Original Article

Association between dietary macronutrients and body composition in college students

Huini Ding MMed[1], Yuhui Sun MMed[1], Wenjing Wang MMed[1], Yijia Liu MB[1], Yuning Jiao MB[2], Wangziyan Lu MB[2], Yuandi Xi PhD[1]

[1]*Beijing Key Laboratory of environment and aging, School of Public Health, Capital Medical University, Beijing, China*
[2]*School of Basic Medical Sciences, Capital Medical University, Beijing, China*

Background and Objectives: Evidence regarding macronutrients and body composition remains limited. This study examined the relationship in Chinese college students. **Methods and Study Design:** 498 Beijing college students aged 18–31 years were included. Dietary intake was assessed using a food frequency questionnaire, and body composition was measured by bioelectrical impedance. Linear and logistic regression analyses examined correlations between macronutrients intake and body composition. **Results:** Obesity-related indicators including waist and hip circumference, waist-hip ratio, body mass index, body fat mass, fat mass index and body fat percentage, and muscle-related indicators including soft lean mass, fat free mass, fat-free mass index, skeletal muscle mass, skeletal muscle index were negatively correlated with the proportion of protein intake (p <0.05), and were positively correlated with the proportion of fat intake (p <0.05). All body composition parameters, except waist-hip ratio, were negatively correlated with the proportion of carbohydrate intake (p <0.05). The risk of thinness increased progressively with higher proportion of protein intake (OR: 4.48, 4.57, 7.43; p <0.05). However, higher proportion of protein intake was associated with a reduced risk of overweight (OR :0.41, 0.39; p <0.05) and obesity (OR = 0.09, p = 0.007). Increased risk of overweight (OR = 2.29, p = 0.044) and obesity (OR = 4.42, p = 0.030) were observed in the fourth quartile group of fat intake proportion compared to the first. **Conclusions:** Further studies are warranted to clarify the relationship between body muscle and fat distribution and macronutrients intake composition.

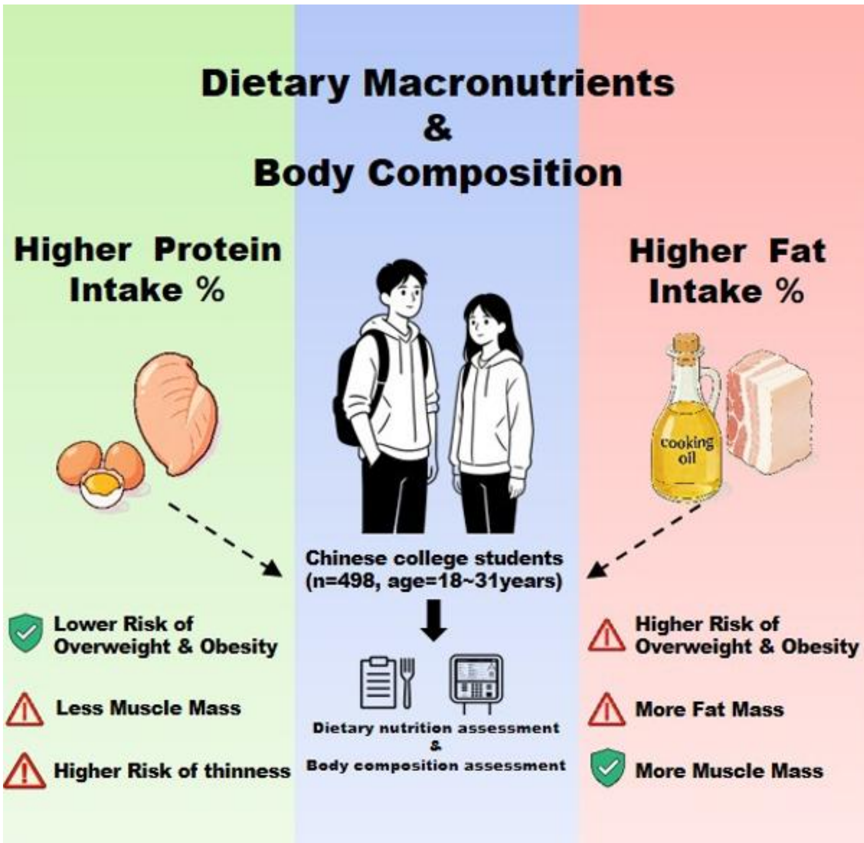
Key Words: cross-sectional study, body composition, carbohydrate, fat, protein

INTRODUCTION

Bioelectrical impedance analysis has become the preferred method among biomedical researchers and clinicians due to its low cost, simplicity and portability.[1] Body composition indicators play a crucial role in assessing nutritional status and overall health. Additionally, they provide essential information for predicting, diagnosing, and managing numerous chronic conditions, particularly in younger populations. For instance, waist-hip ratio and body fat percentage are significant risk factors for type 2 diabetes mellitus (T2DM) and serve as an important diagnostic tool in T2DM prevention.[2] A systematic review has demonstrated that waist circumference and waist-to-hip ratio can predict cardiovascular incidents.[3] Studies indicate that body fat mass and lean mass are key indicators for evaluating the health status of young people. When these measures fall outside the normal range, they may become risk factors for the development of various chronic diseases.[4] Therefore, maintaining healthy body composition is essential for promoting physical fitness among college students.

Body composition is influenced by multiple factors, including sex, age, dietary habits, physical activity levels, and genetic origin. For most individuals, there is an age-related increase in body fat until age 65 years,[5] whereas muscle and bone mass progressively decline with age.[6] Therefore, achieving and maintaining an appropriate body composition in youth establishes an important foundation for long-term health. As dietary intake is a major determinant of body composition in young people, this study focuses on dietary macronutrients, which are dietary energy producer including carbohydrate, fat and protein. Evidence indicates that excessive carbohydrate intake or a high dietary ratio of carbohydrate to fat or protein may elevate insulin levels and promote body fat accumulation.[7] Moreover, a higher proportion of energy intake from fat has been reported to be positively associated with body mass index (BMI).[8] In contrast, protein-rich diets may help reduce fat mass by increasing activity-related energy expenditure and enhancing non-exercise activity thermogenesis.[9]

Corresponding Author: Prof. Yuandi Xi, School of Public Health, Capital Medical University, No.10 Xitoutiao, You An Men Wai Road, Beijing, 100069, China
Tel: +86-15810863506
Email: xiaoer71@ccmu.edu.cn
Manuscript received 14 October 2025. Initial review completed 29 December 2025. Revision accepted 24 February 2026.
doi: 10.6133/apjcn.202606_35(3).0014



Graphical Abstract.

However, few research has specifically examined the relationship between the carbohydrate, fat, protein intake and multiple body composition indicators among college students. This population represents a transitional life stage into adulthood, often characterized by high energy demands. College students generally show considerable concern regarding body weight, calorie intake and healthy dietary patterns.[10] Investigating the relationship between macronutrients intake and body composition may therefore help students better understand how dietary components influence physical health, thereby supporting the development of sustainable and healthy eating habits among young adults.

METHODS

Participants

This cross-sectional investigation enrolled college students. A total of 498 participants (aged 18–31 years) completed the body composition assessment, and 488 completed the dietary intake survey. Ultimately, 474 participants completed all study assessments and were included in the final analysis. Prior to enrollment, all participants provided informed consent. The study was approved by the Ethics Committee of Capital Medical University (Approved number: Z2020SY044).

Dietary nutrition assessment

Dietary intake data were acquired via the Food Frequency Questionnaire (FFQ).[11] Daily total energy and nutrient intakes were calculated based on the China Food Composition Tables.[11] The proportion of energy intake from carbohydrates was calculated using the formula: (energy from carbohydrate intake / total energy intake) × 100%, based on standard conversion factors (4 kcal/g for carbohydrates). Total energy intake was calculated excluding fiber energy. The proportions of energy intake from protein and fat were determined using coefficients of 4 kcal/g for protein and 9 kcal/g for fat, respectively.

Body composition measurements

Body composition assessments were conducted utilizing a bioelectrical impedance analyzer (BIA) (Inbody 770 Co., Seoul, Korea). Height and weight were determined using a portable automatic height and weight meter (Inbody BSM 370). All measurements were performed by a trained research assistant following standardized procedures. Participants were instructed to stand upright, maintain a forward gaze, and remain barefoot and lightly clothed during the assessment. Body mass index (BMI) was calculated as weight (kg) divided by height squared (m^2). Obesity was defined as a BMI $\geq$ 28 kg/m^2 and overweight as 24 kg/m^2 $\leq$ BMI < 28 kg/m^2, according to the criteria of the Working Group on Obesity in China.[12] Normal weight was defined as 18.5 kg/m^2 $\leq$ BMI < 24 kg/m^2, and thinness was defined as < 18.5 kg/m^2. The waist-hip ratio was calculated as the ratio of waist circumference to hip circumference. Further body composition parameters were derived by Inbody 770 Co. using electrophysiology in conjunction with proprietary algorithms (not publicly accessible).

Statistical analysis

Following the assessment of data normality via the Shapiro–Wilk or Kolmogorov–Smirnov tests, normally distributed data are presented as means ± standard deviation (SD), while non-normal data are expressed as median (interquartile range). Baseline characteristics, stratified by sex, were compared using independent samples t-tests for normally distributed variables, Mann-Whitney U tests for skewed variables, and $\chi 2$ tests for categorical variables. One-way analysis of variance (ANOVA) with Bonferroni's correction or Kruskal–Wallis tests were employed to assess differences in body composition parameters across quartiles of protein, fat, and carbohydrate intake proportions. Linear regression models were utilized to evaluate the association between macronutrients intake (protein, fat, and carbohydrate) as independent variables and body composition parameters as the dependent variables. Specifically, Model 1 was unadjusted; Model 2 was adjusted for sex and age; and Model 3 was further adjusted for sex, age, total energy intake, alcohol consumption, and sugar-sweetened beverages intake. Results from multiple logistic regression analyses are presented as odds ratios (ORs) with 95% confidence intervals (CIs). Reference values for waist-hip ratio were defined as ≤ 0.9 for males and ≤ 0.85 for females, and for body fat percentage as < 25% for males and < 30% for females.13 All statistical analyses were conducted using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA). p-value <0.05 was considered statistically significant

RESULTS

Basic characteristics

Participants were stratified into two groups based on sex (Table 1). The study included a total of 498 participants (113 males and 385 females) aged 18 to 31 years. Circumference of waist and hip were significantly higher in males compared to females (p <0.001). Males exhibited significantly elevated levels of BMI, total fat-free mass (FFM), FFM of the trunk, upper and lower limbs, soft lean mass, fat-free mass index (FFMI), skeletal muscle mass, and skeletal muscle index compared to females (p

Table 1. Baseline characteristics of the college students by sex

Variables	Total	Male	Famale	p
Body composition				
N	498	113	385	
Age	20.0 (19.0, 22.0)	20.0 (19.0, 21.0)	20.0 (19.0, 22.0)	0.360
Waist circumference (cm)	77.7 (73.2, 82.8)	80.0 (74.3, 88.2)	77.0 (72.6, 81.9)	<0.001**
Hip circumference (cm)	92.8 (89.6, 96.4)	96.7 (92.5, 101)	91.8 (89.0, 94.8)	<0.001**
Waist-hip ratio	0.840 (0.810, 0.870)	0.830 (0.800, 0.870)	0.840 (0.810, 0.870)	0.314
Body mass index (kg/m^2)	21.7 (20.3, 23.8)	22.6 (20.9, 25.2)	21.5 (20.1, 23.5)	<0.001**
Thinness, n (%)	34.0 (6.80)	6.00 (5.30)	28.0 (7.30)	<0.001**
Normal, n (%)	352 (70.7)	66.0 (58.4)	286 (74.3)	
Overweight, n (%)	85.0 (17.1)	26.0 (23.0)	59.0 (15.3)	
Obesity, n (%)	27.0 (5.40)	15.0 (13.3)	12.0 (3.10)	
Body fat mass (kg)				
Total	17.1 (13.5, 21.2)	13.5 (9.70, 17.6)	18.3 (14.6, 21.6)	<0.001**
Trunk	8.30 (6.30, 10.3)	6.50 (4.40, 9.20)	8.70 (6.80, 10.4)	<0.001**
Upper limbs	2.30 (1.70, 3.00)	1.50 (1.00, 2.20)	2.50 (2.00, 3.10)	<0.001**
Lower limbs	5.60 (4.40, 7.00)	4.30 (3.30, 5.30)	6.00 (5.00, 7.00)	<0.001**
Fat free mass (kg)				
Total	40.2 (36.8, 46.9)	56.5 ± 7.30	38.8 (36.2, 41.4)	<0.001**
Trunk	17.3 (15.9, 20.2)	24.1 ± 3.00	16.7 (15.6, 18.0)	<0.001**
Upper limbs	3.60 (3.10, 4.60)	5.80 ± 1.00	3.40 (3.10, 3.80)	<0.001**
Lower limbs	12.9 (11.5, 15.1)	18.1 ± 2.30	12.3 (11.2, 13.4)	<0.001**
Soft lean mass (kg)	37.7 (34.5, 44.1)	53.2 ± 6.80	36.4 (34.0, 38.9)	<0.001**
Skeletal muscle mass (kg)	21.6 (19.6, 25.6)	31.7 ±4.30	20.8 (19.3, 22.4)	<0.001**
FMI	6.40 (5.00, 8.00)	4.30 (3.30, 5.90)	6.90 (5.60, 8.20)	<0.001**
FFMI	15.1 (14.3, 16.8)	18.4 ± 1.80	14.7 (14.1, 15.5)	<0.001**
Skeletal muscle index, kg/m^2	6.20 (5.70, 7.00)	7.80 ± 0.70	5.90 (5.60, 6.30)	<0.001**
Body fat percentage (%)	30.2 (24.4, 34.3)	19.6 (15.5, 24.1)	32.1 (27.9, 35.4)	<0.001**
Dietary intake				
N	488	107	381	
Energy intake (kcal/d)	1781 (1424, 2296)	1965 (1604, 2575)	1692 (1384, 2230)	<0.001**
Protein intake (g/d)	66.6 (49.5, 89.2)	77.6 (57.5, 98.0)	63.3 (47.4, 87.7)	<0.001**
Fat intake (g/d)	97.1 (79.8, 121)	111 (90.6, 136)	94.9 (76.3, 115)	<0.001**
Carbohydrate intake (g/d)	162 (123, 230)	184 (135, 252)	158 (121, 220)	0.011*
Fiber intake (g/d)	5.90 (3.80, 9.50)	5.50 (3.70, 9.50)	6.00 (3.80, 9.60)	0.520
Energy from				
Protein (%)	14.9 (13.4, 16.4)	15.1 (13.2, 16.2)	14.9 ± 2.60	0.534
Fat (%)	48.7 (44.9, 53.2)	49.6 ± 6.60	48.7 (44.8, 53.0)	0.319
Carbohydrate (%)	36.3 ± 7.20	35.3 ± 7.20	36.6 ± 7.20	0.101
Sugar-sweetened beverages, mL/d	35.0 (7.50, 105)	52.5 (7.50, 250)	35.0 (7.50, 105)	0.007*
Alcohol intake, n (%)	118 (24.2)	35.0 (32.7)	83.0 (21.8)	0.020*

FMI: fat mass index; FFMI: fat-free mass index.
*p <0.05, **p <0.001.

<0.001). In contrast, total body fat mass (BFM), BFM of the trunk, upper and lower limbs, fat mass index (FMI), and body fat percentage (PBF) were higher in females than in males (p <0.001). No significant sex-based differences were observed in age or waist-hip ratio.

The median daily energy intake was 1781 kcal (1965 kcal in males and 1692 kcal in females). Significant sex-based differences were observed in the intake of protein, fat (p <0.001), and carbohydrates (p <0.050). However, there were no significant sex-based differences in fiber intake or the proportion of protein intake, fat, and carbohydrates. Consumption of sugar-sweetened beverages and the prevalence of alcohol consumption were both higher in males compared to females (p <0.050).

Distribution of body composition in dietary intake

Results of the preliminary body composition analysis, stratified by quartiles of dietary protein, fat, and carbohydrate intake proportions, were presented in Tables 2-4. The quartiles of protein intake proportion were defined as Q1 ≤13.3%, 13.3% <Q2 ≤14.9%, 14.9% <Q3 ≤16.3%, and Q4 >16.3% (Table 2). Significant differences across the four quartiles were observed for all body composition parameters, except for skeletal muscle mass, FFMI, and PBF. It was notable that, obesity-related indicators, including waist and hip circumference, waist-hip ratio, BMI, BFM, and FMI, were significantly reduced in Q4 compared to Q1 (p <0.050). In contrast, muscle-related indicators (FFM, soft lean mass, skeletal muscle index) were significantly reduced in Q2 compared to Q1 (p <0.050).

The quartiles of fat intake proportion were defined as follows: Q1 ≤45.2%, 45.2% <Q2 ≤48.9%, 48.9% <Q3 ≤53.3%, and Q4 >53.3% (Table 3). Participants in the highest fat intake quartile exhibited significantly higher waist and hip circumferences, and BFM of trunk compared with those in the second quartile. Additionally, FFM of lower limbs was significantly higher than in the first quartile. No other significant differences in body composition parameters were observed across the four groups. For carbohydrate intake proportion, the quartiles were: Q1 ≤31.1%, 31.1% <Q2 ≤36.3%, 36.3% <Q3 ≤40.1%, and Q4 >40.1%. No significant differences in body composition parameters were observed across the quartiles of carbohydrate intake proportion (Table 4).

Association between macronutrients and body compositions

Linear regression analyses were performed to assess the associations between the proportion of energy intake from macronutrients (protein, fat, and carbohydrates) and body composition parameters, as detailed in Table 5. Model 1 was unadjusted. Model 2 was adjusted for age and sex, and Model 3 was further adjusted for energy intake, alcohol consumption, and intake of sugar-sweetened beverages. Obesity-related indicators, including waist and hip circumference, waist-hip ratio, BMI, BFM, FMI and PBF, demonstrated negative correlations with the proportion of protein intake across all three models (p <0.001). Muscle-related indicators (soft lean mass, FFM, FFMI, skeletal muscle mass, skeletal muscle index) exhibited negative correlations with the proportion of protein intake in the adjusted Models 2 and 3 (p <0.050). In contrast, all body composition parameters, excluding FFMI and PBF, showed positive correlations with the proportion of fat intake across all three models (p <0.050). FFMI showed positive association with the proportion of fat intake only in model 3 (β = 0.044, p <0.001), whereas significant positive associations for PBF were observed in Model 2 (β = 0.100, p = 0.017) and Model 3 (β = 0.196, p <0.001). Regarding the proportion of carbohydrate intake (Table 5), waist and hip circumference, BMI, BFM, FFM of the trunk and upper limbs, FMI, FFMI, and PBF were negatively associated in model 3 (p <0.050). Total FFM showed a negative correlation with the proportion of carbohydrate intake in model 1 (β = -0.121, p = 0.041) and model 3 (β = -0.130, p <0.001), which was attenuated in model 2 (β = -0.061, p = 0.078). Similar patterns were observed for soft lean mass, skeletal muscle index, and skeletal muscle mass (p <0.050). FFM of the lower limbs was inversely associated with the proportion of carbohydrate intake across all three models (p <0.050).

The results of the multiple logistic regression analysis were presented in Table 6. Following adjustment for age, sex, energy intake, sugar-sweetened beverages, and alcohol consumption, high waist-hip ratio (OR = 0.090, 95% CI 0.010, 0.650, p = 0.018), FMI (OR = 0.120, 95% CI 0.060, 0.240, p <0.001), FFMI (OR = 0.070, 95% CI 0.030, 0.160, p <0.001), skeletal muscle index (OR = 0.010, 95% CI 0.000, 0.050, p <0.001), and PBF (OR = 0.090, 95% CI 0.020, 0.300, p <0.001) were inversely associated with the risk of thinness. Conversely, these indicators demonstrated significant positive associations with the risk of overweight and obesity (p <0.001). The risk of thinness increased progressively with higher proportion of protein intake compared to Q1 (OR: 4.48, 4.57, 7.43; p <0.05). However, a higher proportion of protein intake had a association with a reduced risk of overweight (OR = 0.410, 95% CI 0.200, 0.850, p = 0.017; OR = 0.390, 95% CI 0.180, 0.850, p = 0.018) and obesity (OR = 0.090, 95% CI 0.020, 0.520, p = 0.007). Increased risk of overweight (OR = 2.29, 95% CI 1.02, 5.14, p = 0.044) and obesity (OR = 4.42, 95% CI 1.16, 16.9, p = 0.030) were observed in Q4 with a higher proportion of fat intake compared to Q1. No significant correlation was observed between the proportion of carbohydrate intake and BMI categories across the different groups.

DISCUSSION

This cross-sectional study investigated the relationships between dietary macronutrients distribution (the proportions of carbohydrate, fat and protein intake) and body composition parameters. Our analysis identified significant negative correlations between body composition indicators and both the proportions of protein and carbohydrate intake, while positive correlations were observed with the proportion of fat intake. Multivariate logistic regression models indicated that a higher proportion of protein intake was associated with a reduced risk of overweight and obesity, whereas a higher proportion of fat intake was associated with an increased risk.

Table 2. Body composition parameters according to the proportion of energy intake from protein (n=474)

Variables	Q1	Q2	Q3	Q4	*p*
Waist circumference (cm)	80.9 (75.9, 86.4) ‡,§,¶	77.3 (73.2, 81.1) †	77.6 (72.9, 83.3) †	75.9 (71.8, 80.0) †	<0.001**
Hip circumference (cm)	94.2 (90.9, 98.3) ‡,¶	92.0 (88.8, 95.2) †	92.5 (89.9, 97.0)	91.6 (88.7, 94.7) †	<0.001**
Waist-hip ratio	0.850 (0.820, 0.890) §,¶	0.840 (0.810, 0.870)	0.830 (0.800, 0.860) †	0.830 (0.800, 0.860) †	<0.001**
Body mass index (kg/m^2)	22.9 (20.7, 24.9) ‡,¶	21.3 (19.9, 23.3) †	21.7 (20.6, 24.0)	21.2 (19.9, 22.8) †	<0.001**
Body fat mass (kg)					
Total	19.3 (14.7, 23.4) ‡,¶	17.0 (13.7, 20.4) †	17.0 (13.7, 22.0)	15.4 (12.6, 19.9) †	<0.001**
Trunk	9.30 (7.40, 11.5) ‡,¶	8.20 (6.30, 9.90) †	8.10 (6.30, 10.6)	7.30 (5.90, 9.40) †	<0.001**
Upper limbs	2.70 (1.90, 3.40) ¶	2.30 (1.80, 2.80)	2.30 (1.80, 3.10)	2.10 (1.60, 2.80) †	0.002*
Lower limbs	6.30 (5.00, 7.30) ¶	5.60 (4.50, 6.70)	5.80 (4.50, 7.00)	5.20 (4.20, 6.60) †	0.002*
Fat free mass (kg)					
Total	41.1 (38.6, 48.2) ‡	39.5 (36.5, 45.6) †	40.2 (36.7, 47.1)	40.3 (36.4, 45.9)	0.043*
Trunk	18.0 (16.6, 20.8) ‡	17.0 (15.6, 19.3) †	17.5 (15.6, 20.3)	17.0 (15.9, 19.9)	0.042*
Upper limbs	3.80 (3.30, 4.70) ‡	3.50 (3.00, 4.20) †	3.60 (3.10, 4.60)	3.50 (3.10, 4.40)	0.046*
Lower limbs	13.3 (12.2, 15.8) ‡	12.6 (11.4, 14.7) †	13.1 (11.4, 15.4)	12.8 (11.3, 14.7)	0.048*
Soft lean mass (kg)	38.6 (36.3, 45.3) ‡	37.1 (34.3, 42.7) †	37.8 (34.4, 44.3)	37.8 (34.2, 43.0)	0.043*
Skeletal muscle mass (kg)	22.3 (20.6, 26.1)	21.4 (19.5, 24.9)	21.7 (19.6, 25.8)	21.5 (19.5, 25.1)	0.057
FMI	7.00 (5.20, 8.40) ¶	6.40 (5.00, 7.80)	6.30 (5.20, 8.30)	5.90 (4.60, 7.60) †	0.006*
FFMI	15.4 (14.5, 17.0)	14.8 (14.2, 16.0)	15.2 (14.2, 17.1)	15.1 (14.2, 16.7)	0.083
Skeletal muscle index, kg/m^2	6.30 (5.90, 7.20) ‡	6.00 (5.60, 6.70) †	6.10 (5.70, 7.20)	6.10 (5.70, 6.70)	0.024*
Body fat percentage (%)	31.2 (25.4, 35.4)	30.4 (25.5, 33.7)	30.2 (24.3, 35.0)	28.6 (23.3, 33.3)	0.051

FMI: fat mass index; FFMI: fat-free mass index.
†p <0.05, statistically different with Q1
‡p <0.05, statistically different with Q2
§p <0.05, statistically different with Q3
¶p <0.05, statistically different with Q4
*p <0.05, **p <0.001.

Table 3. Body composition parameters according to the proportion of energy intake from fat (n=474)

Variables	Q1	Q2	Q3	Q4	*p*
Waist circumference (cm)	77.0 (73.3, 82.7)	76.6 (72.0, 79.9) ¶	78.8 (73.6, 82.6)	79.4 (73.5, 86.8) ‡	0.011*
Hip circumference (cm)	92.3 (89.6, 95.6)	91.9 (88.9, 94.4) ¶	93.2 (89.6, 96.7)	93.9 (90.0, 98.5) ‡	0.013*
Waist-hip ratio	0.830 (0.800, 0.870)	0.830 (0.800, 0.860)	0.840 (0.820, 0.880)	0.850 (0.810, 0.880)	0.079
Body mass index (kg/m^2)	21.8 (20.3, 23.7)	21.3 (20.1, 22.9)	21.7 (20.1, 24.0)	22.4 (20.4, 24.7)	0.078
Body fat mass (kg)					
Total	17.0 (13.0, 21.5)	16.3 (13.1, 20.0)	17.8 (14.0, 21.3)	18.3 (14.2, 23.4)	0.078
Trunk	8.20 (6.10, 10.4)	7.60 (5.90, 9.70) ¶	8.60 (6.60, 10.4)	8.90 (6.40, 11.4) ‡	0.048*
Upper limbs	2.30 (1.60, 3.00)	2.20 (1.60, 2.80)	2.50 (1.70, 3.00)	2.40 (1.80, 3.40)	0.173
Lower limbs	5.40 (4.40, 6.70)	5.50 (4.40, 6.60)	5.80 (4.50, 7.00)	5.80 (4.80, 7.40)	0.127
Fat free mass (kg)					
Total	39.9 (36.8, 44.5)	39.9 (36.7, 44.7)	40.0 (36.7, 46.0)	42.3 (37.6, 49.6)	0.057
Trunk	17.0 (15.9, 19.3)	17.0 (15.6, 19.3)	17.2 (16.0, 19.8)	18.2 (16.1, 21.2)	0.063
Upper limbs	3.50 (3.10, 4.20)	3.50 (3.10, 4.30)	3.50 (3.10, 4.30)	3.80 (3.20, 4.90)	0.088
Lower limbs	12.7 (11.4, 14.3) ¶	12.7 (11.4, 14.8)	12.9 (11.5, 14.8)	13.6 (12.0, 16.2) †	0.034*
Soft lean mass (kg)	37.4 (34.5, 41.8)	37.4 (34.4, 42.2)	37.5 (34.4, 43.2)	39.7 (35.2, 46.7)	0.055
Skeletal muscle mass (kg)	21.4 (19.6, 24.3)	21.4 (19.5, 24.4)	21.4 (19.6, 24.9)	22.8 (20.1, 27.5)	0.067
FMI	6.30 (4.70, 7.90)	6.30 (4.80, 7.60)	6.50 (5.10, 8.30)	6.50 (5.20, 8.30)	0.312
FFMI	15.1 (14.3, 16.1)	14.9 (14.3, 16.5)	15.0 (14.1, 16.8)	15.7 (14.4, 17.2)	0.152
Skeletal muscle index, kg/m^2	6.00 (5.80, 6.60)	6.10 (5.70, 6.70)	6.10 (5.70, 6.90)	6.50 (5.80, 7.30)	0.054
Body fat percentage (%)	30.4 (24.7, 34.4)	29.7 (24.4, 33.7)	30.5 (25.1, 35.0)	30.5 (24.3, 35.1)	0.621

FMI: fat mass index; FFMI: fat-free mass index.
†p <0.05, statistically different with Q1
‡p <0.05, statistically different with Q2
§p <0.05, statistically different with Q3
¶p <0.05, statistically different with Q4
*p <0.05, **p <0.001.

Table 4. Body composition parameters according to the proportion of energy intake from carbohydrate (n=474)

Variables	Q1	Q2	Q3	Q4	*p*
Waist circumference (cm)	78.3 (73.6, 84.2)	77.5 (72.2, 82.3)	78.1 (73.0, 82.4)	77.6 (73.2, 82.8)	0.533
Hip circumference (cm)	93.7 (90.0, 97.4)	92.1 (89.3, 96.4)	92.5 (89.1, 95.3)	92.5 (89.7, 95.9)	0.306
Waist-hip ratio	0.840 (0.820, 0.870)	0.830 (0.810, 0.860)	0.840 (0.820, 0.880)	0.830 (0.800, 0.870)	0.469
Body mass index (kg/m^2)	22.0 (20.4, 24.2)	21.3 (20.1, 23.7)	21.8 (20.1, 23.7)	21.9 (20.4, 23.8)	0.481
Body fat mass (kg)					
Total	17.7 (13.8, 21.7)	16.6 (13.4, 20.5)	17.9 (13.7, 22.0)	17.0 (12.7, 21.2)	0.449
Trunk	8.70 (6.40, 10.6)	7.80 (6.20, 9.90)	8.60 (6.30, 10.5)	8.30 (6.10, 10.3)	0.481
Upper limbs	2.30 (1.80, 3.10)	2.20 (1.60, 2.90)	2.40 (1.80, 3.10)	2.30 (1.60, 3.00)	0.366
Lower limbs	5.60 (4.60, 7.10)	5.40 (4.40, 6.80)	5.80 (4.60, 7.00)	5.40 (4.20, 6.90)	0.425
Fat free mass (kg)					
Total	41.6 (37.5, 48.9)	40.1 (36.7, 47.1)	39.6 (36.4, 43.8)	40.3 (37.2, 45.6)	0.100
Trunk	17.9 (16.1, 20.9)	17.4 (15.8, 20.5)	17.0 (15.7, 19.1)	17.3 (16.0, 20.3)	0.143
Upper limbs	3.80 (3.20, 4.80)	3.50 (3.10, 4.70)	3.50 (3.10, 4.10)	3.50 (3.20, 4.60)	0.168
Lower limbs	13.5 (11.9, 15.8)	12.9 (11.6, 15.6)	12.5 (11.3, 14.3)	12.8 (11.5, 14.9)	0.055
Soft lean mass (kg)	39.1 (35.0, 45.8)	37.5 (34.4, 44.3)	37.0 (34.2, 41.1)	37.8 (34.8, 42.9)	0.096
Skeletal muscle mass (kg)	22.5 (19.9, 26.8)	21.4 (19.5, 25.9)	21.3 (19.5, 23.6)	21.6 (19.9, 24.9)	0.107
FMI	6.40 (5.20, 8.20)	6.20 (4.90, 7.60)	6.90 (5.30, 8.30)	6.40 (4.70, 8.00)	0.294
FFMI	15.7 (14.4, 17.2)	15.0 (14.1, 16.9)	14.9 (14.1, 16.1)	15.1 (14.4, 16.5)	0.174
Skeletal muscle index, kg/m^2	6.40 (5.80, 7.20)	6.10 (5.70, 7.20)	6.00 (5.70, 6.50)	6.10 (5.80, 7.00)	0.129
Body fat percentage (%)	30.2 (23.6, 34.7)	29.3 (23.7, 33.6)	31.3 (25.8, 35.1)	30.3 (24.4, 34.3)	0.256

FMI: fat mass index; FFMI: fat-free mass index.
†*p* <0.05, statistically different with Q1
‡*p* <0.05, statistically different with Q2
§*p* <0.05, statistically different with Q3
¶*p* <0.05, statistically different with Q4
**p* <0.05, ***p* <0.001.

Table 5. The relationship between body compositions and the proportion of energy intake from macronutrient nutrients (n=474)

Body compositions	Model	Protein		Fat		Carbohydrate	
		β	*p*	*β*	*p*	*β*	*p*
Waist circumference (cm)	1	-0.630	<0.001**	0.201	0.001**	-0.088	0.114
	2	-0.704	<0.001**	0.184	0.002*	-0.064	0.245
	3	-0.936	<0.001**	0.381	<0.001**	-0.167	0.004*
Hip circumference (cm)	1	-0.345	0.001**	0.137	0.001**	-0.072	0.055
	2	-0.392	<0.001**	0.127	0.001**	-0.058	0.102
	3	-0.565	<0.001**	0.274	<0.001**	-0.135	<0.001**
Waist-hip ratio	1	-0.004	<0.001**	0.001	0.009*	<0.001	0.365
	2	-0.004	<0.001**	0.001	0.018*	<0.001	0.599
	3	-0.005	<0.001**	0.002	<0.001**	-0.001	0.103
Body mass index (kg/m^2)	1	-0.194	<0.001**	0.060	0.005*	-0.026	0.208
	2	-0.213	<0.001**	0.056	0.009*	-0.019	0.338
	3	-0.304	<0.001**	0.128	<0.001**	-0.058	0.006*
Body fat mass (kg)							
Total	1	-0.503	<0.001**	0.128	0.004*	-0.042	0.315
	2	-0.476	<0.001**	0.139	0.001**	-0.056	0.169
	3	-0.623	<0.001**	0.278	<0.001**	-0.130	0.002*
Trunk	1	-0.264	<0.001**	0.068	0.003*	-0.023	0.292
	2	-0.257	<0.001**	0.071	0.002*	-0.027	0.206
	3	-0.336	<0.001**	0.144	<0.001**	-0.065	0.003*
Upper limbs	1	-0.084	<0.001**	0.021	0.008*	-0.007	0.359
	2	-0.077	<0.001**	0.024	0.002*	-0.010	0.157
	3	-0.101	<0.001**	0.047	<0.001**	-0.023	0.003*
Lower limbs	1	-0.145	<0.001**	0.037	0.005*	-0.012	0.322
	2	-0.130	<0.001**	0.042	0.001**	-0.019	0.104
	3	-0.170	<0.001**	0.082	<0.001**	-0.041	0.001**
Fat free mass (kg)							
Total	1	-0.112	0.479	0.156	0.014*	-0.121	0.041*
	2	-0.276	0.003*	0.113	0.002*	-0.061	0.078
	3	-0.454	<0.001**	0.247	<0.001**	-0.130	<0.001**
Trunk	1	-0.071	0.289	0.066	0.013*	-0.048	0.053
	2	-0.145	<0.001**	0.047	0.003*	-0.021	0.163
	3	-0.225	<0.001**	0.105	<0.001**	-0.051	0.001**
Upper limbs	1	-0.020	0.357	0.020	0.020*	-0.015	0.068
	2	-0.045	<0.001**	0.014	0.008*	-0.006	0.241
	3	-0.071	<0.001**	0.032	<0.001**	-0.015	0.003*
Lower limbs	1	-0.039	0.472	0.062	0.004*	-0.049	0.016*
	2	-0.089	0.008*	0.049	<0.001**	-0.031	0.014*
	3	-0.142	<0.001**	0.094	<0.001**	-0.054	<0.001**
Soft lean mass (kg)	1	-0.104	0.487	0.147	0.014*	-0.115	0.040*
	2	-0.261	0.003*	0.106	0.002*	-0.057	0.078
	3	-0.427	<0.001**	0.232	<0.001**	-0.121	<0.001**
Skeletal muscle mass (kg)	1	-0.064	0.508	0.092	0.017*	-0.072	0.047*
	2	-0.166	0.002*	0.064	0.003*	-0.034	0.099
	3	-0.273	<0.001**	0.144	<0.001**	-0.074	0.001**
FMI	1	-0.171	<0.001**	0.034	0.038*	-0.006	0.692
	2	-0.154	<0.001**	0.040	0.009*	-0.014	0.334
	3	-0.202	<0.001**	0.084	<0.001**	-0.037	0.014*
FFMI	1	-0.021	0.551	0.026	0.069	-0.019	0.138
	2	-0.058	0.016*	0.015	0.109	-0.006	0.541
	3	-0.100	<0.001**	0.044	<0.001**	-0.020	0.034*
Skeletal muscle index, kg/m^2	1	-0.014	0.418	0.017	0.012*	-0.013	0.040*
	2	-0.032	0.004*	0.012	0.004*	-0.006	0.111
	3	-0.051	<0.001**	0.027	<0.001**	-0.014	0.001**
Body fat percentage (%)	1	-0.505	<0.001**	0.068	0.205	0.011	0.835
	2	-0.402	<0.001**	0.100	0.017*	-0.032	0.417
	3	-0.491	<0.001**	0.196	<0.001**	-0.085	0.041*

FMI: fat mass index; FFMI: fat-free mass index.
Model 1: unadjusted; Model 2: adjusted for sex and age; Model 3: adjusted for sex, age, energy intake, alcohol intake, sugar-sweetened beverages..
**p* <0.05, ***p* <0.001.

Table 6. Factors contributing to different BMI (n=474)

Variable	Thinness		Overweight		Obesity	
	OR (95% CI)	*p*	OR (95% CI)	*p*	OR (95% CI)	*p*
Waist-hip ratio (Ref: male ≤0.9, female ≤0.85)	0.090 (0.010, 0.650)	0.018*	3.67 (2.11, 6.38)	<0.001**	29.1 (8.75, 96.8)	<0.001**
FMI	0.120 (0.060, 0.240)	<0.001**	10.5 (5.97, 18.3)	<0.001**	72.6 (25.3, 208)	<0.001**
FFMI	0.070 (0.030, 0.160)	<0.001**	4.75 (3.34, 6.74)	<0.001**	14.8 (7.77, 28.3)	<0.001**
Skeletal muscle index, kg/m^2	0.010 (0.000, 0.050)	<0.001**	19.5 (9.63, 39.5)	<0.001**	725 (130, 4031)	<0.001**
Body fat percentage (%) (Ref: male <25%, female <30%)	0.090 (0.020, 0.300)	<0.001**	28.3 (8.19, 97.7)	<0.001**	480 (44.5, 5185)	<0.001**
Energy from protein (%)						
Q1 (Ref)						
Q2	4.48 (1.13, 17.8)	0.033*	0.410 (0.200, 0.850)	0.017*	0.440 (0.150, 1.34)	0.149
Q3	4.57 (1.09, 19.2)	0.038*	0.650 (0.330, 1.29)	0.217	0.390 (0.120, 1.22)	0.104
Q4	7.43 (1.82, 30.3)	0.005*	0.390 (0.180, 0.850)	0.018*	0.090 (0.020, 0.520)	0.007*
Energy from fat (%)						
Q1 (Ref)						
Q2	0.730 (0.270, 1.98)	0.538	0.790 (0.350, 1.78)	0.568	0.620 (0.140, 2.86)	0.539
Q3	0.620 (0.220, 1.74)	0.361	2.01 (0.950, 4.25)	0.068	1.57 (0.390, 6.35)	0.523
Q4	0.420 (0.130, 1.29)	0.130	2.29 (1.02, 5.14)	0.044*	4.42 (1.16, 16.9)	0.030*
Energy from carbohydrate (%)						
Q1 (Ref)						
Q2	1.81 (0.650, 4.99)	0.255	0.710 (0.350, 1.44)	0.347	0.430 (0.120, 1.55)	0.198
Q3	1.05 (0.330, 3.36)	0.939	0.590 (0.280, 1.21)	0.148	0.620 (0.190, 2.00)	0.426
Q4	2.01 (0.670, 5.98)	0.210	0.840 (0.410, 1.69)	0.616	0.630 (0.200, 2.01)	0.437

Adjusted for sex, age, energy intake, alcohol intake, sugar-sweetened beverages.
*p <0.05, **p <0.001.

There are significant differences in body composition between males and females. In the present study, total body fat mass was 13.5 kg in males and 18.3 kg in females, whereas skeletal muscle mass was 31.7 kg in males and 20.8 kg in females. Liang et al.[14] measured the body composition of 5121 Chinese Han participants, and reported body fat mass of 18.33 kg in males and 19.82 kg in females, alongside skeletal muscle mass of 28.67 kg and 20.09 kg, respectively. These findings suggest that males generally possess greater skeletal muscle mass, whereas females tend to have higher body fat mass. Lifestyle differences, varying levels of physical activity, and dietary behaviors are likely key contributors to these sex-based disparities. A cross-sectional study conducted in Korea demonstrated that higher body fat was correlated with an increased risk of cardiovascular disease (CVD).[15] Moreover, high skeletal muscle mass efficiently decreased risk for a CVD event.[16] Recent epidemiological and clinical studies have demonstrated a significant association between the excessive accumulation of abdominal adipose tissue, particularly visceral adipose tissue (VAT) and subcutaneous adipose tissue (SAT), and an elevated risk of metabolic disorders including type 2 diabetes mellitus (T2DM)[17] and hypertension.[18] Consequently, individuals should prioritize body fat management and focus on strategies for obesity prevention and chronic disease mitigation through muscle building.

To date, evidence regarding the association between dietary protein intake and body composition indicators remain inconsistent. Previous studies suggested that high-protein diets were associated with favorable body composition[19,20] and promoted increases in lean body mass while reducing fat mass.[21] High protein diet have also been shown to achieve more total and abdominal fat mass loss in women.[22] Our findings are consistent with these previous studies, as obesity-related indicators showed a negative correlation with the proportion of protein intake across all three models. Logistic regression analyses further revealed that a higher proportion of protein intake was associated with a lower risk of overweight and obesity. Protein is known to induce greater satiety than carbohydrates or fats,[23] implying that higher-protein diets may reduce total energy intake and promote weight loss. However, muscle-related indicators demonstrated inverse association with the proportion of protein intake after adjusting for sex and age. This negative correlation became more pronounced when additional adjustments were made for energy intake, alcohol consumption, and sugar-sweetened beverages in Model 2. Suggests that the association between protein intake and body composition might be moderated by energy intake and dietary habits. Although high-protein diets are commonly regarded as beneficial for preserving muscle mass,[24] most of the studies were conducted in energy-restricted or weight-loss populations.[25-28] A randomized trial demonstrated that when resistance exercise was included, energy restriction combined with increased protein intake did not alter proteolysis but attenuated the decline in skeletal muscle protein synthesis.[26] Furthermore, combining higher dietary protein intake with intense exercise has been shown to promote greater gains in lean mass and losses in fat mass.[21] Collectively, these findings suggest that weight loss on a high-protein diet should be accompanied by appropriate exercise to maintain muscle mass.

In a previous study,[29] body fat percentage was found to have a significant positive association with carbohydrate intake but no significant association with fat intake. A meta-analysis of randomized trials indicated that both low carbohydrate diet and low fat diet were associated with greater reductions in body weight.[30] However, another randomized controlled trial demonstrated that restricting dietary fat resulted in greater body fat loss compared to restricting dietary carbohydrates among adults with obesity.[31] In our study, body fat mass and body fat percentage were positively associated with the proportion of fat intake but negatively associated with the proportion of carbohydrate intake. Similarly, individuals in the highest quartile of fat intake exhibited a higher risk of overweight and obesity. In contrast, carbohydrate intake did not show similar results in logistic regression as it did in correlation analysis. This discrepancy may stem from the unique characteristics of carbohydrate intake in this population, leading to findings inconsistent with prior studies. According to the Chinese Dietary Reference Intakes,[32] carbohydrates should contribute 50–65% and fat 20–30% of total dietary energy. In the present study, only 8 participants met the recommended carbohydrate intake range, whereas all participants exceeded the recommended range for fat intake. These findings highlight the need for furtherresearch to elucidate the body fat distribution in Chinese adults whose carbohydrate intake falls below the recommended limit or whose fat intake exceeds it. The low-carbohydrate, high-fat dietary pattern observed among university students may be related to increased eating out and a grater consumption of fast food,[33] which can contribute to health issues. In recent years, the ketogenic diet (KD)—a high-fat, very-low-carbohydrate dietary regimen—has gained considerable attention as a potential intervention for weight management. Emerging evidence suggests that KD induces a metabolic state of nutritional ketosis, characterized by elevated circulating ketone bodies, which may promote lipolysis and reduce adiposity.[34] Clinical studies have demonstrated its efficacy in facilitating short- to medium-term weight loss, possibly through mechanisms such as enhanced satiety, reduced insulin secretion, and increased fat oxidation.[34] However, the long-term sustainability and broader metabolic implications of this dietary approach remain subjects of ongoing investigation. It is noteworthy that most previous studies were long-term trials conducted among overweight populations. In contrast, 72% of participants in our study were of normal weight. Therefore, further studies involving a broader range of population are necessary to fully understand these relationships.

The role of dietary fat in health remains a subject of scientific debate, with interpretations of epidemiological data sometimes yielding conflicting public health messages.[35] To date, research examining the effects of fat intake on muscle mass remains scarce, with limited comprehensive investigations and inconclusive findings in this area. Moreover, most studies have predominantly focused on elderly populations. In this study, linear regression analyses indicated that the proportion of fat intake was positively associated with muscle-related indicators, including skeletal muscle mass. Furthermore, participants in the highest fat-intake quartile exhibited significantly higher fat free mass of lower limbs compared with those in to the lowest quartile. A cross-sectional study conducted in US involving 5,356 individuals aged 20-59 years identified low fat intake as a risk factor for muscle mass loss.[36] Their results demonstrated an inverted U-shaped relationship between dietary fat intake and appendicular lean mass, with a turning point of 1.88 grams of fat per kilogram of body weight per day. Below this threshold, muscle mass increased with rising fat intake. However, beyond this point, muscle mass declined sharply despite continued increases in fat consumption. Our findings align with this model, as 68.8% of participants (326 out of 474) in the present study had fat intakes below this 1.88 g/kg/day threshold. This suggests that for a significant majority of our participants, fat intake was within a range where its increase could be positively associated with muscle mass, supporting the concept that maintaining adequate, but not excessive, fat intake is crucial for muscle health. Evidence from a longitudinal study conducted in Japan indicated that the dietary intake of short-chain fatty acids may help prevent muscle strength decline in community-dwelling older adults.[37] Multiple studies have highlighted the beneficial effects of omega-3 fatty acids and the ratio of unsaturated to saturated fats on muscle health.[38-40] Potential mechanisms may be related to the role of fat in the synthesis of steroid hormones, including testosterone,[41] which is essential for muscle maintenance and growth.[42] These findings collectively underscore the importance of balanced and qualitative fat intake for maintaining muscle function and preventing age-related muscle loss.

Investigations into the connection between carbohydrate intake and body muscle mass remain limited, with findings often presenting inconsistencies. Some studies suggest that diets low in carbohydrates and high in protein,[43] as well as a reduced ratio of carbohydrates to protein in the diet, may help preserve lean muscle mass.[44] Conversely, a cross-sectional analysis of Korean individuals conducted between 2008 and 2011 revealed that higher proportion of carbohydrate intake was associated with increased total limb lean mass and the skeletal muscle mass index.[45] In the present study, however, we observed an inverse relationship between the proportion of carbohydrate intake and muscle-related indicators, including soft lean mass and skeletal muscle index. Although a low-carbohydrate diet seemed beneficial for muscle mass enhancement in this context, excessively restricting carbohydrates might pose health risks. Such dietary patterns often include elevated levels of animal-derived fats or proteins,[46] potentially leading to reduced fiber consumption, which could impair bowel function[47] and disrupt gut microbiota balance.[48] Therefore, further research is necessary to explore how variations in macronutrients composition influence body muscle mass among Chinese adults.

This study had certain limitations that warrant acknowledgment. First, the sample size was uneven, with female participants outnumbering males by approximately four times. This substantial imbalance may mask potential sex-specific associations between macronutrients intake and body composition. Given the well-established physiological differences in body fat distribution, hormonal profiles, and metabolic responses to dietary components between sexes, stratified analyses by sex might reveal distinct relationship patterns that were not detectable in our overall analysis. Future studies with larger and more balanced samples are warranted to explore whether the observed associations differ between male and female college students. Second, the prevalence of overweight individuals differed substantially between sexes, with rates of 40.4% among males and 18.7% among females. According to Zhao et al.,[49] a 10% increase in BMI corresponded to an additional dietary energy intake of 0.002–0.004 kcal/d, which may partly explain greater statistical significance observed among male participants. Although sex was incorporated as a confounding factor in the regression models, its potential impact on the results cannot be fully disregarded. Third, simultaneous variations in nutrient proportions might influence body composition. For instance, in this study, a reduced proportion of carbohydrate intake coincided with an increased proportion of protein intake, which may independently enhance satiety, decrease total energy intake, and positively affect body composition.[50] Additional research is warranted to elucidate the relationship between nutrient proportions and their combined effects on body composition. Future studies employing controlled feeding trials or comparing specific dietary patterns, such as time-restricted eating, may help establish causality and explore practical interventions for improving body composition in college students.[51] The associations observed in our study highlight the role of habitual macronutrients balance in shaping body composition in young adults. Future research should explore whether these relationships hold in populations with distinct metabolic or neuromuscular conditions, where nutrient requirements and body composition dynamics differ fundamentally. For instance, in spinal muscular atrophy, serum copper concentration has been identified as a significant correlate of increased adiposity and reduced muscularity.[52] Investigating interactions between macronutrients intake, trace element status, and body composition in such groups could yield insights for targeted nutritional strategies.

Conclusion

Obesity and muscle-related indicators were found to be negatively correlated with the proportion of protein intake, while positively correlated with the proportion of fat intake. In the adjusted models, all body composition parameters, except for waist-hip ratio, exhibited a negative correlation with the proportion of carbohydrate intake. A reduced risk of overweight and obesity was associated with a higher proportion of protein intake and a lower proportion of fat intake. Additional research is warranted to elucidate the relationship between body muscle mass, fat mass and macronutrients intake composition among Chinese adults.

ACKNOWLEDGEMENTS

The authors thank Mr. Endi Hodaj for his professional assistance in revising the language of this paper.

DISCLOSURE ON THE USE OF AI AND AI-ASSISTED TECHNOLOGIES

No AI or AI-assisted technologies were used in the preparation of this manuscript. The authors reviewed and edited the content and takes full responsibility for the content of the publication.

CONFLICT OF INTEREST AND FUNDING DISCLOSURES

The authors declare no conflict of interest.

This research was supported by National Natural Science Foundation of China (No.82273620, and No.82003459).

REFERENCES

1. Ellis KJ. Human body composition: in vivo methods. Physiol Rev. 2000; 80:649-80. doi: 10.1152/physrev.2000.80.2.649.
2. Chen Y, He D, Yang T et al. Relationship between body composition indicators and risk of type 2 diabetes mellitus in chinese adults. BMC Public Health. 2020; 20:452. doi: 10.1186/s12889-020-08552-5.
3. de Koning L, Merchant AT, Pogue J, Anand SS. Waist circumference and waist-to-hip ratio as predictors of cardiovascular events: meta-regression analysis of prospective studies. Eur Heart J. 2007; 28:850-56. doi: 10.1093/eurheartj/ehm026.
4. Al-Sofiani ME, Ganji SS, Kalyani RR. Body composition changes in diabetes and aging. J Diabetes Complications. 2019; 33:451-59. doi: 10.1016/j.jdiacomp.2019.03.007.
5. Wilson PWF, Kannel WB. Obesity, diabetes, and risk of cardiovascular disease in the elderly. Am J Geriatr Cardiol. 2002; 11:119-23, 125. doi: 10.1111/j.1076-7460.2002.00998.x.
6. JafariNasabian P, Inglis JE, Reilly W, Kelly OJ, Ilich JZ. Aging human body: changes in bone, muscle and body fat with consequent changes in nutrient intake. J Endocrinol. 2017; 234:R37-51. doi: 10.1530/JOE-16-0603.
7. Sievenpiper JL. Low-carbohydrate diets and cardiometabolic health: the importance of carbohydrate quality over quantity. Nutr Rev. 2020; 78:69-77. doi: 10.1093/nutrit/nuz082.
8. Kahleova H, Hlozkova A, Fleeman R, Fletcher K, Holubkov R, Barnard ND. Fat quantity and quality, as part of a low-fat, vegan diet, are associated with changes in body composition, insulin resistance, and insulin secretion. A 16-week randomized controlled trial. Nutrients. 2019; 11:615. doi: 10.3390/nu11030615.
9. Teske JA, Billington CJ, Kotz CM. Neuropeptidergic mediators of spontaneous physical activity and non-exercise activity thermogenesis. Neuroendocrinology. 2008; 87:71-90. doi: 10.1159/000110802.
10. Ramirez-Contreras C, Farran-Codina A, Izquierdo-Pulido M, Zeron-Rugerio MF. A higher dietary restraint is associated with higher BMI: a cross-sectional study in college students. Physiol Behav. 2021; 240:113536. doi: 10.1016/j.physbeh.2021.113536.
11. Zhao D, Gong Y, Huang L et al. Validity of food and nutrient intakes assessed by a food frequency questionnaire among chinese adults. Nutr J. 2024; 23:23. doi: 10.1186/s12937-024-00921-9.
12. Mu M, Wang S, Sheng J et al. Dietary patterns are associated with body mass index and bone mineral density in chinese freshmen. J Am Coll Nutr. 2014; 33:120-28. doi: 10.1080/07315724.2013.874897.
13. Song P, Li X, Bu Y et al. Temporal trends in normal weight central obesity and its associations with cardiometabolic risk among chinese adults. Sci Rep. 2019; 9:5411. doi: 10.1038/s41598-019-41986-5.
14. Liang X, Chen X, Li J, Yan M, Yang Y. Study on body composition and its correlation with obesity: a cohort study in 5121 chinese han participants. Medicine (Baltimore). 2018; 97:e10722. doi: 10.1097/MD.0000000000010722.
15. Lee K. Muscle mass and body fat in relation to cardiovascular risk estimation and lipid-lowering eligibility. J Clin Densitom. 2017; 20:247-55. doi: 10.1016/j.jocd.2016.07.009.
16. Tyrovolas S, Panagiotakos D, Georgousopoulou E et al. Skeletal muscle mass in relation to 10 year cardiovascular disease incidence among middle aged and older adults: the ATTICA study. J Epidemiol Community Health. 2020; 74:26-31. doi: 10.1136/jech-2019-212268.
17. Nordstrom A, Hadrevi J, Olsson T, Franks PW, Nordstrom P. Higher prevalence of type 2 diabetes in men than in women is associated with differences in visceral fat mass. J Clin Endocrinol Metab. 2016; 101:3740-6. doi: 10.1210/jc.2016-1915.
18. Liu J, Fox CS, Hickson DA et al. Impact of abdominal visceral and subcutaneous adipose tissue on cardiometabolic risk factors: the jackson heart study. J Clin Endocrinol Metab. 2010; 95:5419-26. doi: 10.1210/jc.2010-1378.
19. Brown AF, Prado CM, Ghosh S et al. Higher-protein intake and physical activity are associated with healthier body composition and cardiometabolic health in hispanic adults. Clin Nutr ESPEN. 2019; 30:145-51. doi: 10.1016/j.clnesp.2019.01.002.
20. Farnsworth E, Luscombe ND, Noakes M, Wittert G, Argyiou E, Clifton PM. Effect of a high-protein, energy-restricted diet on body composition, glycemic control, and lipid concentrations in overweight and obese hyperinsulinemic men and women. Am J Clin Nutr. 2003; 78:31-39. doi: 10.1093/ajcn/78.1.31.
21. Longland TM, Oikawa SY, Mitchell CJ, Devries MC, Phillips SM. Higher compared with lower dietary protein during an energy deficit combined with intense exercise promotes greater lean mass gain and fat mass loss: a randomized trial. Am J Clin Nutr. 2016; 103:738-46. doi: 10.3945/ajcn.115.119339.
22. Clifton PM, Bastiaans K, Keogh JB. High protein diets decrease total and abdominal fat and improve CVD risk profile in overweight and obese men and women with elevated triacylglycerol. Nutr Metab Cardiovasc Dis. 2009; 19:548-54. doi: 10.1016/j.numecd.2008.10.006.
23. Westerterp-Plantenga MS, Nieuwenhuizen A, Tome D, Soenen S, Westerterp KR. Dietary protein, weight loss, and weight maintenance. Annu Rev Nutr. 2009; 29:21-41. doi: 10.1146/annurev-nutr-080508-141056.
24. Tagawa R, Watanabe D, Ito K, Ueda K, Nakayama K, Sanbongi C, et al. Dose-response relationship between protein intake and muscle mass increase: a systematic review and meta-analysis of randomized controlled trials. Nutr Rev. 2020; 79:66-75. doi: 10.1093/nutrit/nuaa104.
25. Areta JL, Burke LM, Camera DM et al. Reduced resting skeletal muscle protein synthesis is rescued by resistance exercise and protein ingestion following short-term energy deficit. Am J Physiol Endocrinol Metab. 2014; 306:E989-97. doi: 10.1152/ajpendo.00590.2013.
26. Hector AJ, McGlory C, Damas F, Mazara N, Baker SK, Phillips SM. Pronounced energy restriction with elevated protein intake results in no change in proteolysis and reductions in skeletal muscle protein synthesis that are mitigated by resistance exercise. Faseb J. 2018; 32:265-75. doi: 10.1096/fj.201700158RR.
27. Josse AR, Atkinson SA, Tarnopolsky MA, Phillips SM. Increased consumption of dairy foods and protein during diet- and exercise-induced weight loss promotes fat mass

loss and lean mass gain in overweight and obese premenopausal women. J Nutr. 2011; 141:1626-34. doi: 10.3945/jn.111.141028.
28. Leidy HJ, Carnell NS, Mattes RD, Campbell WW. Higher protein intake preserves lean mass and satiety with weight loss in pre-obese and obese women. Obesity (Silver Spring). 2007; 15:421-29. doi: 10.1038/oby.2007.531.
29. Patel PA, Patel PP, Chiplonkar SA, Patel AD, Khadilkar AV. Association of body fat with stress levels and dietary intakes in indian women. Women Health. 2019; 59:591-600. doi: 10.1080/03630242.2018.1539429.
30. Ge L, Sadeghirad B, Ball GDC et al. Comparison of dietary macronutrient patterns of 14 popular named dietary programmes for weight and cardiovascular risk factor reduction in adults: systematic review and network meta-analysis of randomised trials. Bmj. 2020; 369:m696. doi: 10.1136/bmj.m696.
31. Hall KD, Bemis T, Brychta R et al. Calorie for calorie, dietary fat restriction results in more body fat loss than carbohydrate restriction in people with obesity. Cell Metab. 2015; 22:427-36. doi: 10.1016/j.cmet.2015.07.021.
32. Yuan X, Ouyang Y, Wei Y et al. [Relationship between the percentage of energy intake from macronutrients and obesity among adult residents in 15 provinces of china in 1991-2018]. Wei Sheng Yan Jiu. 2024; 53:189-208. doi: 10.19813/j.cnki.weishengyanjiu.2024.02.003. (in Chinese)
33. Lim H, Ji S, Hwang H et al. Relationship between bone density, eating habit, and nutritional intake in college students. J Bone Metab. 2018; 25:181-6. doi: 10.11005/jbm.2018.25.3.181.
34. Leaf A, Rothschild JA, Sharpe TM et al. International society of sports nutrition position stand: ketogenic diets. J Int Soc Sports Nutr. 2024; 21:2368167. doi: 10.1080/15502783.2024.2368167.
35. Li D. Is it really good for you to eat fat as much as you could? Science China. Life Sciences. 2018; 61:363-4. doi: 10.1007/s11427-017-9194-3.
36. Wang S, Zhang Y, Zhang D, Wang F, Wei W, Wang Q, et al. Association of dietary fat intake with skeletal muscle mass and muscle strength in adults aged 20-59: NHANES 2011-2014. Front Nutr. 2023; 10:1325821. doi: 10.3389/fnut.2023.1325821.
37. Otsuka R, Zhang S, Furuya K et al. Association between short-chain fatty acid intake and development of muscle strength loss among community-dwelling older japanese adults. Exp Gerontol. 2023; 173:112080. doi: 10.1016/j.exger.2023.112080.
38. Ganapathy A, Nieves JW. Nutrition and sarcopenia-what do we know? Nutrients. 2020; 12:1775. doi: 10.3390/nu12061755.
39. Okamura T, Hashimoto Y, Miki A et al. Reduced dietary omega-3 fatty acids intake is associated with sarcopenia in elderly patients with type 2 diabetes: a cross-sectional study of KAMOGAWA-DM cohort study. J Clin Biochem Nutr. 2020; 66:233-37. doi: 10.3164/jcbn.19-85.
40. Therdyothin A, Phiphopthatsanee N, Isanejad M. The effect of omega-3 fatty acids on sarcopenia: mechanism of action and potential efficacy. Mar Drugs. 2023; 21:399. doi: 10.3390/md21070399.
41. Whittaker J, Wu K. Low-fat diets and testosterone in men: systematic review and meta-analysis of intervention studies. J Steroid Biochem Mol Biol. 2021; 210:105878. doi: 10.1016/j.jsbmb.2021.105878.
42. Mauvais-Jarvis F, Lindsey SH. Metabolic benefits afforded by estradiol and testosterone in both sexes: clinical considerations. J. Clin. Invest.. 2024; 134:e180073. doi: 10.1172/JCI180073.
43. Layman DK, Evans EM, Erickson D et al. A moderate-protein diet produces sustained weight loss and long-term changes in body composition and blood lipids in obese adults. J Nutr. 2009; 139:514-21. doi: 10.3945/jn.108.099440.
44. Layman DK, Boileau RA, Erickson DJ et al. A reduced ratio of dietary carbohydrate to protein improves body composition and blood lipid profiles during weight loss in adult women. J Nutr. 2003; 133:411-7. doi: 10.1093/jn/133.2.411.
45. Kim HN, Song SW. Association between carbohydrate intake and body composition: the korean national health and nutrition examination survey. Nutrition. 2019; 61:187-93. doi: 10.1016/j.nut.2018.11.011.
46. Lagiou P, Sandin S, Lof M, Trichopoulos D, Adami H, Weiderpass E. Low carbohydrate-high protein diet and incidence of cardiovascular diseases in swedish women: prospective cohort study. Bmj. 2012; 344:e4026. doi: 10.1136/bmj.e4026.
47. Brinkworth GD, Noakes M, Clifton PM, Bird AR. Comparative effects of very low-carbohydrate, high-fat and high-carbohydrate, low-fat weight-loss diets on bowel habit and faecal short-chain fatty acids and bacterial populations. Br J Nutr. 2009; 101:1493-502. doi: 10.1017/S0007114508094658.
48. Cani PD, Bibiloni R, Knauf C et al. Changes in gut microbiota control metabolic endotoxemia-induced inflammation in high-fat diet-induced obesity and diabetes in mice. Diabetes. 2008; 57:1470-81. doi: 10.2337/db07-1403.
49. Zhao J, Sun J, Su C. Gender differences in the relationship between dietary energy and macronutrients intake and body weight outcomes in chinese adults. Nutr J. 2020; 19:45. doi: 10.1186/s12937-020-00564-6.
50. Leidy HJ, Clifton PM, Astrup A et al. The role of protein in weight loss and maintenance. Am J Clin Nutr. 2015; 101:1320S-9S. doi: 10.3945/ajcn.114.084038.
51. Yüzbaşıoğlu M, Özder A. Comparison of time-restricted eating and a six-meal diet: effects on body composition and biochemical parameters. Asia Pac J Clin Nutr. 2025; 34:589-95. doi: 10.6133/apjcn.202508_34(4).0010.
52. Long Q, Feng Y, Yu Y, Chen F, Ma M, Mao S. Association between serum copper concentration and body composition in children with spinal muscular atrophy: a cross-sectional study. Asia Pac J Clin Nutr. 2025; 34:84-90. doi: 10.6133/apjcn.202502_34(1).0008.