Original Article

# Dietary assessment from inflammation and gut microbiota perspectives in urban Chinese adults aged 40-69 years: Association with chronic diseases

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**Background and Objectives:** Current evidence suggests that gut microbiota dysbiosis accelerates aging and aging-related diseases through pro-inflammatory pathways. This study aimed to evaluate dietary quality in relation to inflammation and gut microbiota, and to explore their relationship with chronic diseases among urban Chinese adults aged 40-69 years. **Methods and Study Design:** A cross-sectional study was conducted among urban Chinese adults aged 40-69 years. Dietary quality was assessed by dietary intake, dietary inflammation index (DII), and dietary index for gut microbiota (DI-GM). Log-binomial regression was performed to examine the associations between DII, DI-GM and chronic diseases. **Results:** An excessive energy proportion from fat (37.4%) and an insufficient contribution from carbohydrates (44.7%) indicated an imbalance in macronutrient intake. The medians and interquartile ranges for DII and DI-GM of the participants were 1.3 (0.2, 2.5) and 3.0 (2.0,5.0), respectively, suggesting a pro-inflammatory and gut microbiota-unfavorable dietary tendency. Livestock contributed most to dietary inflammation in the population (standardized $\beta = 0.251$), whereas vegetables showed the strongest inverse effect (standardized $\beta = -0.500$). A higher DI-GM score was suggested to be a protective factor against self-reported dysglycemia (OR = 0.311; 95%CI: 0.118, 0.818). **Conclusions:** The participants exhibited an imbalance in macronutrient intake and a dietary tendency that was pro-inflammatory and unfavorable to gut microbiota. Notably, this study revealed a negative relationship between DI-GM and dysglycemia in middle-aged and elderly population, which underscores the potential of targeting gut microbiota through diet for chronic disease prevention in this population.

**Key Words: dietary inflammation index, dietary index for gut microbiota, chronic diseases, middle-aged and elderly, cross-sectional study**

## INTRODUCTION

In the past few decades, China has undergone dramatic demographic and epidemiological transitions, characterized by an aging population and a rising burden of chronic diseases.[1] The prevalence of chronic diseases continues to rise with the aging population and is becoming the leading contributor to the disease burden for individuals and society.[2,3] Furthermore, the aging process is often accompanied by chronic, low-grade systemic inflammation and gut microbiota dysbiosis, both of which have been demonstrated to influence the onset and progression of chronic diseases.[4,5] In this context, diet and nutrition have emerged as pivotal modifiable factors for healthy aging. Healthy dietary patterns have been shown to play a critical role in disease prevention and healthy aging, potentially by modulating systemic inflammation and gut microbiota.[6-8] Notably, around the age of 50, individuals undergo significant physiological and metabolic shifts that mark a transition in disease susceptibility and nutritional needs, and the recommended intakes alter at this age for energy and nutrients including vitamin D,

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calcium and sodium.[9-11] Moreover, epidemiological evidence suggests a trend toward earlier onset of chronic diseases, underscoring the importance of targeted dietary assessment in populations approaching or entering this pivotal life stage.[12,13]

The dietary inflammation index (DII) was developed based on a comprehensive literature review to reflect the overall inflammatory potential of the diet.[14] Previous studies have reported that a pro-inflammatory diet is associated with an increased risk of age-related adverse outcomes, including cardiovascular disease, frailty, and muscle loss.[15] Recently, Kase et al. developed a novel dietary index for gut microbiota (DI-GM) based on longitudinal evidence on the association between diet and gut microbiota, aiming to assess the dietary quality associated with gut microbiota profiles.[16] In subsequent analyses, DI-GM was found to be positively correlated with creatinine-adjusted enterodiol and enterolactone (markers of gut microbiota diversity), suggesting that this index could be effective in identifying dietary patterns that are either beneficial or detrimental to the gut microbiota. While the association between DI-GM and health outcomes has been analyzed in several studies among the U.S. population,[17-20] its application and association with health outcomes in the Chinese population remain entirely unexplored. Furthermore, although the general dietary challenges facing middle-aged and older adults are well-recognized, a comprehensive assessment that integrates both the inflammatory potential and gut microbiota-favorability of the diet, and their combined relationship with chronic diseases, is lacking.

This study aimed to comprehensively evaluate the dietary quality of Chinese adults aged 40-69 years from inflammation and gut microbiota perspectives. Furthermore, the associations between DII, DI-GM and age-related chronic diseases were explored within the total population.

## METHODS

### *Study design and participants*

A cross-sectional study was conducted among urban residents aged 40-69 years from 29 cities in China. The cities were strategically selected to ensure broad geographical coverage, encompassing four municipalities (Beijing, Shanghai, Tianjin, Chongqing) and 15 provinces (e.g., Guangdong, Sichuan, Jiangsu, Shanxi, Shandong, Hubei, etc.), representing diverse socioeconomic and dietary cultures. The inclusion criteria for participants were as follows: (1) Aged 40-69 years; (2) Sufficient literacy to complete dietary records using a mobile phone. Study data were collected from January 2 to February 27, 2024. A self-administered questionnaire was applied to collect demographic information, disease status and the use of nutritional supplements and fortified foods. The 24-hour dietary records were collected by a validated digital tool called the Eat-Right Assistant.[21] Participants were fully trained prior to the start of the study to ensure that they were able to complete the meal records independently. To facilitate the estimation of food portions, each participant was provided with standardized portion-estimation aids (e.g., artificial food models, photo booklets, and grid-marked placemats). The survey team performed daily quality assurance checks on the dietary records. In cases of aberrant food intake values, follow-up telephone interviews were conducted. To ensure the data quality, all the questionnaire responses and dietary records were scrutinized upon completion of data collection. Ultimately, 300 urban residents with complete data were included in the statistical analysis.

The study adhered to the guidelines outlined in the Declaration of Helsinki and received approval from the Ethics Committee of Capital Medical University (Z2024SY053). Informed consent was obtained from all subjects involved in the study.

### *Dietary intake assessment*

The total daily intake of each food item was summarized after converting the food items to their normal state weight (i.e., 100% edible portion). In addition, total energy and nutrient intake was calculated based on the Chinese Food Composition Table (6th Edition).[22,23] We further calculated the contribution of various food groups to total energy and nutrient intake, as well as the proportion of energy derived from carbohydrates, fat, and protein.

### *Calculation of DII*

The DII was used to assess the inflammatory potential of the diet according to Shivappa et al.[14] 23 out of the 45 food parameters in the original DII were used in this study, including seven pro-inflammatory parameters (energy, carbohydrate, protein, total fat, saturated fatty acids (SFAs), iron (Fe) and cholesterol) and 16 anti-inflammatory parameters (monounsaturated fatty acids (MUFAs), polyunsaturated fatty acids (PUFAs), fiber, magnesium (Mg), niacin, thiamine, riboflavin, vitamin A, vitamin C, vitamin E, β-carotene, zinc (Zn), selenium, anthocyanin, isoflavones and alcohol intake (g). To minimize potential bias from different energy intake, the energy-adjusted DII was calculated according to established methods.[24] A positive DII score ($DII > 0$) indicates a pro-inflammatory diet, whereas a negative value ($DII < 0$) indicates an anti-inflammatory diet.

### *Calculation of DI-GM*

The DI-GM was determined based on the scoring criteria proposed by Kase et al.,[16] and 14 foods or nutrients constitute the DI-GM components, with avocados, broccoli, chickpeas, coffee, cranberries, fermented dairy, fiber, green tea, soybean, and whole grains being beneficial components, whereas red meat, processed meat, refined grains, and high-fat diet (≥40% of total energy from fat) are considered unfavorable factors. Based on the foods consumed by the participants, 11 out of the 14 original DI-GM components were applicable: seven beneficial components (avocados, broccoli, coffee, fermented dairy, fiber, soybean and whole grains) and four unfavorable components (red meat, processed meat, refined grains, and high-fat diet). A score of 1 was assigned for participants who consumed above the sex-specific median for each beneficial component and for participants who consumed below the sex-specific median for each unfavorable component. A score of 0 was assigned for consumption below the sex-specific median for a beneficial component or above the sex-specific median for an unfavorable component. The scores for each component were summed to obtain the overall DI-GM score. The details of each components and scoring criteria used in this study can be seen in Supplementary Table 1.

### *Statistical analysis*

Continuous variables are expressed as median and interquartile range (IQR), and Wilcoxon rank sum test was used to compare subgroup differences. Categorical data are expressed as number (%), and subgroup differences were analyzed using the Chi-square test. Multivariate linear regression was used to analyze the relative contribution of food groups to DII score among the population, along with a subgroup analysis in two age groups. Log-binomial regression models were performed to examine the associations between DII, DI-GM and the risk of chronic diseases. Subgroup analysis was conducted to address potential effect modification by gender. Statistical significance was defined as a two-sided $p < 0.05$. All statistical analyses were performed using IBM SPSS Statistics 25.0 (IBM Corp., Armonk, New York, USA).

## RESULTS

### *Basic characteristics of the population*

This study included 300 participants (75 men, 225 women), aged 40 to 69 years. Among them, 177 (59.0%) were under 50 years old, while 123 (41.0%) were aged 50 or older (Table 1).

### *Dietary intake of the study population*

Nutrient source analysis demonstrated that cereals (30.7%) and livestock products (13.2%) were the primary contributors to energy intake (Table 2). Compared to Dietary Reference Intakes for Chinese Residents (2023), the study population exhibited an excessively high proportion of energy derived from fat (37.4%), coupled with an insufficient contribution from carbohydrates (44.7%), indicating a dietary imbalance in macronutrient distribution (Table 2). Protein intake was predominantly derived from animal-based sources (61.0%), with high-quality protein accounting for a greater proportion (68.8%) compared to non-high-quality protein (31.2%) (Table 2). Further analysis of specific nutrients showed that cereals (22.4%) and vegetables (16.2%) were the main sources of dietary

**Table 1.** Basic characteristics stratified by age groups

| Characteristics | Total population (n = 300) | Age <50 (n = 177) | Age ≥50 (n = 123) | *p* |
|---|---|---|---|---|
| Gender, n (%) | | | | 0.946 |
| Man | 75 (25.0) | 44 (24.9) | 31 (25.2) | |
| Woman | 225 (75.0) | 133 (75.1) | 92 (74.8) | |
| Education level, n (%) | | | | |
| Junior high school and below | 13 (4.3) | 4 (2.3) | 9 (7.3) | <0.001*** |
| High school/technical school/secondary school | 90 (30.0) | 25 (14.1) | 65 (52.8) | |
| College or above | 197 (65.7) | 148 (83.6) | 49 (39.8) | |
| Household income (CNY), n (%) | | | | <0.001*** |
| <10, 000 | 17 (5.7) | - | 17 (13.8) | |
| 10, 000-19, 999 | 178 (59.3) | 104 (58.8) | 74 (60.2) | |
| 20, 000-29, 999 | 83 (27.7) | 53 (29.9) | 30 (24.4) | |
| ⩾30, 000 | 22 (7.3) | 20 (11.3) | 2 (1.6) | |
| City classification[†], n (%) | | | | 0.012* |
| First-tier cities | 25 (8.3) | 18 (10.2) | 7 (5.7) | |
| New first-tier cities | 43 (14.3) | 16 (9.0) | 27 (22.0) | |
| Second-tier cities | 120 (40.0) | 73 (41.2) | 47 (38.2) | |
| Third-tier cities and below | 112 (37.3) | 70 (39.5) | 42 (34.1) | |
| Residence status, n (%) | | | | <0.001*** |
| Living alone or with partner | 131 (43.7) | 50 (28.2) | 81 (65.9) | |
| Living with children | 169 (56.3) | 127 (71.8) | 42 (34.1) | |
| Use of nutritional supplements and fortified foods, n (%) | | | | 0.012* |
| No | 57 (19.0) | 42 (23.7) | 15 (12.2) | |
| Yes | 243 (81.0) | 135 (76.3) | 108 (87.8) | |
| Dysglycemia, n (%) | | | | 0.033* |
| No | 257 (85.7) | 158 (89.3) | 99 (80.5) | |
| Yes | 43 (14.3) | 19 (10.7) | 24 (19.5) | |
| Hypertension, n (%) | | | | 0.647 |
| No | 238 (79.3) | 142 (80.2) | 96 (78.0) | |
| Yes | 62 (20.7) | 35 (19.8) | 27 (22.0) | |
| Dyslipidemia, n (%) | | | | 0.155 |
| No | 272 (90.7) | 164 (92.7) | 108 (87.8) | |
| Yes | 28 (9.3) | 13 (7.3) | 15 (12.2) | |

[†] City classification was based on the “2022 City Commercial Appeal Rankings”. Specifically, first-tier cities include Beijing, Shanghai, Guangzhou, and Shenzhen; New first-tier cities are cities that approach first-tier cities in one or more aspects (e.g., Chengdu, Chongqing, Hangzhou); Second-tier cities are cities with strong economic vitality (e.g., Kunming, Jinan, Shenyang).

*$p$ <0.05, **$p$ <0.01, ***$p$ <0.001.

**Table 2.** Food sources of energy and nutrients in the study population

| | Total population, Median (IQR) | Age <50, Median (IQR) | Age ≥50, Median (IQR) | $p$ |
|---|---|---|---|---|
| Food sources of energy | | | | |
| Cereals (%) | 30.7 (17.8, 46.0) | 32.6 (19.0, 48.0) | 29.6 (16.6, 42.6) | 0.309 |
| Livestock (%) | 13.2 (2.1, 24.8) | 14.1 (3.2, 25.3) | 11.0 (1.5, 22.0) | 0.183 |
| Eggs (%) | 4.7 (0.0, 7.9) | 3.8 (0.0, 7.4) | 5.4 (2.2, 9.0) | 0.005** |
| Milk & Dairy products (%) | 6.3 (0.0, 11.1) | 5.8 (0.0, 11.1) | 6.5 (0.0, 11.0) | 0.826 |
| Vegetables (%) | 3.0 (1.6, 4.9) | 2.9 (1.6, 4.4) | 3.3 (1.6, 5.4) | 0.130 |
| Oils & Fats (%) | 9.2 (5.1, 15.4) | 8.5 (4.7, 14.9) | 10.0 (5.4, 16.1) | 0.220 |
| Others (%) | 20.9 (8.3, 34.6) | 18.8 (9.1, 34.8) | 21.7 (7.6, 33.9) | 0.971 |
| Nutrient sources of energy | | | | |
| Carbohydrate (%) | 44.7 (33.4, 53.4) | 45.7 (32.8, 55.2) | 43.8 (34.1, 50.5) | 0.304 |
| Fat (%) | 37.4 (30.1, 45.3) | 37.2 (28.8, 44.8) | 37.7 (32.9, 45.8) | 0.230 |
| Protein (%) | 17.9 (15.0, 20.8) | 17.9 (15.1, 20.8) | 17.8 (14.8, 21.0) | 0.956 |
| Food sources of protein | | | | |
| Animal-based foods (%) | 61.0 (43.8, 73.0) | 61.8 (45.0, 74.1) | 59.8 (42.7, 71.7) | 0.414 |
| Plant-based foods (%) | 39.0 (27.0, 56.2) | 38.2 (25.9,55.0) | 40.2 (28.6, 56.8) | 0.414 |
| High-quality protein/ Non-high-quality protein | 3.1 | 3.2 | 2.8 | 0.341 |
| High quality protein (%) † | 68.8 (55.8, 79.9) | 68.6 (57.0, 80.8) | 69.0 (54.6, 76.7) | 0.461 |
| Non-high-quality protein (%) ‡ | 31.2 (20.1, 44.2) | 31.4 (19.2, 43.0) | 31.0 (23.3, 45.4) | 0.461 |
| Food sources of carbohydrates | | | | |
| Animal-based food (%) | 6.1 (2.0, 11.6) | 6.3 (1.8, 11.6) | 5.9 (2.1, 11.7) | 0.737 |
| Cereals (%) | 61.6 (40.3, 77.6) | 62.7 (41.3, 81.4) | 59.6 (39.3, 72.9) | 0.296 |
| Vegetables (%) | 5.1 (2.7, 9.7) | 4.8 (2.6, 8.1) | 5.8 (2.7, 11.0) | 0.144 |
| Snacks & Sweets & Fast foods (%) | 0 (0, 23.2) | 0 (0, 25.6) | 0 (0, 22.6) | 0.600 |
| Others (%) | 8.9 (0.9, 19.4) | 8.3 (0.1, 17.5) | 10.5 (2.1, 21.7) | 0.083 |
| Food sources of fat | | | | |
| Plant-based foods (%) | 46.7 (31.2, 60.4) | 45.5 (31.1, 58.2) | 49.3 (31.9, 62.2) | 0.207 |
| Animal-based foods (%) | 53.3 (39.6, 68.8) | 54.5 (41.8, 68.9) | 50.7 (37.8, 68.1) | 0.207 |
| Saturated fatty acids /Unsaturated fatty acids | 0.8 | 0.8 | 0.8 | 0.805 |
| Saturated fatty acids (%) | 43.9 (38.7, 46.8) | 43.5 (39.4, 46.4) | 44.6 (38.2, 47.6) | 0.661 |
| Unsaturated fatty acids (%) | 54.3 (51.1, 59.9) | 54.6 (51.7, 58.8) | 53.3 (50.7, 60.5) | 0.561 |
| Food sources of dietary fiber | | | | |
| Cereals (%) | 22.4 (9.1, 51.4) | 26.6 (9.9, 53.2) | 19.4 (8.2, 50.3) | 0.377 |
| Potatoes & Legumes (%) | 5.2 (0.0, 16.8) | 3.8 (0.0, 51.8) | 7.9 (0.0, 57.2) | 0.340 |
| Vegetables (%) | 16.2 (5.7, 36.2) | 16.6 (5.7, 34.4) | 14.3 (5.8, 38.3) | 0.854 |
| Others (%) | 10.6 (0.0, 34.2) | 9.3 (0.0, 36.4) | 10.7 (0.0, 31.8) | 0.718 |
| Food sources of calcium | | | | |
| Cereals (%) | 6.0 (2.5, 12.1) | 6.0 (2.4, 12.4) | 6.1 (2.6, 11.0) | 0.474 |
| Vegetables (%) | 22.1 (11.4, 33.7) | 21.8 (11.6, 32.7) | 22.8 (11.1, 33.9) | 0.714 |
| Livestock & Poultry (%) | 2.1 (0.6, 4.2) | 2.4 (0.9, 4.5) | 1.6 (0.4, 3.2) | 0.045* |
| Eggs (%) | 4.5 (0.0, 8.7) | 4.0 (0.0, 7.5) | 4.9 (2.5, 10.3) | 0.022* |
| Milk & Dairy products (%) | 28.3 (0.0, 47.8) | 28.9 (0.0, 48.0) | 27.0 (0.0, 47.4) | 0.938 |
| Others (%) | 20.0 (6.3, 43.5) | 20.6 (6.2, 43.5) | 17.9 (6.4, 46.8) | 0.852 |

IQR: interquartile range.

†High-quality protein sources: eggs, poultry and livestock, aquatic products, milk and dairy products, soybean and soy products.

‡Non-high-quality protein sources: plant-based foods other than soybean and soy products.

*$p$ <0.05, **$p$ <0.01

fiber, while milk (28.3%) and vegetables (22.1%) provided the majority of calcium intake (Table 2).

### *DII and DI-GM of the study population*

DII and DI-GM were used to evaluate dietary quality regarding inflammation and gut microbiota, respectively (Table 3). The DII scores of the study population ranged from -3 to 4.3, with a median (IQR) of 1.3 (0.2, 2.5), indicating a pro-inflammatory dietary tendency. The DI-GM scores ranged from 0 to 7, with a median (IQR) of 3.0 (2.0, 5.0). Given that the maximum possible DI-GM score is 11 in this study population, the observed score suggests an overall low level, inferring a dietary performance unfavorable to gut microbiota.

### *Contribution of different food groups to DII*

General linear models were employed to evaluate the contribution of food group consumption to DII score, with standardized $\beta$ coefficients representing the relative contributions (Table 4). The food groups most strongly associated with lower DII score were, in order of effect magnitude: vegetables (standardized $\beta$ = -0.500), soybeans & nuts (standardized $\beta$ = -0.319), and fruits (standardized $\beta$ = -0.164). Conversely, the food groups most strongly associated with higher DII score were: livestock products (standardized $\beta$ = 0.251), snacks & sweets (standardized $\beta$ = 0.143), and poultry (standardized $\beta$ = 0.113).

**Table 3.** DII and DI-GM scores of the participants

| Dietary indices | Total population | | | Age <50 | | | Age ≥50 | | | $p$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | Minimum | Maximum | Median (IQR) | Minimum | Maximum | Median (IQR) | Minimum | Maximum | Median (IQR) | |
| DII score | -3.6 | 4.3 | 1.3 (0.2, 2.5) | -1.8 | 3.8 | 1.4 (0.4, 2.6) | -3.6 | 4.3 | 1.1 (-0.3, 2.5) | 0.071 |
| DI-GM score | 0.0 | 7.0 | 3.0 (2.0, 5.0) | 0.0 | 7 | 3.0 (2.0, 4.0) | 1.0 | 6.0 | 4.0 (3.0, 5.0) | 0.053 |

IQR: interquartile range; DII, dietary inflammation index; DI-GM, dietary index for gut microbiota.
The Wilcoxon rank sum test was used to compare the differences in DII score and DI-GM score between the two age groups.

**Table 4.** Contribution of different food groups to DII among the participants

| Food groups | Total population | | Age <50 | | Age ≥50 | |
|---|---|---|---|---|---|---|
| | Standardized β[†] | $p$ | Standardized β[†] | $p$ | Standardized β[†] | $p$ |
| Refined grains | 0.083 | 0.068 | 0.076 | 0.220 | 0.048 | 0.487 |
| Whole grains | -0.021 | 0.646 | -0.053 | 0.387 | 0.043 | 0.532 |
| Vegetables | -0.500 | <0.001*** | -0.480 | <0.001*** | -0.513 | <0.001*** |
| Fruits | -0.164 | <0.001*** | -0.225 | <0.001*** | -0.101 | 0.145 |
| Soybeans & Nuts | -0.319 | <0.001*** | -0.373 | <0.001*** | -0.265 | <0.001*** |
| Livestock | 0.251 | <0.001*** | 0.231 | <0.001*** | 0.298 | <0.001*** |
| Poultry | 0.113 | 0.013* | 0.103 | 0.092 | 0.115 | 0.116 |
| Aquatic products | -0.069 | 0.128 | 0.018 | 0.772 | -0.129 | 0.071 |
| Eggs | 0.001 | 0.984 | 0.033 | 0.595 | -0.015 | 0.826 |
| Milk & Dairy products | 0.064 | 0.157 | 0.038 | 0.543 | 0.080 | 0.245 |
| Snacks & Sweets | 0.143 | 0.002** | 0.232 | <0.001*** | 0.059 | 0.402 |
| Oils & Fats | 0.065 | 0.155 | 0.039 | 0.527 | 0.123 | 0.103 |
| Beverages | 0.062 | 0.163 | -0.022 | 0.719 | 0.142 | 0.042* |

DII, dietary inflammation index.
[†] Standardized beta coefficients (standardized β) are presented to compare the relative contributions of food groups to DII.
*$p$ <0.05, **$p$ <0.01, ***$p$ <0.001.

***The intake of DI-GM components among the study population***

As shown in Supplementary Table 2, dietary intake of DI-GM components was compared against sex-specific median. For gut microbiota-beneficial components, only a small proportion of participants (<10%) met the sex-specific median intake for most foods, except for fiber, soybeans, and whole grains. Regarding unfavorable components associated with lower DI-GM scores, refined grains and red meat were the primary contributors, with less than 50% of participants consuming amounts below the sex-specific median intake.

***The associations between DII, DI-GM and chronic diseases***

Logistic regression models were used to analyze the associations of DII and DI-GM with self-reported chronic disease outcomes (Table 5, Supplementary Table 3-4). No significant association was observed between either dietary index and hyperlipidemia or hypertension in this population (all $p$ > 0.05; Tables S3-S4). Notably, significant associations between dietary indices and dysglycemia were observed (Table 5). After full covariate adjustment, DI-GM was associated with a reduced risk of dysglycemia (OR = 0.726; 95% CI: 0.558, 0.944). Participants with higher DI-GM scores (≥5) showed substantially reduced dysglycemia risk compared to those with low scores (≤2) (OR = 0.311; 95% CI: 0.118, 0.818). Further analysis of dysglycemia risk revealed that a combined diet characterized by both lower DII (anti-inflammatory) and higher DI-GM (gut microbiota-friendly) was associated with enhanced protection (OR = 0.228; 95% CI: 0.056, 0.927).

***Subgroup analysis based on gender classification***

To address potential effect modification by gender, we performed stratified analyses based on gender classification. As shown in Supplementary Table 5, although the association between DI-GM and dysglycemia appeared stronger in males (OR = 0.484; 95% CI: 0.288, 0.816) compared with females (OR = 0.864; 95% CI: 0.620, 1.205), the interaction between gender and DI-GM was not statistically significant ($p$ for interaction > 0.05). This suggests that gender did not significantly modify the association between DI-GM and dysglycemia in this population. Additionally, no significant gender interactions were observed for the associations of DII or DI-GM with hypertension or dyslipidemia (all $p$ for interaction > 0.05).

## DISCUSSION

This cross-sectional study among urban Chinese adults aged 40-69 years revealed an imbalanced macronutrient intake, characterized by excessive fat and insufficient carbohydrates, alongside an overall pro-inflammatory and gut microbiota-unfavorable dietary tendency. We

**Table 5.** Associations between DII, DI-GM and dysglycemia

| | Model 1 | | Model 2 | | Model 3 | |
|---|---|---|---|---|---|---|
| | OR (95%CI) | $p$ | OR (95%CI) | $p$ | OR (95%CI) | $p$ |
| DII | | | | | | |
| Q1 | Ref. | Ref. | Ref. | Ref. | Ref. | Ref. |
| Q2 | 0.899 (0.339, 2.33) | 0.812 | 0.765 (0.281, 2.09) | 0.601 | 0.748 (0.273, 2.05) | 0.571 |
| Q3 | 0.764 (0.297, 1.96) | 0.576 | 0.699 (0.267, 1.83) | 0.466 | 0.699 (0.267, 1.83) | 0.466 |
| Q4 | 1.14 (0.463, 2.81) | 0.776 | 1.11 (0.466, 2.75) | 0.826 | 1.11 (0.447, 2.76) | 0.823 |
| DII continuous | 0.995 (0.789, 1.26) | 0.969 | 0.988 (0.779, 1.25) | 0.920 | 1.25 (0.488, 3.22) | 0.638 |
| DI-GM | | | | | | |
| ≤2 | Ref. | Ref. | Ref. | Ref. | Ref. | Ref. |
| 3 | 0.587 (0.244, 1.41) | 0.234 | 0.549 (0.222, 1.36) | 0.194 | 0.526 (0.211, 1.31) | 0.168 |
| 4 | 0.445 (0.172, 1.15) | 0.095 | 0.441 (0.169, 1.15) | 0.094 | 0.428 (0.163, 1.12) | 0.085 |
| ≥5 | 0.343 (0.134, 0.884) | 0.027* | 0.317 (0.121, 0.833) | 0.020 * | 0.311 (0.118, 0.818) | 0.018* |
| DI-GM continuous | 0.745 (0.577, 0.961) | 0.024* | 0.731 (0.563, 0.949) | 0.019* | 0.726 (0.558, 0.944) | 0.017* |
| DII * DI-GM | | | | | | |
| Pro-inflammatory and unfavorable to gut microbiota [†] | Ref. | Ref. | Ref. | Ref. | Ref. | Ref. |
| Composite diet category [§] | 0.407 (0.163, 1.02) | 0.054 | 0.358 (0.140, 0.916) | 0.032* | 0.343 (0.133, 0.886) | 0.027* |
| Anti-inflammatory and beneficial to gut microbiota [‡] | 0.251 (0.064, 0.984) | 0.047* | 0.235 (0.058, 0.953) | 0.043* | 0.228 (0.056, 0.927) | 0.039* |

Dysglycemia: Self-reported presence of abnormal blood glucose or diagnosed diabetes. DII, dietary inflammation index; DI-GM, dietary index for gut microbiota.

[†] Pro-inflammatory and unfavorable to gut microbiota: participants belong to the fourth quartile of DII and the first quartile of DI-GM.

[‡] Anti-inflammatory and beneficial to gut microbiota: participants belong to the first quartile of DII and the fourth quartile of DI-GM.

[§] Composite diet category: participants not falling into the above two groups.

Model 1: adjusted for age and gender.

Model 2: adjusted for education level, household income, city classification and residence status based on model 1.

Model 3: total dietary energy intake and use of nutritional supplementation were adjusted based on model 2. Total dietary energy intake wasn't adjusted in model 3 for DII, since it has been adjusted in the DII calculation process.

*$p$ <0.05

identified livestock products as the greatest contributor to dietary inflammation, and vegetables showed the strongest inverse effect. Notably, a higher DI-GM score was significantly associated with lower odds of self-reported dysglycemia. A combined pattern of lower DII and higher DI-GM conferred a stronger protective association.

Compared to the recommended intake for Chinese adults,11 participants in this study demonstrated an imbalanced macronutrient distribution characterized by excessive fat intake (>30% of total energy) and insufficient carbohydrate consumption (<50% of total energy), while maintaining appropriate protein intake (10%-20% of total energy) and adequate high-quality protein proportion (>50% of total protein). This nutritional pattern reflects an ongoing dietary transition in China, where economic development has improved protein quality but also led to excessive fat intake, a shift known to exacerbate systemic inflammation and adversely impact gut microbiota homeostasis.[25-30] Correspondingly, the overall dietary tendency among participants was pro-inflammatory, with over half demonstrating positive DII scores, a finding consistent with reports in other Chinese cohorts.[31] Our analysis further identified key food group determinants of dietary inflammation: vegetables, soybeans, and fruits were significantly associated with lower DII scores, whereas livestock products were associated with higher DII scores. Notably, vegetables demonstrated the strongest inverse association with DII. This anti-inflammatory effect likely stems not only from dietary fiber, which known to promote the production of short-chain fatty acids (SCFAs),[32,33] but also from a synergistic array of bioactive compounds including polyphenols, vitamin C, and carotenoids.[34,35] Conversely, the pro-inflammatory effect of livestock products likely stems from their high saturated fat content, a known dietary factor that can exacerbate inflammatory pathways.[36,37]

We observed a significant inverse association between DI-GM score and the risk of self-reported dysglycemia, which aligns with previous studies utilizing the National Health and Nutrition Examination Survey (NHANES) database in the U.S. population.[38-40] These studies demonstrate that a higher DI-GM score is not only associated with a reduced risk of diabetes,[38] but its protective effect may also be partially mediated through lower phenotypic age and body mass index.[39] Furthermore, a high DI-GM score has been linked to improved survival outcomes among individuals with diabetes and pre-diabetes.[40] While these studies established the index's validity in Western cohorts, our study provides crucial preliminary evidence for its relevance in an urban Chinese population, offering cross-cultural support for the concept that a microbiota-supportive diet is linked to metabolic health. The protective association observed in our study can be further interpreted through the specific dietary intake patterns of our cohort. The relatively higher proportion of participants meeting the criteria for beneficial components such as whole grains and soybeans, which likely provided a foundational intake of fermentable fibers. These substrates are pivotal for gut microbiota to produce SCFAs, which are known to enhance intestinal barrier integrity, suppress systemic inflammation, and improve insulin sensitivity.[41-43] Conversely, the prevalent poor control of unfavorable components like red meat and refined grains, reflected in the overall low DI-GM score, may have promoted the proliferation of pro-inflammatory bacterial taxa and increased intestinal permeability, contributing to metabolic endotoxemia and impaired glucose regulation.[29,30,44]

Since DII is a well-validated index associated with chronic diseases in previous studies,[45-47] its null association in our study possibly due to the relatively modest sample size, self-reported disease status, or unique inflammatory effects of the dietary intake among the study population, which tend to attenuate observable associations. Meanwhile, the significant association observed for DI-GM, but not for DII, suggests that in this specific population, the dietary pathway influencing metabolic health might be more directly captured by the modulation of gut microbiota and microbiota-derived metabolites.[48] Notably, our finding revealed that a combined pattern of lower DII (anti-inflammatory) and higher DI-GM (gut microbiota-friendly) conferred a stronger protective association against dysglycemia. This suggests that while their primary mechanistic emphases may differ, both anti-inflammatory and microbiota-supportive dietary components contribute synergistically to metabolic health, and their combined evaluation offers a more comprehensive assessment of diet-related risk.[4,49,50]

Our findings have significant implications for clinical practice and public health strategies. Dietary assessment among the participants revealed an imbalanced macronutrient intake, alongside an overall pro-inflammatory and gut microbiota-unfavorable dietary tendency. Notably, this study represents an initial exploration of the DI-GM in a Chinese population and provide preliminary evidence upon the association of gut microbiota-supportive dietary patterns and risk of dysglycemia. These findings support the development of targeted dietary strategies aimed at improving dietary quality to promote metabolic health. A potential limitation is the incomplete adaptation of the DI-GM to this study population. We pragmatically adapted the original index based on the foods consumed by the participants, using 11 of its 14 components due to the absence of chickpea, cranberries, and green tea in our dietary data. Additionally, the DI-GM components were validated predominantly in Western populations, and their impact may differ in a Chinese population with different baseline gut microbiota profiles. The application of DI-GM in this study is based on the assumption that it retains discriminatory power in the Chinese context. Future research are needed to develop or validate a gut microbiota-related dietary index more suited to Chinese dietary culture, which would enhance the precision and public health applicability of dietary recommendations for gut health and disease prevention in China.

The main strengths of this study include the use of a validated digital dietary assessment tool across multiple cities and the novel exploration of the DI-GM in a Chinese population. Despite these strengths, several limitations merit consideration. Firstly, as an observational study, we cannot definitively establish causality. Secondly, self-reported disease status may introduce misclassification bias. Thirdly, although we adjusted for several key covariates, residual confounding from unmeasured factors including physical activity, smoking, drinking and medication use are possible. Fourthly, the single 24-hour dietary recall might not capture habitual intake, which may introduce non-differential misclassification of DII and DI-GM, potentially attenuating the observed associations. Finally, the generalizability of our findings should be interpreted with caution due to the study's relatively modest sample size and its specific participant profile. Participants were recruited from an urban setting and exhibited characteristics associated with higher socioeconomic status and health consciousness. Coupled with the pronounced gender imbalance (approximately 75% female), these factors may limit the direct extrapolation of our results to the broader Chinese adult population, particularly to individuals from rural areas, those with lower socioeconomic status, or populations with a more balanced gender distribution.

### *Conclusion*

This cross-sectional study provides preliminary epidemiological evidence that a dietary pattern characterized by higher favorability for gut microbiota (reflected by a higher DI-GM score) and lower inflammatory potential (reflected by a lower DII score) may be associated with a reduced risk of dysglycemia in urban Chinese middle-aged and older adults. Further investigations in prospective cohorts and interventional studies are warranted to confirm these findings and elucidate the underlying causal pathways.

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## CONFLICT OF INTEREST AND FUNDING DISCLOSURES

The authors declare no conflict of interest.

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