Outcome measures Dietary knowledge was accessed by a validated CHNS questionnaire. Appendicular skeletal muscle mass was calculated using a validated anthropometric equation derived from a representative Chinese population. Based on the 2021 Chinese consensus on sarcopenia, the appendicular skeletal muscle mass was categorised as 'normal' or 'low' using sex-specific cut-off values.

Results The prevalence of low muscle mass in the study population was 31.20%, with a higher prevalence in females (34.22%). People with low muscle mass have a significantly lower dietary knowledge score (mean difference: −1.74, 95% CI −2.20 to −1.29). In the cross-sectional analysis, one score higher in dietary knowledge score was associated with a 4% lower odds of low muscle mass (OR=0.96, 95% CI 0.93 to 0.99). Compared with people in the lowest quartile of dietary knowledge, people in the highest quartile have a 44% lower odds of low muscle mass (OR=0.56, 95% CI 0.35 to 0.91). In the longitudinal analysis, no significant association was found between dietary knowledge and low muscle mass, yet the upper 95% CI was close to one (HR=0.97, 95% CI 0.93 to 1.01).

Conclusions Sufficient dietary knowledge may play a protective role in maintaining normal muscle mass in Chinese adults aged 60 or above.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ The study population was from the China Health and Nutrition Survey, a multiregional survey featuring a large and diversified Chinese population.
⇒ Both the cross-sectional and longitudinal associations between dietary knowledge and muscle mass were analysed, offering various temporal perspectives.
⇒ Due to data availability, a major limitation is that muscle mass was derived from a validated equation for Chinese adults, instead of using dual X-ray absorptiometry or bioelectrical impedance analysis.

INTRODUCTION

A normal muscle mass is essential for maintaining one's daily activities. Muscle mass decreases as the body ages. This decline accelerates after age 50, with an average annual decline rate of 1.5%–5.0% of total muscle mass.[1] As a major component of muscle mass, appendicular skeletal muscle mass (ASM) is crucial in functions such as movement. The ASM index (ASMI), which is the ASM divided by squared height in metres, has been used in categorising low muscle mass.[2] Low muscle mass is associated with various adverse health outcomes, including longer hospital stays, decreased quality of life, higher mortality and the need of long-term care.[3] It is one recognised root cause and contributor to older adults' disabilities.[4] In 2020, the Chinese older adults (aged 60 and above) reached 260 million, accounting for 18.70% of the Chinese population.[5] Given the significant burden that adverse health conditions place on individuals and society, exploring risk factors for the decline of muscle mass in the massive 260 million people is crucial and raising awareness of the importance of maintaining muscle mass as a key aspect of healthy ageing in China.

Dietary knowledge plays an important role in regulating dietary intake, and the effect is independent of educational background and occupation.[6] Balanced diet intake has been recognised as an efficient way to maintain muscle mass in elders, especially in women.[7] A 3-year cohort study of Japanese older adults demonstrated that those who more closely followed the Japanese Food Guide Spinning Top had, on average, a higher skeletal muscle index compared to those with lower adherence to the guide.[8] It may be rational to assume dietary knowledge is associated with musculoskeletal health in older adults.

Dietary education in China is not well developed. Although the Chinese government has implemented several dietary education activities, most were aimed at students and the youth.[9 10] It is, therefore, meaningful to explore the association between dietary knowledge and muscle mass in the ageing Chinese population. To our best knowledge, current research mainly focuses on diet structure and dietary formulations. There is far less research exploring the effect of dietary knowledge on muscle mass in the Chinese population. Using a national survey, our study may contribute to establishing a healthy ageing society and improving the quality of life for the large Chinese older adults.

Materials and methods

Study population

The study population was selected from the China Health and Nutrition Survey (CHNS). CHNS is a national open-cohort survey conducted by the Chinese Center for Disease Control and Prevention and the University of North Carolina. Surveys have been conducted in 1991, 1993, 1997, 2000, 2004, 2006, 2009, 2011 and 2015. The CHNS study applied a multistage, random cluster sampling approach to recruit study participants. Stratified by income (low, middle, and high), four counties and two cities from each province were selected using a weighted sampling scheme. Villages from counties and urban and suburban neighbourhoods from cities were then selected randomly. In each village/neighbourhood, multiple households were randomly selected and all household members were interviewed. Details of the cohort and sampling procedure have been published elsewhere.[11] The evaluation of dietary knowledge was started in 2004 and was largely revised in 2015. The staff training manual was revised in 2006. To ensure the consistency of the dietary knowledge questionnaire and survey results, data between 2006 and 2011 were used.

A total of 11 860 participants attended the CHNS in 2006. Participants were excluded if they (1) aged less than 60 or were pregnant by 2006 (n=7244); (2) dietary knowledge data were unavailable (n=15); (3) demographic and health data were unavailable (n=3114). The sample size for cross-sectional analysis was 1487 people. Furthermore, we excluded 464 people with low skeletal muscle mass in 2006, resulting in a cohort of 1023 people for the longitudinal analysis.

Sample size calculation

In a cross-sectional study that investigated 36 374 healthy Chinese individuals, the prevalence of low muscle mass in people aged 40 or above was 17% (3502 out of 20 652), and 31.2% (748 out of 2401) in people aged 65 or above.[12] Assuming a positive linear association between age and the prevalence of low muscle mass, we estimated the prevalence of low muscle mass in Chinese people aged 60 or above was roughly 28%. With a statistical significance of 0.05 and 90% power, a total of 926 people was required to detect a 10% difference in prevalence which we regarded as of clinical importance. Our study population was 1487 people for the cross-sectional analysis and 1023 people for the longitudinal analysis, thus fulfilled the sample size requirement.

Assessment of dietary knowledge

Dietary knowledge was the study exposure of this research. It was evaluated by a questionnaire containing 12 statements. The assessment of the questionnaire related to the diet has been previously evaluated for its reliability and validity.[11 13] It has been widely used to assess dietary knowledge in the Chinese population.[10 14] The Cronbach's alpha was 0.88 for this questionnaire in this study population, indicating the questionnaire was internally consistent.[15] For each statement, a respondent must choose among 'strongly disagree', 'disagree', 'neutral', 'unknown', 'agree', or 'strongly agree'. Each statement was categorised as 'True' or 'False'.[10] If a respondent answered 'strongly disagree' or 'disagree' for the 'True' statement, they received zero point, and if they chose 'agree' or 'strongly agree', they received two points. If a respondent answered 'strongly disagree' or 'disagree' for the 'False' statement, they received two points, and if they chose 'agree' or 'strongly agree', they received zero point. Respondents who chose 'neutral' or 'unknown' received one point regardless of the statement's category. The respondent's dietary knowledge score was the total score of all 12 statements. The maximum score of this questionnaire was 24, and the minimum score was zero. A higher score indicates that the respondent was well versed in dietary knowledge.

Assessment of ASM

The ASM was estimated by a validated anthropometric equation derived from a group of 763 Chinese adults recruited from four vastly different regions (Jinan, Guangzhou, Xi'an and Chengdu) in China.[16] The equation has a high R^2 of 0.90, showing a good prediction of ASM in Chinese adults. It has been cross validated with a correlation coefficient of 0.941, suggesting a strong agreement between the result of this ASM equation and dual X-ray absorptiometry (DXA). In addition, this equation has been applied in multiple research with similar study populations to that of our study.[17–20]

Following the 2021 Chinese consensus on sarcopenia, low muscle mass was defined as ASMI<7.0 kg/m^2 for males, and below 5.4 kg/m^2 for females.[21] Height and weight were measured to the nearest 0.1 cm or 0.1 kg. The detailed procedure of measurement can be found in the CHNS work manual.[22]

Covariates

Demographic, lifestyle and health-related factors were adjusted in this study. We selected covariates based on published research and clinical guidelines.[3 4 8 21] Demographic data included age, sex, education level, residence, marital status and socioeconomic levels. Education levels were categorised into primary or below/secondary/tertiary education. The residence was dichotomised into urban/rural residence. The socioeconomic level was measured using per capita annual household income in Chinese Yuan, inflated to the value of the Chinese Yuan in 2015.

Lifestyle factors were smoking status (smoker/non-smoker), drinking status (drinker/non-drinker), knowledge of Chinese Food Guide Pagoda/the Dietary Guidelines for Chinese Residents, physical activity and daily average dietary intake of carbohydrates/fat/protein. Chinese Food Guide Pagoda was designed to reflect the principles of balanced diets in the context of Chinese cuisine. It showed the recommended amounts of a broad variety of foods, including fats, dairy products, animal meats, vegetables and cereals.[23] Following the recommendation could lead to a balanced diet that meets the daily requirement of nutrients.

Physical activity was assessed by a standardised questionnaire that collected the average hours per week an individual spent in the occupational, domestic, leisure and travel sectors. The physical activity questionnaire has been used in all the CHNS surveys in past decades.[24] The average hour of each sector was then multiplied by the sector-specific metabolic equivalent of task (MET) intensity level to calculate the MET hours per week.[25] All sector's MET hours per week were added up to get the total MET hours per week. The higher the total value, the more physically active the individual was.

Daily average dietary intake of carbohydrate/fat/protein was an individual's daily average intake measured over three consecutive days. Each participant was interviewed for three consecutive days, during which the food consumed was weighted, identified and categorised using the Chinese Food Composition Table. The composition table contains the standard nutrient composition per 100 g of identified food. By multiplying the intake amount with nutrient composition, the carbohydrate/fat/protein intake can be calculated. The detailed calculation and survey protocol can be obtained from the household food investigation manual of the CHNS survey.[22]

Health-related factors were body mass index (BMI), systolic blood pressure (SBP) and diastolic blood pressure (DBP). BMI was categorised into underweight (below 18.5 kg/m^2), normal weight (18.5–23.9 kg/m^2), and overweight or obese (24 kg/m^2 and above).[26] History of type 2 diabetes mellitus, hypertension, myocardial infarction and stroke was collected because these diseases may put patients on food restriction, which may make patients more aware of dietary knowledge.[27 28] Type 2 diabetes mellitus was identified if a participant was diagnosed by physicians or on antidiabetic therapy. Resting blood pressure was measured three times by trained medical practitioners on the day of the CHNS survey, and the average was used as the blood pressure value. The very detailed blood pressure measurement guidance for CHNS has been published.[22] People were hypertensive if either they were diagnosed, with antihypertensive therapy, or with average SBP≥140 mm Hg/DBP≥90 mm Hg on the day of the CHNS survey. Myocardial infarction and stroke status were self-reported by the study participants. As patients with digestive diseases are often on diet restriction, self-reported status of having digestive diseases within 4 weeks prior to the survey was collected.

Statistical analysis

In this study, continuous data were presented as the mean (SD) or median with an IQR. Categorical data were presented as n (%). The baseline characteristics of 1487 participants were summarised and stratified by their baseline muscle mass category.

To offer various temporal perspectives, both cross-sectional and longitudinal analyses were conducted. A cross-sectional analysis was conducted first, applying multivariable logistic regression to explore the association between dietary knowledge and ASM in 2006. Following the cross-sectional analysis, a multivariable Cox regression was conducted to explore the association between dietary knowledge and ASM in a cohort of 1023 people free of low muscle mass on the baseline year of 2006.

As the physical examination was conducted on the day of the CHNS interview, the entry date was the interview date of the year 2006; the exit date was the interview date of the year 2011 or the date of withdrawal, whichever was earlier. The follow-up period was defined as the interval between the entry and the exit date. The outcome event was defined as the incidence of low muscle mass according to the Chinese consensus.[21] Schoenfeld's residuals showed no violation (p=0.52) of the proportional hazards assumption. Sensitivity analyses were conducted in adults without baseline comorbidities and free of digestive diseases within 4 weeks prior to the CHNS study. All analyses were performed using STATA V.16.0/MP (StataCorp). A two-sided p<0.05 was considered to be statistically significant.

Patient and public statement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

RESULTS

In 2006, the prevalence of low muscle mass in the study population was 31.20%, with a higher prevalence in females (34.22%) than in males (27.42%). Low muscle mass was more commonly found in people of older age, rural residents, smokers, less-educated people and those at a lower socioeconomic level. Compared with people with normal muscle mass, people with low muscle mass have a significantly lower dietary knowledge score (mean difference: −1.74, 95% CI −2.20 to −1.29, p<0.001), and they were less aware of Chinese Food Guide Pagoda or dietary

Table 1 Baseline characteristics of participants stratified by their muscle mass status at 2006

Characteristics	All (n=1487)	Muscle mass status	
		Normal (n=1023)	Low (n=464)
Age, mean (SD) (year)	66.89 (6.09)	65.90 (5.56)	69.06 (6.63)
Male, n (%)	660 (44.38)	479 (46.82)	181 (39.01)
Urban residence, n (%)	492 (33.09)	389 (38.03)	103 (22.20)
Married, n (%)	1196 (80.43)	852 (83.28)	344 (74.14)
Smoking, n (%)	369 (24.82)	244 (23.85)	125 (26.94)
Drinking, n (%)	405 (27.24)	287 (28.05)	118 (25.43)
Educational level, n (%)			
Primary and below	1076 (72.36)	689 (67.35)	387 (83.41)
Secondary	281 (18.90)	226 (22.09)	55 (11.85)
Tertiary and above	130 (8.74)	108 (10.56)	22 (4.74)
Per capita household income, median (IQR) (Chinese yuan)	5604 (8646)	6881 (9850)	3876 (5247)
Body mass index, mean (SD) (kg/m^2)	23.33 (3.63)	25.00 (2.97)	19.66 (1.79)
Systolic blood pressure, mean (SD) (mm Hg)	129.87 (20.35)	132.27 (19.93)	124.58 (20.28)
Diastolic blood pressure, mean (SD) (mm Hg)	80.50 (11.68)	82.17 (11.66)	76.82 (10.85)
Comorbidities, n (%)			
Hypertension	623 (41.90)	480 (46.92)	143 (30.82)
Diabetes	36 (2.42)	34 (3.32)	2 (0.43)
Stroke	26 (1.75)	23 (2.25)	3 (0.65)
Myocardial infarction	16 (1.08)	13 (0.27)	3 (0.65)
Have digestive diseases in the past 4 weeks	64 (4.30)	35 (3.42)	29 (6.25)
Daily average dietary intake, mean (SD) (g)			
Carbohydrate	292.19 (116.27)	295.92 (117.53)	283.97 (113.15)
Fat	68.06 (36.75)	71.51 (36.96)	60.46 (35.13)
Protein	61.67 (23.39)	64.70 (23.44)	54.98 (21.88)
Physical activity, mean (SD) (MET hours/week)	139.57 (115.40)	126.35 (112.78)	150.68 (122.61)
ASMI, mean (SD) (kg/m^2)	6.52 (1.12)	6.93 (0.94)	5.61 (0.92)
Dietary knowledge score, mean (SD) (point)	17.47 (4.20)	18.01 (3.89)	16.27 (4.61)
Knowing Chinese Food Guide Pagoda or the Dietary Guidelines for Chinese Residents, n (%)	121 (8.14)	98 (9.58)	23 (4.96)

*was column percentage unless otherwise indicated.
ASMI, appendicular skeletal muscle mass index; IQR, interquartile range; MET, metabolic equivalent of task; SD, standard deviation.

guidelines. In addition, they have a lower daily average dietary intake of fat (−15.45%) and protein (−15.02%) but a similar intake of carbohydrates (−4.04%). Those with low muscle mass were more commonly to have digestive diseases within 4 weeks prior to the CHNS survey (6.25% vs 3.42%) (table 1).

Differences in dietary knowledge in people of various muscle mass status

Compared with people with normal muscle mass, people with low muscle mass have a much lower proportion of correct answers in Q2 (−10.40%), Q4 (−14.97%), Q6 (−12.77%) and Q7 (−11.62%). People of low muscle mass were less aware of the health effects of sugar, high-fat diets, animal products, fatty meat and animal fat. They also less recognised the benefits of dairy and bean products, as stated in Q8 and Q9 (table 2).

Cross-sectional analysis on the association between dietary knowledge and muscle mass

A total of 464 (31.20%) people were with low muscle mass in 2006. Adjusted for sex and age, model 1 shows a negative association between dietary knowledge and low muscle mass. The findings were consistent with further adjustments for other demographic and lifestyle factors. Additional control for health factors has not significantly changed the association shown in model 3, in which dietary knowledge was inversely associated with low muscle mass (OR=0.96, 95% CI 0.93 to 0.99). By modelling dietary knowledge as a categorical variable, there were consistent

Table 2 Participants' proportion of correctly answering dietary knowledge questions, stratified by muscle mass status at 2006

Item	Question	Correct answer	Muscle mass status		χ^2 test p value
			Normal (n=1023)	Low (n=464)	
Q1	Choosing a diet with a lot of fresh fruits and vegetables is good for one's health.	True	84.75	86.64	0.87
Q2	Eating a lot of sugar is good for one's health.	False	83.68	73.28	<0.001
Q3	Eating a variety of foods is good for one's health.	True	90.03	85.13	0.02
Q4	Choosing a diet high in fat is good for one's health.	False	81.13	66.16	<0.001
Q5	Choosing a diet with a lot of staple foods (rice and rice products and wheat products) is not good for one's health.	True	58.55	51.72	0.04
Q6	Consuming a lot of animal products daily (fish, poultry, eggs and lean meat) is good for one's health.	False	64.71	51.94	<0.001
Q7	Reducing the amount of fatty meat and animal fat in the diet is good for one's health.	True	82.31	70.69	<0.001
Q8	Consuming milk and dairy products is good for one's health.	True	93.45	87.93	<0.001
Q9	Consuming beans and bean products is good for one's health.	True	95.70	89.22	<0.001
Q10	Physical activities are good for one's health.	True	94.53	90.52	0.003
Q11	Sweaty sports or other intense physical activities are not good for one's health.	False	39.30	41.81	0.50
Q12	The heavier one's body is, the healthier he or she is.	False	89.54	86.42	0.01

negative associations between dietary knowledge and low muscle mass. Compared with people in the lowest dietary knowledge quartile, people in the highest quartile have a 44% lower odds of low muscle mass (OR=0.56, 95% CI 0.35 to 0.91). The test for trend showed no dose–response effect in the association (p=0.31) (table 3).

Longitudinal analysis on the association between baseline dietary knowledge and muscle mass

A total of 1023 people entered the cohort, with a total follow-up time of 5098.51 years and a median follow-up time of 4.98 years. No participants have withdrawn from the study. Within the follow-up period, 141 (13.78%) incidences of low muscle mass were identified. The incidence rate of low muscle mass in people of the lowest quartile of dietary knowledge was 313.98 per 10 000 person years. Along with the increase in quartile, the incidence rate declined to 257.23, 276.20 and 262.08 per 10 000 person years, respectively; no evidence of a trend was found (p=0.54).

With adjustment for age and sex, dietary knowledge score was associated with muscle mass. The strength of association decreased from very strong (p=0.003) to insignificant (p=0.16) as more confounding factors were adjusted. However, although with a p>0.05 in models 2 and 3, the upper 95% confidence levels slightly exceeded 1.00. People with one higher baseline dietary knowledge

Table 3 Logistic regression results of the association between baseline dietary knowledge and muscle mass (n=1487)

	Model 1*		Model 2†		Model 3‡	
	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value
Dietary Knowledge Score	0.92 (0.90 to 0.95)	<0.001	0.96 (0.93 to 1.00)	0.05	0.96 (0.93 to 0.99)	0.04
Dietary Knowledge Category						
Quartile 1 (the lowest)	As reference	–	As reference	–	As reference	–
Quartile 2	0.48 (0.36 to 0.65)	<0.001	0.72 (0.48 to 1.08)	0.11	0.72 (0.48 to 1.09)	0.12
Quartile 3	0.35 (0.25 to 0.49)	<0.001	0.47 (0.30 to 0.74)	0.001	0.48 (0.30 to 0.76)	0.002
Quartile 4 (the highest)	0.37 (0.26 to 0.51)	<0.001	0.55 (0.34 to 0.88)	0.01	0.56 (0.35 to 0.91)	0.02
Test for trend		0.01		0.29		0.30

*Adjusted for age and sex.
†Adjusted for age, sex, residence, education, smoking, drinking, body mass index, marital status, per capita household income, daily physical activity, and daily average dietary intake of carbohydrate/fat/protein.
‡Adjusted as model 2 with further adjustment for knowing of dietary guideline, systolic blood pressure, diastolic blood pressure, diabetes, hypertension, myocardial infraction, stroke and having digestive diseases in the past 4 weeks.

Table 4 Cox regression results of the association between dietary knowledge and muscle mass (n=1023)

	Model 1*		Model 2†		Model 3‡	
	HR (95% CI)	P value	HR (95% CI)	P value	HR (95% CI)	P value
Dietary Knowledge Score	0.94 (0.91 to 0.98)	0.003	0.97 (0.93 to 1.01)	0.14	0.97 (0.93 to 1.01)	0.12
Dietary Knowledge Category						
Quartile 1 (the lowest)	As reference	–	As reference	–	As reference	–
Quartile 2	0.72 (0.46 to 1.12)	0.14	0.90 (0.57 to 1.42)	0.65	0.90 (0.57 to 1.44)	0.67
Quartile 3	0.74 (0.46 to 1.17)	0.19	0.82 (0.50 to 1.32)	0.41	0.82 (0.51 to 1.34)	0.43
Quartile 4 (the highest)	0.74 (0.46 to 1.21)	0.24	1.08 (0.64 to 1.81)	0.78	1.05 (0.63 to 1.78)	0.84
Test for trend		0.49		0.51		0.57

*Adjusted for age and sex.
†Adjusted for age, sex, residence, education, smoking, drinking, body mass index, marital status, per capita household income, daily physical activity, and daily average dietary intake of carbohydrate/fat/protein.
‡Adjusted as model 2 with further adjustment for knowing of dietary guideline, systolic blood pressure, diastolic blood pressure, diabetes, and hypertension, myocardial infraction, stroke, and having digestive diseases in the past 4 weeks.

score may be possible to have an average of 3% decrease in the rate of low muscle mass (HR=0.97, 95% CI 0.93 to 1.01). The baseline quartile of dietary knowledge score was not associated with low muscle mass after adjusting for multiple factors (table 4). Sensitivity analyses showed similar findings as the primary findings (table 5).

DISCUSSION

In this study, a negative association between dietary knowledge and low muscle mass in Chinese people aged 60 and above was found. The association persisted in cross-sectional analyses but was not observed in longitudinal analyses. Per one unit higher dietary knowledge score is associated with a 4% decrease in the odds of having low muscle mass. People in the highest dietary knowledge quartile have 44% lower odds of having low muscle mass than those with the lowest dietary knowledge. In the longitudinal analyses, one score higher in dietary knowledge may have a possible 3% lower risk of developing low muscle mass in people aged 60 and above.

In the cross-sectional study, the OR decreased in the higher dietary knowledge category compared with the lowest quartile. One interesting finding is that the minimum OR was found in the third quartile of the dietary knowledge score. The rationale behind this phenomenon remains unclear. One possible reason could be that in this study, people in the third quartile have the maximum average baseline ASMI (6.8 kg/m^2). Higher ASMI is more resistant to muscle loss; therefore, in the cross-sectional study, which assessed the association between dietary knowledge and muscle loss at a given time, people in the third quartile of dietary knowledge had the minimum odds of low muscle mass. The longitudinal study only showed a possible negative association between dietary knowledge and low muscle mass with an upper 95% CI of 1.01 when the dietary score was

Table 5 Sensitivity analysis in participants without baseline comorbidities or digestive diseases within 4 weeks prior to the CHNS survey

	Cross-sectional (n=807)*		Longitudinal (n=504)*	
	OR (95% CI)	P value	HR (95% CI)	P value
Dietary Knowledge Score	0.98 (0.93 to 1.03)	0.43	0.96 (0.91 to 1.01)	0.14
Dietary Knowledge Category				
Quartile 1 (the lowest)	As reference	–	As reference	–
Quartile 2	0.86 (0.49 to 1.49)	0.59	0.99 (0.53 to 1.87)	0.98
Quartile 3	0.51 (0.28 to 0.93)	0.03	0.66 (0.33 to 1.32)	0.24
Quartile 4 (the highest)	0.60 (0.32 to 1.11)	0.11	0.81 (0.40 to 1.64)	0.55
Test for trend		0.49		0.63

*Adjusted for age, sex, residence, education, smoking, drinking, body mass index, marital status, per capita household income, daily physical activity and daily average dietary intake of carbohydrate/fat/protein, knowing of dietary guideline, systolic blood pressure and diastolic blood pressure.

modelled as a continuous variable. This may be due to the reduction of statistical power when a continuous variable was categorised.[29] More research is needed to investigate the possible threshold of dietary knowledge in preventing muscle loss.

Similar to our findings, some studies have demonstrated the association between nutrition knowledge and health in the Chinese and Western populations. Studies using CHNS data have demonstrated that diet-related knowledge is positively associated with self-reported health status in Chinese adults.[30 31] One research on older adults (age: 65–79) in five European countries showed that high nutrition-related knowledge scores were associated with better health status.[32] The mechanism of the positive association between dietary knowledge and muscle mass may be explained indirectly through dietary patterns. Recent systematic reviews and research have shown that dietary knowledge is positively associated with healthy eating and protein intake.[6 9] Milk, beans and their products have been recognised as favourable dietary protein sources.[33] In questions that investigate people's awareness of the benefits of dairy and bean products (Q8 and Q9), people of low muscle mass have significantly lower correct rates (−5.52% for dairy products, −6.62% for bean products). It is possible that insufficient awareness of protein sources correlates with less intake of these foods. In the study population, the daily average protein intake in people of low muscle mass (male: 59.70 g/day, female: 52.00 g/day) was far below the recommended level (male: 65.00 g/day, female: 55.00 g/day) for the Chinese population.[14] On the contrary, people with normal muscle mass have a much higher daily intake (male: 69.22 g/day, female: 60.71 g/day). Dietary protein is a crucial component of muscle maintenance and hypertrophy; insufficient protein intake may not be able to maintain the minimum muscle function, and thus prone to ageing, chronic disease and other risk factors for muscle loss.[34]

As aforementioned, people with low muscle mass in the study population were less aware of the possible harmful effects of a high-fat diet, fatty meat and animal fat. However, these people have a slightly lower share of total energy from dietary fat than those with normal muscle mass (28.40% vs 30.60%). Within our study period, the average percentage of total energy from dietary fat in the entire Chinese population has exceeded the recommended level for Chinese residents.[14 35] In the same period, the share of total energy taken from saturated fatty acid (SFA) and the proportion of people with a high intake of SFA have elevated.[35] Affected by the lack of dietary knowledge and the increasing share of SFA in the Chinese diet, it may be rational to propose that people with low muscle mass have a higher proportion of SFA in their total fat intake.

Fatty acid plays a key part in modulating skeletal muscle mass, and SFA has been found to affect muscle through various approaches. Mice fed high-SFA diets have increased SFA storage in muscle,[36] leading to fatty infiltration and accelerated insulin resistance.[37] In turn, insulin resistance facilitates metabolic breakdowns of skeletal muscle.[38] Palmitate, a commonly used SFA, was reported to be linked with muscle wasting and atrophy through upregulating the expressions of proatrophic genes like atrogin-1/MAFbx, and repressing PKB/Akt-directed signalling, which is a key mediator of protein synthesis.[39] Nonetheless, the food structure at the individual level was unavailable to examine the SFA share. Further research with a detailed food structure questionnaire would be helpful in evaluating our findings.

This study has several shortcomings. First, food frequency, nutritional supplements and preferred food processing techniques at the individual level were not evaluated as they were unavailable in CHNS. It is clear that food frequency data at the individual level could be useful in supporting and further validating if one's dietary knowledge is correlated with food intake. A more detailed collection of dietary intake should be performed in future research. The food processing technique affects nutrient digestibility, and vast regional differences in food processing techniques exist in China.[40] Second, this study focused on Chinese older adults only; therefore, its findings may not be generalised to other ethnic groups. Third, a formula was used to estimate muscle mass in this literature. While the formula is not as precise as DXA, it provides a highly accurate estimate of muscle mass. It is important to acknowledge the potential bias associated with using this formula to estimate muscle mass. As all the participants were estimated using the same formula, the possible bias of the formula created a non-differential misclassification of exposure; and our results were possibly underestimated. Nonetheless, it is worth noting that the formula used in the study was derived from a diverse population recruited from several regions of China and has been widely applied and validated in several studies. The formula was applied consistently across all study participants, making the results comparable within the study. Therefore, we regarded the formula in this study as appropriate and reliable in estimating muscle mass in the Chinese population aged 60 and above. Fourth, the physical activity questionnaire used in CHNS was developed by professionals, but no information on validation has been revealed to our best knowledge. Nevertheless, the wide application of this questionnaire in all the CHNS surveys and the strict quality control procedures applied by CHNS staff have rendered the usefulness of the questionnaire. Fifth, the measurement of food intake may be underestimated as left-over food might have been discarded by the time of measurement, and the amount of food purchased could be self-reported.

To our best knowledge, this study may be the first study that evaluates the extent to which dietary knowledge affects muscle mass in a representative Asian population vulnerable to muscle loss. As the Chinese population are not generally well versed in dietary knowledge, our findings demonstrate the necessity of enhancing dietary knowledge education in Chinese older adults. We found that people with lower muscle mass had lower dietary knowledge scores, lower levels of education, and lower household income per capita compared with the population mean. Therefore, these lower income, less-educated populations may be a primary target audience group for dietary education. SFAs may have negative impacts on muscle mass and function. Therefore, high-SFA food like animal organs and fatty pork is suggested to be consumed with caution, especially in people vulnerable to muscle loss. In conclusion, dietary knowledge may be a potential protective factor against low muscle mass in Chinese people aged 60 years and beyond. Well-designed educational programmes should be considered as an important component of dietary interventions to reduce the risk of low muscle mass.

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Contributors QL conceived and designed the study, collected, analysed and interpreted the data. QL, LW and YM drafted the manuscript and provided critical feedback on the study design, assisted with data collection and interpretation, and revised the manuscript for important intellectual content. YG contributed to the study design, conducted the statistical analyses, and helped interpret the data. All authors approved the final manuscript. QL is the guarantor who accepts full responsibility for the work, had access to the data, and controlled the decision to publish.

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Ethics approval This study is a retrospective cohort study using the public-accessible CHNS dataset. The CHNS dataset is cohosted by the University of North Carolina at Chapel Hill and the National Institute for Nutrition and Food Safety, China Centre for Disease Control and Prevention. The institutional review committees from the University of North Carolina at Chapel Hill and the National Institute for Nutrition and Food Safety, China Centre for Disease Control and Prevention approved the CHNS survey protocols and instruments and the process for obtaining informed consent for the survey (Ref.: 201524). The research was conducted in accordance with the Declaration of Helsinki (as revised in Tokyo 2004). Research data are publicly available, fully anonymised and it is impossible for researchers to identify any participants. Participants gave informed consent to participate in the study before taking part.

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REFERENCES

1. Keller K, Engelhardt M. Strength and muscle mass loss with aging process. age and strength loss. *Muscles Ligaments Tendons J* 2013;3:346–50.
2. Chen L-K, Liu L-K, Woo J, *et al*. Sarcopenia in Asia: consensus report of the Asian working group for Sarcopenia. *J Am Med Dir Assoc* 2014;15:95–101.
3. Prado CM, Purcell SA, Alish C, *et al*. Implications of low muscle mass across the continuum of care: a narrative review. *Ann Med* 2018;50:675–93.
4. Volpi E, Nazemi R, Fujita S. Muscle tissue changes with aging. *Curr Opin Clin Nutr Metab Care* 2004;7:405–10.
5. Akimov AV, Gemueva KA, Semenova NK. The seventh population census in the PRC: results and prospects of the country's demographic development. *Her Russ Acad Sci* 2021;91:724–35.
6. Spronk I, Kullen C, Burdon C, *et al*. Relationship between nutrition knowledge and dietary intake. *Br J Nutr* 2014;111:1713–26.
7. Wolfe RR. The role of dietary protein in optimizing muscle mass, function and health outcomes in older individuals. *Br J Nutr* 2012;108 Suppl 2:S88–93.
8. Huang CH, Okada K, Matsushita E, *et al*. Dietary patterns and muscle mass, muscle strength, and physical performance in the elderly: A 3-year cohort study. *J Nutr Health Aging* 2021;25:108–15.
9. Wardle J, Parmenter K, Waller J. Nutrition knowledge and food intake. *Appetite* 2000;34:269–75.
10. Zhou L, Zeng Q, Jin S, *et al*. The impact of changes in dietary knowledge on adult overweight and obesity in China. *PLoS One* 2017;12:e0179551.
11. Popkin BM, Du S, Zhai F, *et al*. Cohort profile: the China health and nutrition survey--monitoring and understanding socio-economic and health change in China, 1989-2011. *Int J Epidemiol* 2010;39:1435–40.
12. Liu X, Hou L, Xia X, *et al*. Prevalence of Sarcopenia in multi Ethnics adults and the association with cognitive impairment: findings from West-China health and aging trend study. *BMC Geriatr* 2020;20:63:63.:.
13. Yuan Y-Q, Li F, Wu H, *et al*. Evaluation of the validity and reliability of the Chinese healthy eating index. *Nutrients* 2018;10:114.
14. Wang S-S, Lay S, Yu H-N, *et al*. Dietary guidelines for Chinese residents (2016): comments and comparisons. *J Zhejiang Univ Sci B* 2016;17:649–56.
15. Tavakol M, Dennick R. Making sense of Cronbach's alpha. *Int J Med Educ* 2011;2:53–5.
16. Wen X, Wang M, Jiang C-M, *et al*. Anthropometric equation for estimation of Appendicular Skeletal muscle mass in Chinese adults. *Asia Pac J Clin Nutr* 2011;20:551–6.
17. Hu X, Zhang L, Wang H, *et al*. Malnutrition-Sarcopenia syndrome predicts mortality in hospitalized older patients. *Sci Rep* 2017;7:3171:3171.:.
18. Yang M, Hu X, Wang H, *et al*. Sarcopenia predicts readmission and mortality in elderly patients in acute care wards: a prospective study. *J Cachexia Sarcopenia Muscle* 2017;8:251–8.
19. Gao K, Cao L-F, Ma W-Z, *et al*. 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.
20. Ruan G-T, Xie H-L, Zhang H-Y, *et al*. Inflammatory geriatric nutritional risk index stratified the survival of older adults with cancer Sarcopenia. *Cancer Med* 2023;12:6558–70.
21. Liu J, Ding Q, Zhou B, *et al*. Chinese expert consensus on diagnosis and treatment for elderly with Sarcopenia(2021). *Chinese Journal of Geriatrics* 2021;40:943–52.
22. Institute of Nutrition and Food Hygiene China CDC. China health and nutrition survey. Work Manual 2006, 2006. Available: https://www.cpc.unc.edu/projects/china/data/questionnaires/Training_Manual_2006_short.pdf
23. The Chinese Nutrition Society. Dietary guidelines and the food guide pagoda. *Journal of the American Dietetic Association* 2000;100:886–7.
24. Zou Q, Wang H, Su C, *et al*. Longitudinal association between physical activity and blood pressure, risk of hypertension among Chinese adults: China health and nutrition survey 1991–2015. *Eur J Clin Nutr* 2021;75:274–82.
25. Ainsworth BE, Haskell WL, Whitt MC, *et al*. Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc* 2000;32(9 Suppl):S498–504.

26 Xu W, Zhang H, Paillard-Borg S, *et al*. Prevalence of overweight and obesity among Chinese adults: role of Adiposity indicators and age. *Obes Facts* 2016;9:17–28.
27 Ley SH, Hamdy O, Mohan V, *et al*. Prevention and management of type 2 diabetes: dietary components and nutritional strategies. *Lancet* 2014;383:1999–2007.
28 Hermansen K. Diet, blood pressure and hypertension. *Br J Nutr* 2000;83 Suppl 1:S113–9.
29 Altman DG, Royston P. The cost of Dichotomising continuous variables. *BMJ* 2006;332:1080.
30 Sun Y, Dong D, Ding Y. The impact of dietary knowledge on health: evidence from the China health and nutrition survey. *Int J Environ Res Public Health* 2021;18:3736.
31 Yang Y, He D, Wei L, *et al*. Association between diet-related knowledge, attitudes, behaviors, and self-rated health in Chinese adult residents: a population-based study. *BMC Public Health* 2020;20:720.
32 Jeruszka-Bielak M, Kollajtis-Dolowy A, Santoro A, *et al*. Are nutrition-related knowledge and attitudes reflected in lifestyle and health among elderly people? A study across five European countries. *Front Physiol* 2018;9:994:994.:.
33 Sun Y, Liu B, Snetselaar LG, *et al*. Association of major dietary protein sources with All-Cause and Cause-Specific mortality: prospective cohort study. *J Am Heart Assoc* 2021;10:e015553.
34 Tipton KD, Phillips SM. Dietary protein for muscle hypertrophy. *Nestle Nutr Inst Workshop Ser* 2013;76:73–84.
35 Shen X, Fang A, He J, *et al*. Trends in dietary fat and fatty acid intakes and related food sources among Chinese adults: a longitudinal study from the China health and nutrition survey (1997–2011). *Public Health Nutr* 2017;20:2927–36.
36 Timmers S, de Vogel-van den Bosch J, de Wit N, *et al*. Differential effects of saturated versus unsaturated dietary fatty acids on weight gain and Myocellular lipid profiles in mice. *Nutr Diabetes* 2011;1:e11.
37 Gilbert M. Role of skeletal muscle lipids in the pathogenesis of insulin resistance of obesity and type 2 diabetes. *J Diabetes Investig* 2021;12:1934–41.
38 Capel F, Pinel A, Walrand S. Accumulation of Intramuscular toxic lipids, a link between fat mass accumulation and Sarcopenia. *OCL* 2019;26:24.
39 Lipina C, Hundal HS. Lipid modulation of skeletal muscle mass and function. *J Cachexia Sarcopenia Muscle* 2017;8:190–201.
40 Li J, Hsieh Y-HP. Traditional Chinese food technology and cuisine. *Asia Pac J Clin Nutr* 2004;13:147–55.