Original Article

Trajectories of Food Group Intake and Risk of Type 2 Diabetes Mellitus: China Health and Nutrition Survey 1997–2018

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Abstract

Objective This study aimed to identify multi-food intake trajectory patterns and examine their associations with incident type 2 diabetes mellitus (T2DM) among Chinese adults without diabetes.

Methods This longitudinal analysis included adults aged ≥ 8 years seven waves (1997–2018) of the China Health and Nutrition Survey. Group-based trajectory modeling characterized 21-year intake patterns for nine food groups. *Cox* proportional hazards models estimated hazard ratios (*HRs*) for incident T2DM.

Results During 33,659 person-years of follow-up, 422 of 4,464 participants developed T2DM. Decreased intake of dark-colored vegetables was associated with higher T2DM risk in men (*HR* 1.42, 95% confidence interval [*CI*]: 1.06–1.92) and women (*HR* 1.73, 95% *CI*: 1.13–2.64). Additional sex-specific associations were observed. In women, higher risk was associated with high (*HR* 1.70, 95% *CI*: 1.01–2.85) or moderate (HR 1.56, 95% *CI*: 1.01–2.40) rice intake. Increasing red meat intake in men (*HR* 1.90, 95% *CI*: 1.30–2.77) and fluctuatng high red meat intake in women (*HR* 3.00, 95% *CI*: 1.07–8.45) were associated with higher risk. Conversely, fluctuating intake of other grains in men (*HR* 0.52, 95% *CI*: 0.33–0.84) and moderate fluctuating intake of aquatic products in women (*HR* 0.58, 95% *CI*: 0.34–0.97) was associated with lower T2DM risk.

Conclusion Long-term food group intake trajectories showed heterogeneous associations with incident T2DM, with several associations differing by sex. These findings highlight potential importance of long-term dietary patterns in T2DM prevention.

Key words: Food groups; Trajectory; Type 2 diabetes mellitus; Adult; China

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INTRODUCTION

Diabetes mellitus (DM), characterized by chronic hyperglycemia and impaired carbohydrate, lipid, and protein metabolism due to to insulin deficiency or resistance, is a major global health challenge[1]. According to the International Diabetes Federation's Diabetes Atlas, an estimated 536 million adults aged 20–79 years had diabetes in 2021, and this number is projected to reach 783 million by 2045[2]. In China, the prevalence of diabetes increased from 10.9% in 2013 to 12.4% in 2018[3,4], underscoring the need for effective prevention strategies.

Type 2 diabetes mellitus (T2DM), which accounts for 90%–95% of DM cases, arises from complex interactions between genetic and environmental factors, with modifiable risk factors, including unhealthy diet and physical inactivity[5,6]. Other established risk factors include sedentary behavior, unbalanced diet, lack of exercise, and obesity[7,8]. A 32-year prospective cohort study (n = 205,852) across three U.S. populations showed that sustained adherence to healthy dietary patterns was associated with a lower incidence of chronic diseases, including T2DM (hazard ratio [*HR*] 0.70, 95% confidence interval [*CI*]: 0.69–0.72)[9]. Evidence also supports comprehensive lifestyle modification—including weight management, regular physical activity (≥ 30 min/day), dietary optimization, smoking cessation, and moderate alcohol consumption—for the prevention and management of T2DM[10].

Diet is an important modifiable factor in T2DM risk. The World Health Organization (WHO) emphasizes that healthy dietary patterns not only prevent malnutrition but also reduce the risk of noncommunicable diseases, including diabetes, cardiovascular diseases (CVDs), and cancer[10-13]. Substantial epidemiological evidence indicates that associations with T2DM vary across food groups. Refined grains (e.g., white rice) and processed meats are associated with higher T2DM risk[12,14], whereas whole grains, fruits, and vegetables are associated with lower risk[15-17]. For other food groups, including aquatic products, eggs, and dairy products, evidence remains inconclusive, reporting positive, negative, or null associations[18-21]. However, existing studies have predominantly relied on dietary intake assessed at a single time point, which maay not capture changes in food consumption over time. Longitudinal dietary monitoring may provide a more accurate T2DM risk assessment by examining temporal variations in eating behaviors that single time point assessments miss.

Although previous studies have explored the association between dietary intake and T2DM risk, several limitations remain. Existing studies have often relied on food frequency questionnaires, which may have limited precision for quantifying dietary intake, and few have examined longitudinal changes in food consumption. Another methodological concern is the common use of quantile-based categorization of dietary exposures, which may obscure heterogeneity in longitudinal intake patterns. Moreover, evidence on the association between long-term food intake patterns and T2DM risk in Chinese populations remains limited, despite substantial variations in dietary patterns across Western Pacific, Southeast Asia, the Americas, and Africa. Therefore, studies using repeated quantitative dietary assessments to characterize longitudinal intake patterns may provide further insight into diet–T2DM associations and inform population-specific prevention strategies.

Accordingly, using 21-year longitudinal data from seven waves of the China Health and Nutrition Survey (CHNS), this study aimed to (1) identify distinct trajectory patterns of multiple dietary components among non-diabetic Chinese adults using group-based trajectory modeling (GBTM) and (2) assess their associations with incident T2DM.

MATERIALS AND METHODS

Study Design

We analyzed longitudinal data from seven waves (1997, 2000, 2004, 2006, 2009, 2015, and 2018) of the CHNS, a nationally representative cohort study[22]. The reporting of this study conforms to the Strengthening of Observational Studies in the Epidemiological Guidelines.

This study examined the trajectory patterns of food intake among participants from 1997 to 2018 and investigated the association between these patterns and subsequent risk of developing T2DM. During this period, CHNS collected fasting blood samples from respondents in 2009, 2015, and 2018 for blood glucose testing. To unify the definition of the outcome indicators, this study used data from 2009, 2015, and 2018 for survival analysis, and the period from 2009 to 2018 was referred to as the "survival analysis period". During the "survival analysis period," follow-up was conducted to determine whether the subjects developed T2DM.

The end of the follow-up period included one of the following situations: participants developed T2DM, were lost to follow-up, or completed the last round of the survey. This study used all the dietary data obtained from the respondents from 1997 to 2018 to identify trajectories and calculate cumulative averages, and this period was referred to as the "track identification period." Since the investigators' dietary habits will change after developing diabetes, this study only used the survey data from the round before the subjects developed diabetes for trajectory identification and cumulative average calculation (if the participants' last round of survey data shows that they did not develop diabetes, all rounds of survey data are used).

Participants

For this study, we selected adults aged ≥ 18 years, including women who were not pregnant or lactating, and who had participated in the 2009, 2015, and 2018 surveys (*n* = 24,372). We then excluded those who had a dietary data deficiency or abnormal daily energy intake (men: < 800 kcal or > 6,000 kcal; women: < 600 kcal or > 4,000 kcal), blood sample deficiency, or demographic information deficiency. Among the remaining participants (*n* = 19,499), those in at least two follow-up waves from 2009 to 2018 who were not diagnosed with T2DM when they first entered the Kaplan–Meier "survival analysis period" were selected (*n* = 8,886). Participants with fewer than three waves of available dietary data before T2DM diagnosis were excluded. Finally, we excluded participants who self-reported diabetes in the 1997–2006 survey to ensure that all participants were nondiabetic when they entered the "survival analysis period." A total of 4,464 respondents were included in the analysis, including 2,044 men and 2,420 women (see Appendix 1). We also utilized multiple imputation techniques to address missing values, with the objective of acquiring as many qualified samples as possible.

This survey was approved by the Institutional Review Committee of the National Institute for Nutrition and Health, Chinese Center for Disease Control and Prevention (No. 2015-017 and No. 2018-004). All participants signed an informed consent form prior to the participation in the survey.

Measurement of Food Intake

Dietary intake was assessed using three consecutive 24-hour recalls (including 2 weekdays and on2e weekend day), with household cooking oil and condiment consumption allocated to individuals proportionally based on their contribution to the total household energy intake during the recording period. Daily food consumption (g/day) and total energy intake (kcal/day) were calculated using the Chinese Food Composition Table. We analyzed nine major food groups: (1) rice and rice products (e.g., rice cakes, rice noodles); (2)wheat and wheat products (e.g., white bread, noodles, mantou); (3) other grains (e.g., corn, barley, oats, millet); (4) red meat (pork, beef, lamb); (5) poultry (chicken, duck); (6) aquatic products (fish, shrimp, shellfish); (7) dark-colored vegetables (e.g., spinach, broccoli, tomatoes, carrots, peppers, pumpkin, purple cabbage); (8) light-colored vegetables (e.g., cabbage, lotus root, turnip); and (9) fruits (e.g., apples, oranges, grapes, strawberries). C average intake of each food group was calculated using all available dietary data from the trajectory identification period (1997–2018).

Measurement of Blood Glucose Indicators and Diagnostic Criteria of T2DM

Blood samples were collected via venipuncture and glucose tests were immediately performed with strict quality control. Fasting blood glucose (FPG) levels were measured using the oxidase method (CHOD-PAP; Randox Laboratories Ltd., London, UK). Glycosylated hemoglobin (HbA1c) levels were measured using a high-performance liquid chromatography system (HLC-723 G7; Tosoh Corporation, Tokyo, Japan). According to the diagnosis and classification of WHO and the guidelines for the prevention and treatment of diabetes mellitus in China[23,24], T2DM is defined by fulfilling at least one of the three following conditions: (a) FPG ≥ 7.0 mmol/L; (b) HbA1c ≥ 6.5%); or (c) Self reported T2DM and/or administration of diabetes treatments.

Assessment of Covariates

The following measures were considered covariates: age (in years); education level (primary school and below, completed middle school, high school and above); per capita family income (tertiles: low, medium, high); geographic region (rural, urban); smoking and alcohol-drinking status (current smoker/drinker, nonsmoker/nondrinker); sleep duration (< 6 h, 6–9 h, > 9 h); total physical activity (METs h/week); chronic disease history (previous diagnosis with hypertension, myocardial infarction, apoplexy, or cancer); waist circumference (WC); and systolic blood pressure (SBP). We also considered other diet-related factors as adjusted covariates,

including total energy intake (TEI) and cumulative average values calculated from other food groups, excluding the independent variables (rice and its products, wheat and its products, other grains, red meat, poultry, aquatic products, dark-colored vegetables, light-colored vegetables, and fruits).

Statistical Analysis

Group-based trajectory modeling was used to identify single and multiple trajectories of food intake between men and women[25,26]. Trajectory modeling was executed using the STATA plug-in, employing a continuous norming distribution for continuous data, with follow-up years serving as the timescale for these trajectories. The selection of the most suitable model adhered to strict statistical criteria: (a) models with a smaller Bayesian information criterion were regarded as superior fits; (b) each trajectory class encompassed at least 2% of the sample population; and (c) average posterior probability of membership within each group with values exceeding 0.7 served as an indicator of adequate internal reliability[27].

Characteristics are summarized using the median (interquartile range) or mean (standard deviation) for continuous variables and counts (proportion) for discrete variables. After verifying the proportional hazards assumption using Schoenfeld residual plots, we employed *Cox* proportional hazards models to estimate the *HRs* for T2DM incidence. Analysis of the association between the trajectory groups and T2DM was performed using the *Cox* proportional hazard regression model, with diabetes as the outcome variable and follow-up years as the time variable. Two models were constructed: Model 1 was a crude model; Model 2 incorporated adjustments for age, urban-rural residence, educational attainment, income level, physical activity level, sleep duration, smoking status (adjusted solely for male participants, with no adjustment for female participant), alcohol consumption, history of chronic diseases, body mass index (BMI), SBP, TEI, intake derived from the first round of dietary data pertaining to the study's independent variable (for instance, when examining rice and rice product consumption, the first round of dietary data for rice and its products was utilized), as well as the cumulative average intake of other major food categories excluding the study's independent variable (specifically, when studying rice and rice product intake, the cumulative average of other major foods such as wheat and their products, other grains, red meat, poultry, aquatic products, dark-colored vegetables, light-colored vegetables, and fruits, excluding rice and its products, was employed). The covariates utilized were those relative to the baseline (2009–2015). Dose-response relationships were evaluated using restricted cubic splines (RCSs) with three knots.

All analyses were conducted using SAS (version 9.4; SAS Institute, Cary, NC, USA) and Stata/SE (version 15.0; StataCorp, Station, TX, USA) software. Statistical significance was determined using a *P*-value of < 0.05.

RESULTS

Basic Information on the Sample

We included 4,464 participants in the longitudinal analysis, all of whom visited three or more times between 1997 and 2018. The mean age of the participants ranged from 42.5 in 1997 to 60.4 in 2018 with a basic gender balance, and more than two-thirds of them were rural residents. Educational level and annual household income of the participants increased with survey year, whereas the level of physical activity showed a decreasing trend. Total energy intake decreased, whereas BMI, WC, SBP, and diastolic blood pressure increased (Table 1).

Separate Trajectory Analysis

Stratified analysis by sex was used to identify the trajectory of food intake of rice and its products, wheat and its products, other grains, red meat, poultry, aquatic products, dark-colored vegetables, light-colored vegetables, and fruits. Figures 1 and 2 show the food intake trajectory groups identified between 1997 and 2018 among male and female participants. Four types of rice trajectory groups, wheat trajectory groups, three types of other grain trajectory groups were identified: four types of red meat trajectory groups, three types of poultry trajectory groups, and aquatic products trajectory groups; three types of dark-colored vegetables and light-colored vegetables; and two types of fruit trajectory groups. The number and proportion of participants in each food trajectory group, as well as the names marked for that group, are shown in Appendices 2–6 displays the model parameters of the GBTM for the intake trajectories of rice and its products, wheat and its products, other grains, red meat, poultry, aquatic products, dark-colored vegetables, light-colored vegetables, and fruits stratified by sex.

The results of the *Cox* multiple regression analysis of the associations between food intake

trajectory groups and T2DM risk are shown in Figure 3. Among male participants, lower T2DM risk was associated with other grain intake trajectories in "low increase" group and "moderate fluctuation" group compared with "no intake" group, with a *HR* of 0.60 (95% *CI*: 0.45–0.81) and 0.52 (95% *CI*: 0.33–0.84), respectively. For the red meat intake, the risk of T2DM in the "medium increase" trajectory group (*HR* 1.90, 95% *CI*: 1.30–2.77) was significantly higher than that in the "moderate stability" group. Among female participants, lower T2DM risk was associated with other grain intake trajectories in "moderate fluctuation" group (*HR* 0.56, 95% *CI*: 0.34–0.90). For the red meat intake, the risk of T2DM was significantly increased in the "medium-level stability" group (*HR* 1.47, 95% *CI*: 1.01–2.21) and "high-level fluctuation" group (*HR* 3.00, 95% *CI*: 1.07–8.45) when adjusted for all covariates. Using the "basically no intake" trajectory as the reference trajectory, we found that individuals in the "moderate fluctuation" trajectory of aquatic product (*HR* 0.58, 95% *CI*: 0.34–0.97), the "low increase" trajectory of poultry (*HR* 0.65, 95% *CI*: 0.48–0.90) all had a lower risk of T2DM. For dark-colored vegetable

Table 1. Cross-sectional characteristics of the study sample from CHNS (1997–2018)

Baseline Characteristics	1997	2000	2004	2006	2009	2015	2018
N	2,174	2,787	3,124	3,375	4,061	4,064	3,510
Sex							
Male	992 (45.63)	1,251 (44.89)	1,429 (45.74)	1,513 (44.83)	1,857 (45.73)	1,846 (45.42)	1,582 (45.07)
Female	1,182 (54.37)	1,536 (55.11)	1,695 (54.26)	1,862 (55.17)	2,204 (54.27)	2,218 (54.58)	1,928 (54.93)
Age, years (mean ± SD)	42.45 ± 10.70	44.76 ± 10.94	48.07 ± 11.45	49.47 ± 11.79	51.75 ± 12.11	57.52 ± 12.09	60.40 ± 11.92
Geographic region, *n* (%)							
Urban	569 (26.17)	681 (24.43)	813 (26.02)	893 (26.46)	2,074 (26.45)	1,085 (26.7)	903 (25.73)
Rural	1,605 (73.83)	2,106 (75.57)	2,311 (73.98)	2,482 (73.54)	2,987 (73.55)	2,979 (73.3)	2,607 (74.27)
Distribution of education level, *n* (%)							
Primary school	1,313 (60.4)	1,705 (61.18)	1,510 (48.34)	1,557 (46.13)	1,907 (46.96)	1,797 (44.22)	1,445 (41.17)
Middle school	573 (26.36)	715 (25.65)	1,015 (32.49)	1,082 (32.06)	1,368 (80.65)	1,346 (33.12)	1,203 (34.27)
High school and above	288 (13.25)	367 (13.17)	599 (19.17)	736 (21.81)	786 (19.35)	921 (22.66)	862 (24.56)
Per capita annual household income, yuan/year [median (*IQR*)]	8,345.0 (4,863.0–13,181.1)	9,633.4 (5,294.6–15,544.9)	11,158.7 (6,307.1–20,011.4)	13,150.8 (7,522.8–23,209.0)	22,076.7 (12,379.9–38,650.8)	44,861.5 (20,697.1–72,316.2)	53,664.0 (21,242.1–84,656.1)
Total PA [median (*IQR*)]	341.07 (352.63)	257.85 (313.44)	187.44 (269.96)	184.73 (259.11)	173.80 (240.90)	99.25 (165.07)	108.81 (159.09)
Average daily energy intake, kcal (mean ± SD)	2,530.27 ± 721.68	2,396.03 ± 671.63	2,333.34 ± 719.87	2,360.97 ± 733.31	2,239.02 ± 679.97	2,019.88 ± 727.30	2,006.99 ± 663.98
BMI, kg/m^2 (mean ± SD)	22.14 ± 2.77	22.76 ± 3.02	23.00 ± 3.12	23.16 ± 3.17	23.37 ± 3.31	24.14 ± 3.84	24.31 ± 3.66
WC, cm (mean ± SD)	76.51 ± 8.24	78.71 ± 9.13	80.14 ± 9.36	80.92 ± 9.46	82.53 ± 9.80	84.30 ±12.52	85.68 ± 11.18
SBP, mmHg (mean ± SD)	115.94 ± 15.26	117.34 ± 16.18	120.54 ± 16.81	120.09 ± 16.87	124.45 ± 18.43	130.96 ± 19.05	134.17 ± 19.53
DBP, mmHg (mean ± SD)	75.67 ± 10.42	76.59 ± 10.66	78.03 ± 10.87	78.30 ± 10.75	80.83 ± 11.31	82.50 ± 10.95	83.08 ± 11.13

Note. BMI, body mass index; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure. Sex, geographic region, and distribution of education level were categorical variables and are expressed as *n* (%). Age, per capita annual household income, average daily energy intake, BMI, WC, SBP and DBP were continuous variables. For continuous variables, the mean (standard deviation) or median (interquartile range) is used, depending on whether they follow a normal distribution.

intake, the risk of T2DM in the "rapid decline from high levels" trajectory group (*HR* 2.64, 95% *CI*: 1.32–5.28) was significantly higher than that in the "low slight increase" trajectory group. The results of the association between the trajectory groups and T2DM risk are shown in Appendices 7 and 8.

Multi-trajectory Analysis

Appendices 9–11 respectively display the parameters of the GBMTM for multiple trajectories of food intake patterns.

Four distinct sex-specific multi-trajectories of cereal patterns were identified (Figure 4). The "rice-dominated high intake group" (male group 1: 17.1%, female group 1: 17.0%) featured a cereal pattern predominantly composed of rice and its products, characterized by a high intake that gradually decreased (male participants: gradually decreasing from 530 g to around 350 g, female participants: gradually decreasing from 450 g to around 280 g), maintaining a low yet stable intake of wheat and its products, and very low intakes of other grains. The "rice-dominated moderate intake group" (male group 2: 49.1%, female group 2: 47.1%) also featured rice and its products as the primary focus, exhibiting a moderate intake that gradually decreased (male participants: gradually decreasing from 390 g to around 250 g, female participants: gradually decreasing from 330 g to around 210 g), with an appropriate intake of wheat and its products

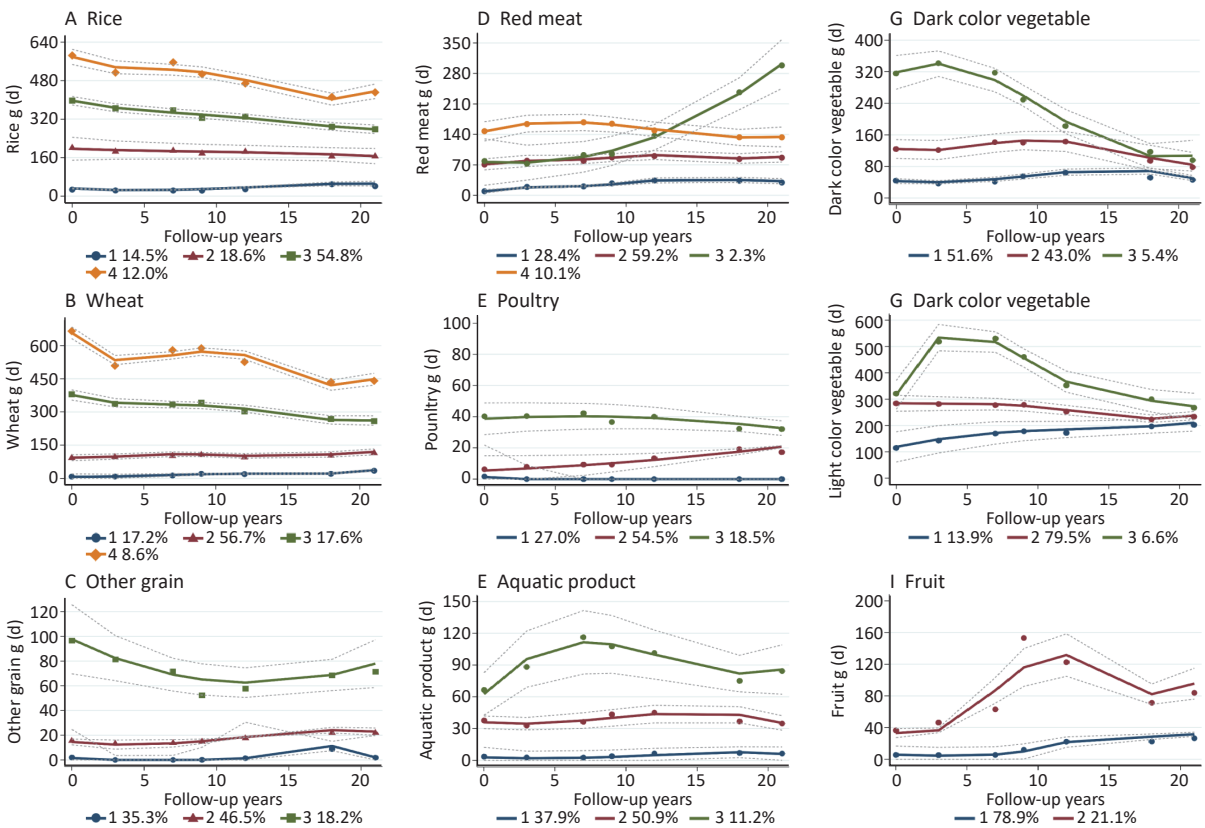

Figure 1. Trajectories of the food intake in China from 1997 to 2018 among male participants. (A) rice among male; (B) wheat among male; (C) other grain among male; (D) red meat among male; (E) poultry among male; (F) aquatic product among male; (G) dark-colored vegetable among male; (H) light-colored vegetable among male; (I) fruit among male. Solid lines depict the average estimated intake of rice, wheat, other grains, red meat, poultry, aquatic products, dark- and light-colored vegetables, and fruits over time, whereas dashed lines represent the 95% *CIs*. Data points represented by dots are weighted based on each individual's responses and the posterior probabilities of group membership. Food intake, measured in grams per day, is shown on the vertical axis. Horizontal axis represents follow-up time in years. Different colored lines correspond to distinct trajectory groups identified within the study population, with the legend indicating the groups and proportion of people represented by each color. *CI*, condifence interval.

(male participants: around 70–100 g, female participants: around 60–70 g), and very low intakes of other grains. The "balanced cereal intake pattern group" (male group 3: 16.5%, female group 4: 16.9%) displayed a balanced cereal intake pattern, with appropriate intakes of rice and its products, wheat and its products, and other grains. The "wheat-dominated moderate-high intake group" (male group 4: 17.3%, female group 3: 19.0%) was characterized by a cereal pattern primarily composed of wheat and its products, exhibiting a high intake that gradually decreased over time (male participants: gradually decreasing from 530 g to around 330 g, female participants: gradually decreasing from 430 g to around 260 g), with very low intakes of rice and its products, and appropriate intakes of other grains. The average rice, wheat, and other grain intakes among the different multi-trajectory groups for both male and female participants at follow-up are presented in Appendices 12 and 13.

Four distinct gender-specific multi-trajectory of meat patterns were identified (Figure 5): The "low consumption group of total meat group" (male group 1: 22.5%, female group 1: 27.4%) was characterized by low consumption of red meat, poultry and aquatic products, which was an intake pattern with a relatively low consumption of total meat. The "balanced intake pattern group" (male group 2: 20.7%, female group 2: 26.2%) was

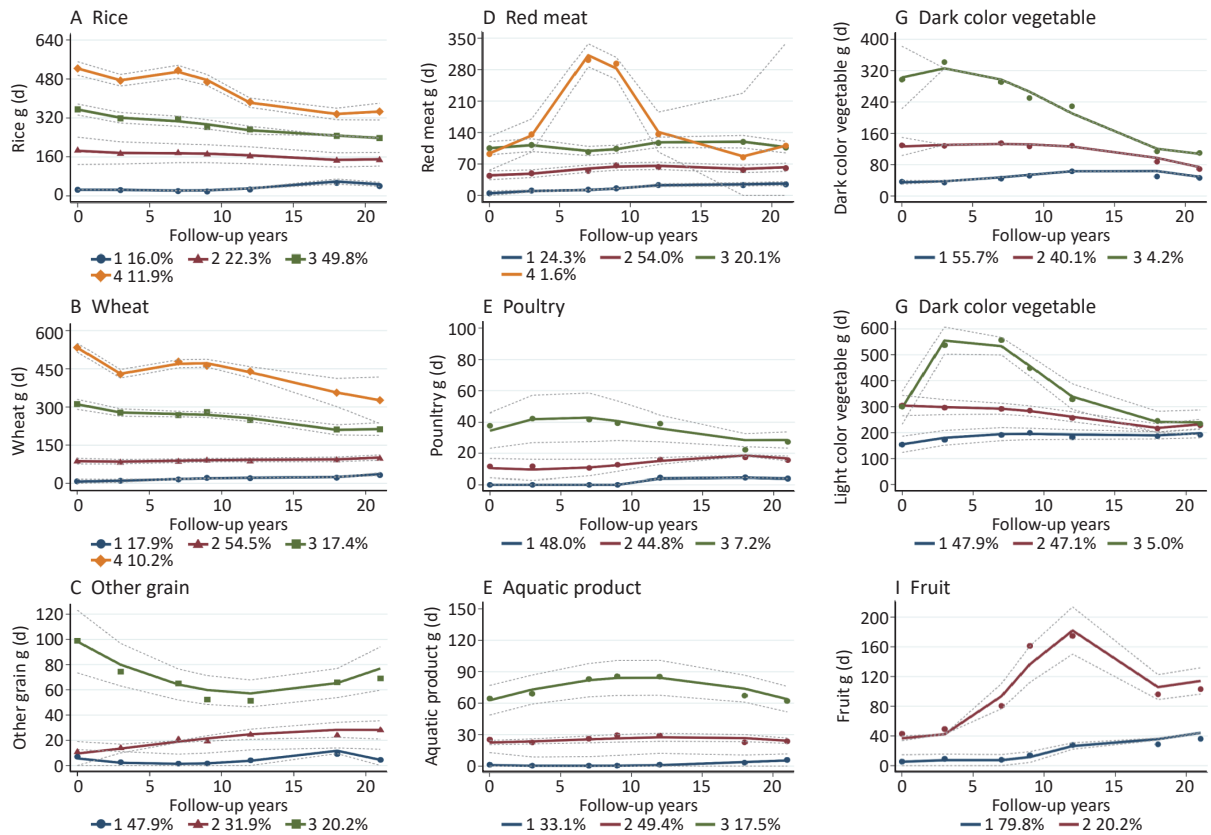

Figure 2. Trajectories of the food intake in China from 1997 to 2018 among female participants. (A) rice among female; (B) wheat among female; (C) other grain among female; (D) red meat among female; (E) poultry among female; (F) aquatic product among female; (G) dark color vegetable among female; (H) light color vegetable among female; (I) fruit among female. Solid lines depict the average estimated intake of rice, wheat, other grains, red meat, poultry, aquatic products, dark- and light-colored vegetables, and fruits over time, whereas dashed lines represent the 95% *CIs*. Data points represented by dots were weighted based on each individual's responses and the posterior probabilities of group membership. Food intake, measured in grams per day, is shown on the vertical axis. Horizontal axis represents follow-up time in years. Different colored lines correspond to distinct trajectory groups identified within the study population, with the legend indicating the groups and proportion of people represented by each color. *CI*, confidence interval.

characterized by a relatively balanced intake pattern of red meat (red meat for men: 60–90 g, red meat for women: 40–70 g), poultry, and aquatic products, especially reaching a certain amount of aquatic product intake (aquatic products for men: 50–80 g, aquatic products for women: 30–70 g). The "medium intake group dominated by red meat" (male group 3: 29.7%, female group 3: 26.0%) was dominated by red meat, showing a moderate intake that gradually increased (red meat for men: 50–90 g, red meat for women: 40–70 g), with very low intake of poultry and aquatic products. The "high intake group was dominated by red meat" (male group 4: 27.1%, female group 4: 20.4%) was dominated by red meat, showing a high intake and maintaining stability (red meat for men: 110–130 g, red meat for women: 90–110 g). Some intake of poultry and aquatic products was observed; however, it was also dominated by red meat. The average red meat, poultry, and aquatic product intakes among the different multi-trajectory groups for both male and female participants at follow-up are presented in Appendices 14 and 15.

Three distinct multi-trajectories of vegetable-fruit patterns were identified (Figure 6): a balanced structure of the vegetable intake" group (male group 2: 67.1%; female group 1: 22.5%). This group was characterized by a moderate intake of light-colored vegetables (approximately 250 g for male participants, and 200 g for female participants) and dark-colored vegetables with a gradual increase in fruit intake. "Decreased intake of dark-colored vegetables" group (male group 1: 24.3%, female group 3: 22.2%). This group was characterized by a high initial intake of dark-colored vegetables, followed by a rapid decrease (male participants: from 200 g to approximately 60 g; female participants: from 180 g to approximately 60 g), while maintaining a moderate intake of light-colored vegetables (120–200 g) and a low intake of fruits.

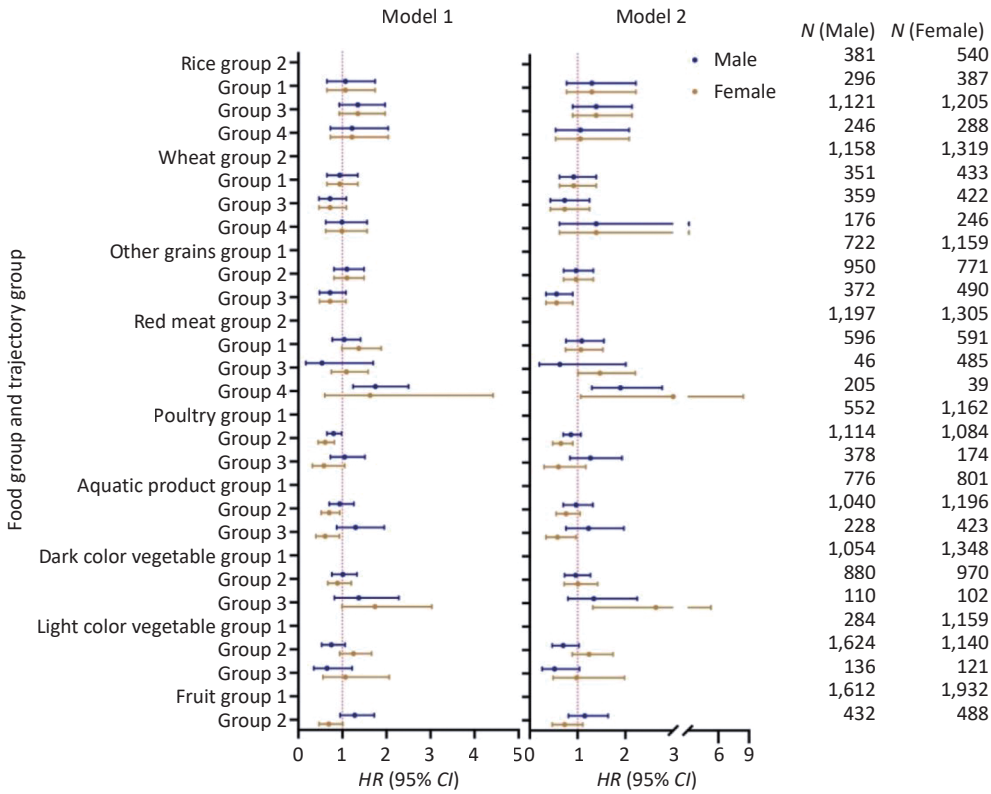

Figure 3. Analysis of associations between trajectory groups and risk of T2DM. Model 1 does not include covariate adjustments. Model 2 incorporates adjustments for factors such as age, education level, geographic locality (urban or rural), urbanization index, annual household income per capita, levels of physical activity, current smoking and drinking status, chronic disease history, accumulated average calculated from other food groups (excluding independent variables), total energy intake, BMI, and systolic blood pressure. Data are presented as *HR* and 95% *CIs*. *HR*, hazard ratio; *CI*, confidence interval; T2DM, type 2 diabetes mellitus; BMI, body mass index.

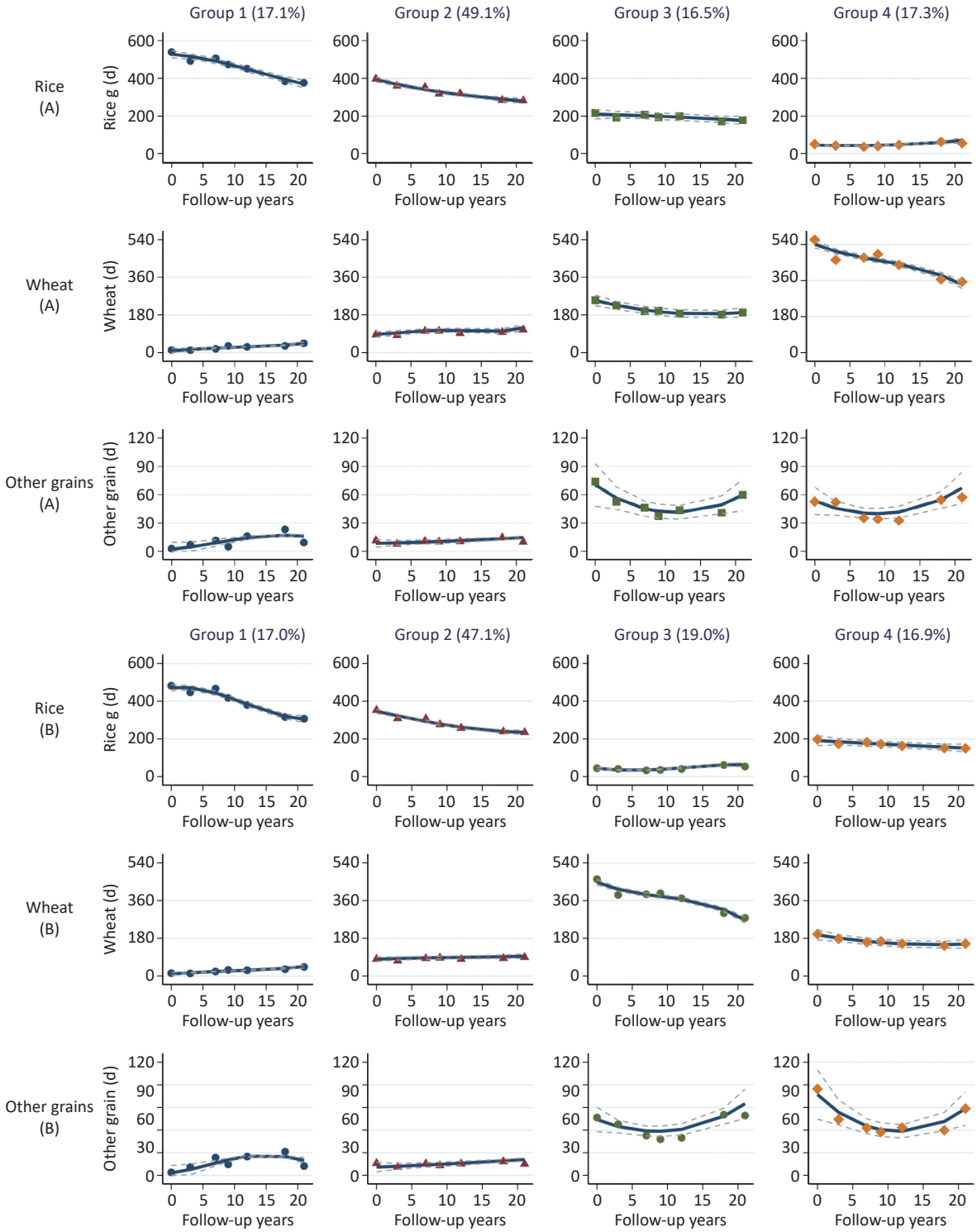

Figure 4. Multivariate trajectories of rice, wheat, and other grain consumption among male participants (Panel A) and female participants (Panel B) in the Chinese population, 1997–2018. Various trajectory groups identified within the study population are represented by distinct colored lines. Each color set of lines illustrates the intake trajectories of rice, wheat, and other grains for the identified population. The legend provides the corresponding group associations and percentage of individuals within each group.

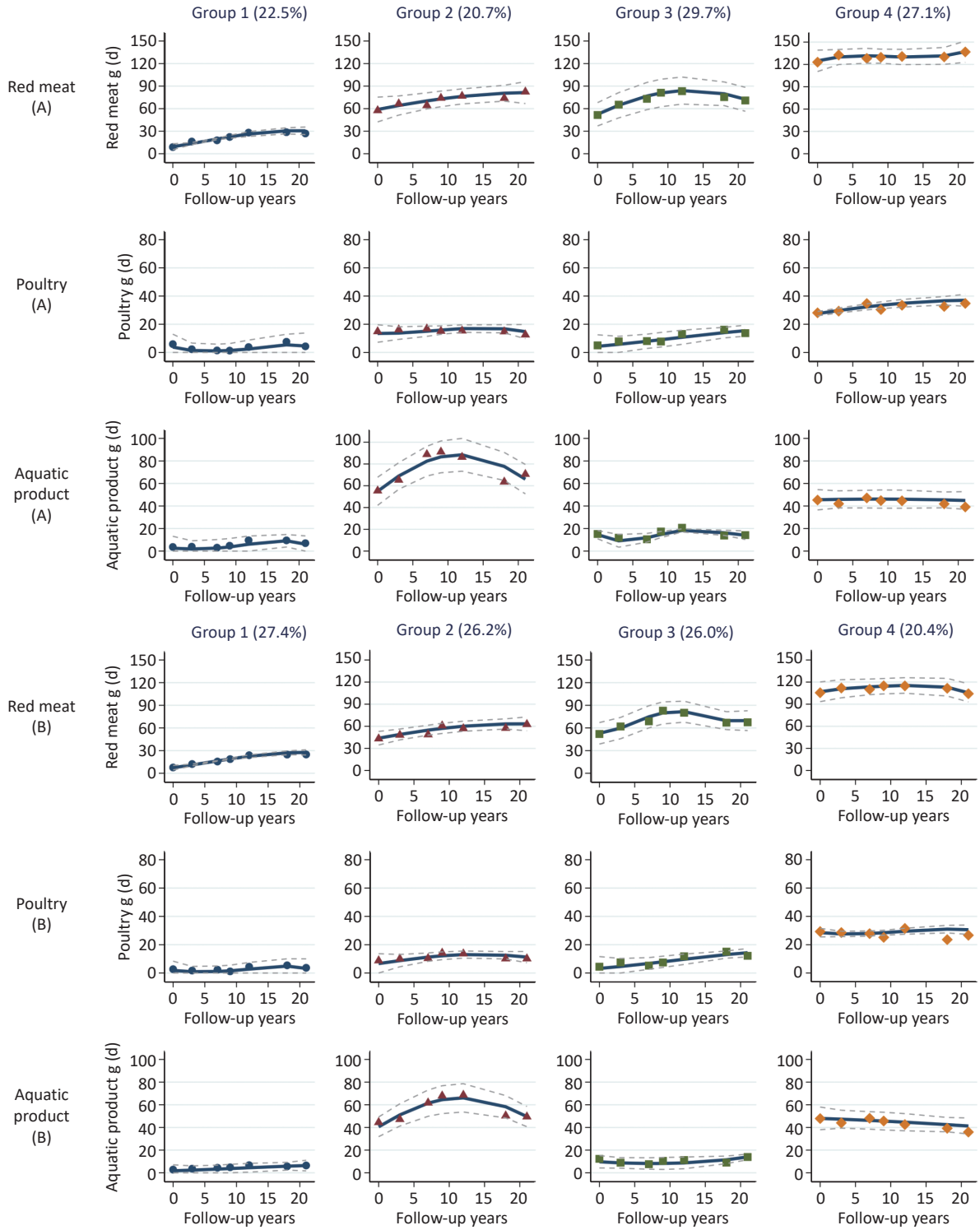

Figure 5. Multivariate trajectories of red meat, poultry, and aquatic product consumption among male participants (Panel A) and female participants (Panel B) in the Chinese population, 1997–2018. Various trajectory groups identified within the study population are represented by distinct colored lines. Each colored set of lines illustrates the intake trajectory of red meat, poultry, and aquatic products for the identified population. The legend provides corresponding group associations and percentage of individuals within each group.

Light-colored vegetable-dominated group (male group 3: 8.6%, female group 2: 55.3%) was characterized by a high intake of light-colored vegetables (male participants: 230–430 g, female participants: 180–280 g) and low intake of dark-colored vegetables and fruits. The average dark-colored vegetable, light-colored vegetable, and fruit intake among the different multi-trajectory groups for both male and female participants at follow-up are presented in Appendices 16 and 17.

Figure 7 presents the findings of the *Cox* multivariate regression analyses exploring the

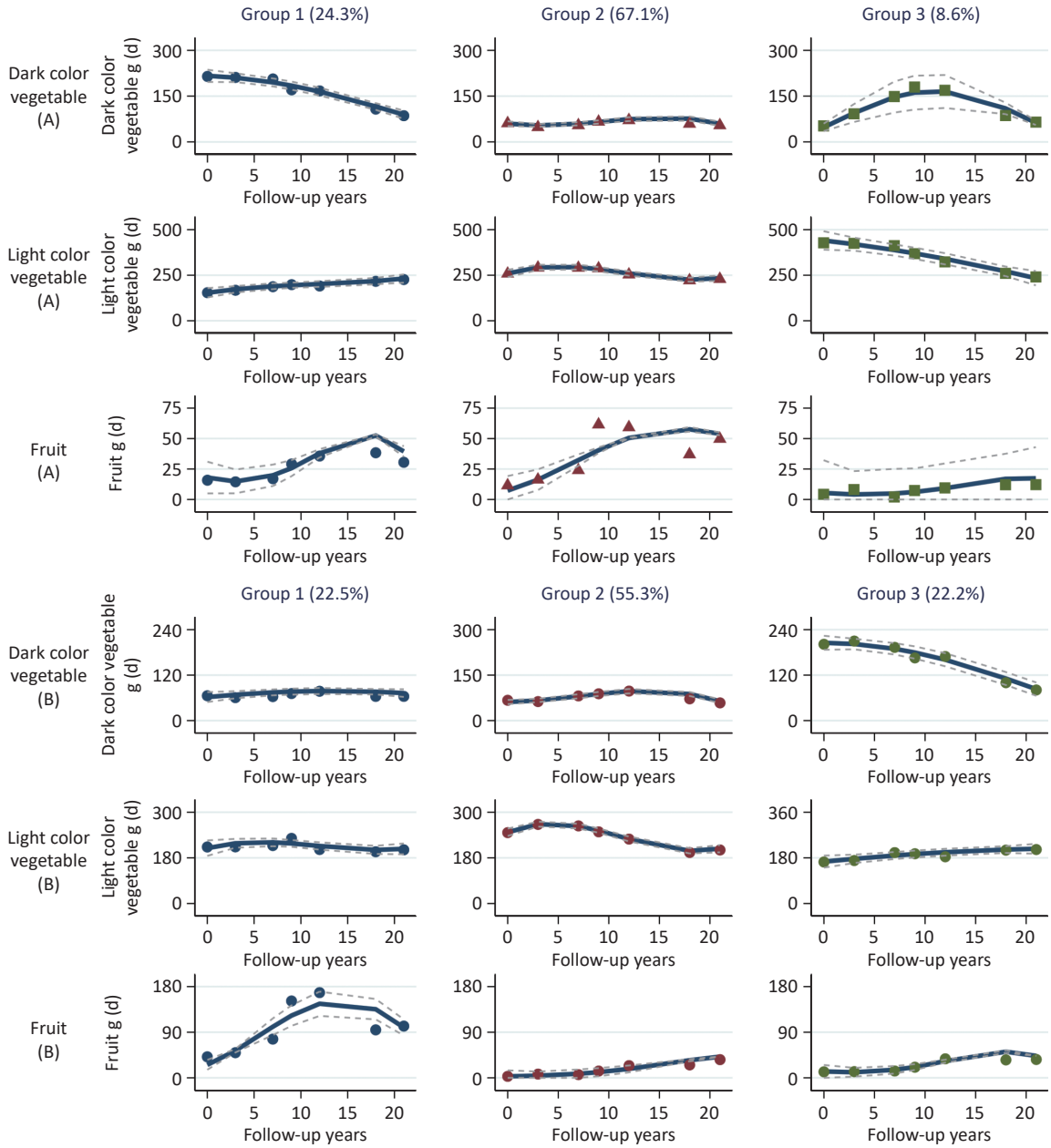

Figure 6. Multivariate trajectories of dark-colored vegetable, light-colored vegetable, and fruit consumption among male participants (Panel A) and female participants (Panel B) in the Chinese population, 1997–2018. Various trajectory groups identified within the study population are represented by distinct colored lines. Each color set of lines illustrates the intake trajectories of dark vegetables, light vegetables, and fruits in the identified population. The legend provides corresponding group associations and percentage of individuals within each group.

associations between multiple trajectories and T2DM risk. The follow-up period for 4,464 participants ranged from 3 to 9 years, with an average follow-up time of 7.54 years. A total of 422 individuals (9.45%) developed diabetes during the follow-up period with 33,659 person-years. Taking the "balanced cereal intake pattern group" as the reference group, the "rice-dominated high intake group" and the "rice-dominated moderate intake group"exhibited a significantly elevated risk of developing T2DM among women, with *HR* of 1.70 (95% *CI*: 1.01–2.85) and 1.56 (95% *CI*: 1.01–2.40), respectively. Regarding the multi-trajectory of red meat, poultry, and aquatic product patterns, the "low consumption group of total meat group" (*HR* 1.46, 95% *CI*: 1.01–2.12) had a significantly elevated

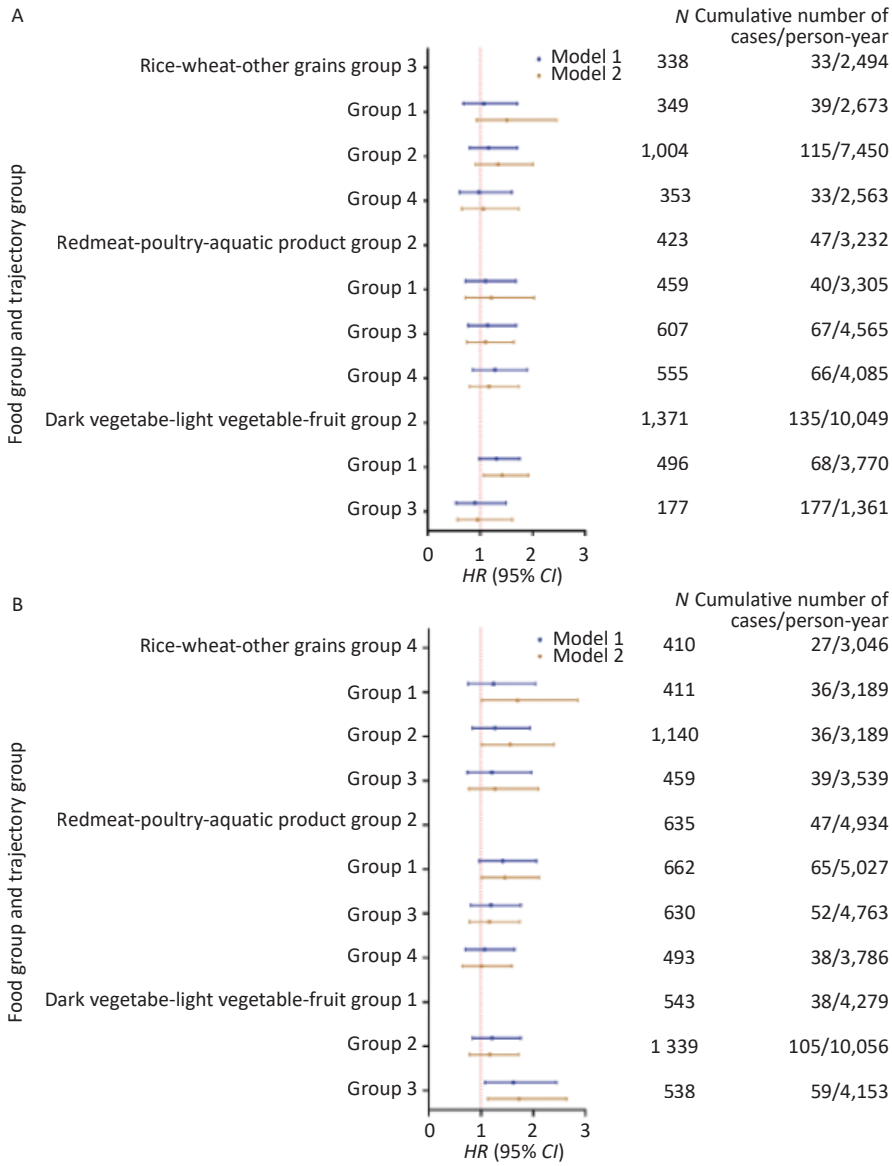

Figure 7. Analysis of associations between multi-trajectories and risk of T2DM among male participants (Panel A) and female participants (Panel B). Model 1 does not include covariate adjustments. Model 2 incorporates adjustments for factors such as age, educational level, geographic locality (urban or rural), urbanization index, annual household income per capita, levels of physical activity, current smoking and drinking status, chronic disease history, total energy intake, BMI, and systolic blood pressure. Data are presented as *HR* and 95% *CIs*. *HR*, hazard ratio; *CI*, confidence interval; BMI, body mass index; T2DM, type 2 diabetes mellitus.

risk of developing T2DM among women compared to the "balanced intake pattern group." In the male study population, the "Decreased intake of dark-colored vegetables" exhibited a 42% increased risk of T2DM (*HR* 1.42, 95% *CI*: 1.06–1.92) compared to the reference group; similarly, in the female study population, this group had a 73% increased risk of diabetes (*HR* 1.73, 95% *CI*: 1.13–2.64). The results of the association between the multi-trajectory groups and T2DM risk are shown in Appendices 18.

Dose-response Relationship Analysis

Appendices 19 and 20 illustrate the dose-response relationship between food intake and the risk of developing T2DM. RCS analysis indicated a significant correlation between food consumption and T2DM risk ($P < 0.05$). According to the nonlinear association test, in men, a nonlinear association was observed between the intake of aquatic products ($P = 0.039$), dark-colored vegetables ($P < 0.001$), and fruits ($P = 0.011$) and the risk of T2DM. Similarly, in women, a nonlinear association was observed between the intake of wheat ($P = 0.028$), red meat ($P = 0.012$), poultry ($P = 0.010$), aquatic products ($P = 0.026$), dark-colored vegetables ($P < 0.001$), and fruits ($P = 0.004$) and the risk of T2DM. A significant increase in T2DM risk was noted in women when rice intake was above 200 g/d and wheat intake exceeded 320 g/d. Conversely, when women's intake of poultry ranged from 0 to 30 g/day and their intake of aquatic products ranged from 0 to 115 g/day, the risk of T2DM significantly decreased. The risk of developing T2DM significantly decreased in both men and women when their intake of dark-colored vegetables ranged from 20 to 120 g/day and similarly when fruit intake ranged from 0 to 20 g/day for men and from 30 to 120 g/day for women.

DISCUSSION

To our knowledge, this study used a multi-trajectory model and longitudinal data from seven waves of the CHNS (1997–2018) to examine temporal changes and interrelationships among diverse dietary patterns associated with T2DM risk. We identified several distinct dietary trajectory patterns with differential associations with T2DM development. Notably, sustained moderate consumption of whole grains was associated with a lower risk of T2DM, whereas a persistently high intake of red meat was associated with a higher risk. Two dietary patterns were particularly associated with increased T2DM risk: predominant white rice consumption with limited whole-grain intake and consistently low consumption of dark-colored vegetables and fruits. These findings provide insight into the associations between long-term dietary patterns dynamics and T2DM risk in a Chinese population.

China has undergone a substantial nutritional transition over the past two decades characterized by significant alterations in dietary composition and food consumption patterns. National surveillance data (2010–2013)[28,29] document a gradual shift from traditional dietary patterns, with a decreasing contributions of cereal-based foods to total energy intake and increasing consumption of animal-derived products. Although cereals remain a dietary staple, refined grains (primarily rice and wheat) have largely replaced whole grains, with limited diversity beyond corn and millet. Concurrently, pork consumption remains high, whereas consumption of healthier alternatives (poultry, fish, and seafood) remains relatively low. Vegetable intake is similarly suboptimal, with dark-colored varieties constituting only 30% of the total vegetable consumption, substantially below the recommended 50%. These dietary changes have coincided with a marked increas in T2DM prevalence, with nationally representative data[30,31] showing a 4.8-fold increase from 2.5% (1994) to 11.9% (2020). The concordance of these dietary changes and increasing T2DM prevalence hghlights the potential contribution of modifiable dietary factors to China's growing metabolic disease burden and the importance for addressing these dietary imbalances.

Trends in Cereal Intake and T2DM

No significant correlation was found between different types of rice and the risk of T2DM. However, in the multi-trajectory analysis of cereal intake patterns, study population with a high intake of rice and its associated products, without incorporating other grains, had a higher risk of developing T2DM. A study in Japan reported similar observations[32], in which an association between the risk of diabetes and rice consumption was found. The study also found that although study participants with higher rice intake tended to have a lower BMI, their risk of developing diabetes remained higher, suggesting that high rice intake may increase the risk of T2DM, independent of BMI. From a dietary perspective, this paradoxical association seems to explain why the prevalence of obesity in Japan is much lower than that in Western populations, yet the prevalence of T2DM in Japan is

comparable to that in Western populations[33]. A prospective cohort study in China evaluated the relationship between dietary carbohydrate intake, glycemic index, glycemic load, and incidence of diabetes[34]. The results indicated that a high intake of foods with high glycemic index (GI) and glycemic load (GL), especially rice, may increase the risk of developing T2DM in Chinese women. The potential mechanism behind high rice consumption and increased risk of diabetes remains uncertain. A plausible explanation is that rice, which has a high GI and serves as a staple food in Asian populations, significantly affects GL. Additionally, during the production of polished rice, many nutrients that may have a protective effect against T2DM, including insoluble fibers and magnesium, are removed. Future research on the mechanism underlying the relationship between rice intake and glucose metabolism is needed to answer these questions.

The types of wheat and wheat products vary greatly between Western and Asian countries, with notable differences between Western and Eastern noodles, pancakes, and steamed buns. Although several studies have explored the relationship between wheat-based food intake and the risk of T2DM, the conclusions remain inconsistent[35-37]. Compared to the association studies on wheat-based foods and the risk of being overweight or obese, limited studies focused on abnormal glucose metabolism and diabetes. In this study, no significant correlation was found between the intake of wheat and wheat products in the trajectory groups and the risk of T2DM, which needs to be verified in future population-based epidemiological studies. Zhang et al. used CHNS data from 1991 to 2015 and found that higher wheat intake was associated with the risk of overweight/obesity among Chinese adults[38]. Furthermore, an inverse association between rice intake and overweight/obesity was observed in Chinese men but not in women, which is consistent with the results of this study.

Trends in Meat Intake and T2DM

We found that a low total meat intake was associated with a higher risk of T2DM. We reviewed relevant literature and found little support to explain the impact of low animal protein intake on the risk of T2DM. Further analyses are required to explore the possible causes and mechanisms. We speculate that people with low animal protein intake tend to shift towards high-carbohydrate or fatty foods to maintain their energy needs, taste preferences, and satiety. This may be the possible reason for the increased risk of T2DM. By analyzing the intake of other foods in the multi-trajectory group (Appendices 14 and 15), we found that the population in the trajectory group with low animal protein intake had a higher proportion of carbohydrates in the form of wheat and its products and a very low intake of dark-colored vegetables and fruits. The findings of this study suggest that a diet characterized by reduced intake of foods containing animal protein does not necessarily have a beneficial effect on health outcomes related to glucose metabolism. It is also important to pay attention to the intake of carbohydrates, fats, and other food components, such as fruits and vegetables, that have protective effects on blood glucose regulation.

Trends in Vegetables and Fruits Intake and T2DM

The trajectory group with a rapid decline in dark-colored vegetable intake had a higher risk of T2DM, suggesting that changes in intake over time, in addition to absolute intake levels, may be relevant to T2DM risk. Currently, Chinese residents are in a period of dietary structure transition, characterized by a decrease in vegetable intake and an increase in the intake of animal foods, especially red meat. A decline in vegetable intake may also be accompanied by greater consumption of energy-dense foods, including meat, high-fat foods, sugar-sweetened beverages, and refined carbohydrates. This dietary shift may reduce the intake of beneficial bioactive components contained in dark-colored vegetables, while increasing exposure to dietary factors associated with inflammation, weight gain, and impaired glucose regulation[39-42]. In China, vegetables are categorized as dark- and light-colored. Dark-colored vegetables contain higher amounts of phytochemicals than light-colored vegetables, which play an important role in reducing inflammatory responses, antioxidation, and free radical scavenging[43,44]. These differences may partly explain the lack of significant association between light-colored vegetable intake and T2DM risk in this study. Vegetables and fruits vary substantially in their nutritional composition, highlighting the potential importance of dietary diversity. Consitent with this concept, a prospective study found that greater diversity in vegetable and fruit intake was associated with a lower risk of T2DM[45].

Possible Mechanisms of Dietary Effects on Glucose Metabolism

However, the etiology and pathogenic mechanisms of T2DM remain unclear. Its prominent

pathophysiological features encompass a reduced capacity of insulin to regulate glucose metabolism, coupled with a lower insulin secretion caused by functional defects in pancreatic β-cells. Chronic low-grade inflammation is a nonspecific, persistent, mild inflammatory condition. This type of inflammation is distinguished by its prolonged duration, mild and continuous stimulation by inflammatory factors, and often inconspicuous clinical manifestations, leading to the designation of "chronic low-grade inflammation." Obesity, T2DM, atherosclerosis, and nonalcoholic fatty liver disease share a pivotal commonality: chronic low-grade inflammation marked by a 2- to 3-fold increase in plasma inflammatory cytokines, which significantly contributes to the onset and progression of these diseases. Chronic low-grade inflammation is a prevalent condition among T2DM patients and exerts a notable influence on both the development of T2DM and its associated complications[46,47].

Diet is a modifiable factor that can influence the onset and progression of diabetes by modulating the body's inflammatory response. A prospective study conducted in the United States investigated the association between pro-inflammatory diets and an elevated risk of CVD revealed that individuals with higher Dietary Inflammation Pattern scores, a metric for evaluating the inflammatory potential of dietary patterns, showed an increased incidence of CVD, including coronary artery disease and stroke, among both genders[48]. Data from a study of older Latino participants demonstrated an inverse relationship between the frequency of fruit and vegetable consumption and the concentrations of C-reactive protein (CRP) and homocysteine. Each additional serving of fruit and vegetables was associated with a 21% reduction in the risk of elevated CRP levels and a 17% decrease in homocysteine concentration[49]. Collectively, the current study underscores the association between healthy diet and diminished levels of inflammatory biomarkers[50]. Diets that exacerbate chronic systemic inflammation are typically characterized by high sugar, salt, and fat contents, as exemplified by processed meat products and fried foods. Foods that mitigate chronic inflammation include fresh fruit, vegetables, whole grains, legumes, nuts, and fish. If chronic inflammation is indeed a common feature in patients with T2DM and plays an important role in the development of T2DM, reducing the intake of foods that promote chronic inflammation may be an effective strategy for preventing T2DM.

Strengths and Limitations

The strengths of the present study include the long follow-up period, quantitative measurement of the main food intake, repeated assessments of dietary intake, detailed collection of demographic and socioeconomic data, lifestyle data allowing for adjustment for potential confounders, and comprehensive comparisons of multiple food intake patterns with T2DM within the same analytical framework. In addition, this study not only focused on the impact of a specific type of food intake, but also on the impact of long-term trends in food intake on the risk of subsequent T2DM, thus offering a novel perspective.

However, this study has some limitations that warrant consideration. First, reliance on three consecutive 24-hour dietary recalls may have underestimated the consumption of sporadically consumed foods, such as whole grains and aquatic products. Second, to fulfill the trajectory model fitting requirements, we imposed stringent inclusion criteria on our study design, potentially diminishing the representativeness of the samples analyzed, which may have limited the generalizability of our findings. Additionally, a certain degree of selection bias exists due to the exclusion of a substantial number of participants. Third, despite extensive covariate adjustments, residual confounding remained possible because of the observational study design.

CONCLUSION

This longitudinal study shows that distinct trajectories of long-term dietary patterns have differential associations with subsequent T2DM. Our findings suggest that monitoring temporal changes in food consumption patterns could serve as a practical tool for early identification of individuals at higher risk of diabetes. The identified dietary trajectories provide an evidence-based framework for developing targeted prevention strategies and highlight the importance of sustained dietary pattern surveillance in public health initiatives. Future research should focus on validating these trajectory patterns in diverse populations and evaluating the effectiveness of trajectory-based interventions in diabetes prevention programs. These efforts could substantially improve our ability to identify high-risk individuals and implement timely and personalized dietary interventions to mitigate the risk of diabetes at the population level.

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Authors' Contributions Data analysis and manuscript writing Methodology and software: Jiguo Zhang, Hongru Jiang, and Lixin Hao. Software, visualization, writing, review, and editing: Jue Liu, Liusen Wang, Weiyi Gong and Weiyi Li. Data collection and project administration: Huijun Wang, Ping Gan, and Jian Wen. Project administration and guidance for manuscript writing: Zhihong Wang and Gangqiang Ding.

Ethics The survey was approved by the Institutional Review Committee of the National Institute for Nutrition and Health, Chinese Center for Disease Control and Prevention (No. 2015-017 and No. 2018-004). All participants signed an informed consent form prior to the survey.

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REFERENCES

1. Magliano DJ, Islam RM, Barr ELM, et al. Trends in incidence of total or type 2 diabetes: systematic review. BMJ, 2019; 366, l5003.
2. Sun H, Saeedi P, Karuranga S, et al. IDF diabetes atlas: global, regional and country-level diabetes prevalence estimates for 2021 and projections for 2045. Diabetes Res Clin Pract, 2022; 183, 109119.
3. Li YZ, Teng D, Shi XG, et al. Prevalence of diabetes recorded in mainland China using 2018 diagnostic criteria from the American Diabetes Association: national cross sectional study. BMJ, 2020; 369, m997.
4. Wang LM, Peng W, Zhao ZP, et al. Prevalence and treatment of diabetes in China, 2013-2018. JAMA, 2021; 326, 2498−506.
5. Fletcher B, Gulanick M, Lamendola C. Risk factors for type 2 diabetes mellitus. J Cardiovasc Nurs, 2002; 16, 17−23.
6. Zheng Y, Ley SH, Hu FB. Global aetiology and epidemiology of type 2 diabetes mellitus and its complications. Nat Rev Endocrinol, 2018; 14, 88−98.
7. GBD 2017 Diet Collaborators. Health effects of dietary risks in 195 countries, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet, 2019; 393, 1958−72.
8. Yusuf S, Joseph P, Rangarajan S, et al. Modifiable risk factors, cardiovascular disease, and mortality in 155 722 individuals from 21 high-income, middle-income, and low-income countries (PURE): a prospective cohort study. Lancet, 2020; 395, 795−808.
9. Wang PL, Song MY, Eliassen AH, et al. Optimal dietary patterns for prevention of chronic disease. Nat Med, 2023; 29, 719−28.
10. 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.
11. Barbaresko J, Lang A, Szczerba E, et al. Dietary factors and all-cause mortality in individuals with type 2 diabetes: a systematic review and meta-analysis of prospective observational studies. Diabetes Care, 2023; 46, 469−77.
12. Schwingshackl L, Hoffmann G, Lampousi AM, et al. Food groups and risk of type 2 diabetes mellitus: a systematic review and meta-analysis of prospective studies. Eur J Epidemiol, 2017; 32, 363−75.
13. Sami W, Ansari T, Butt NS, et al. Effect of diet on type 2 diabetes mellitus: a review. Int J Health Sci (Qassim), 2017; 11, 65−71.
14. Hu EA, Pan A, Malik V, et al. White rice consumption and risk of type 2 diabetes: meta-analysis and systematic review. BMJ, 2012; 344, e1454.
15. Aune D, Norat T, Romundstad P, et al. Whole grain and refined grain consumption and the risk of type 2 diabetes: a systematic review and dose-response meta-analysis of cohort studies. Eur J Epidemiol, 2013; 28, 845−58.
16. Mamluk L, O'Doherty MG, Orfanos P, et al. Fruit and vegetable intake and risk of incident of type 2 diabetes: results from the consortium on health and ageing network of cohorts in Europe and the United States (CHANCES). Eur J Clin Nutr, 2017; 71, 83−91.
17. Ford ES, Mokdad AH. Fruit and vegetable consumption and diabetes mellitus incidence among U. S. adults. Prev Med, 2001; 32, 33−9.
18. Liaset B, Øyen J, Jacques H, et al. Seafood intake and the development of obesity, insulin resistance and type 2 diabetes. Nutr Res Rev, 2019; 32, 146−67.
19. Du HD, Guo Y, Bennett DA, et al. Red meat, poultry and fish consumption and risk of diabetes: a 9 year prospective cohort study of the China Kadoorie Biobank. Diabetologia, 2020; 63, 767−79.
20. Aune D, Norat T, Romundstad P, et al. Dairy products and the risk of type 2 diabetes: a systematic review and dose-response meta-analysis of cohort studies. Am J Clin Nutr, 2013; 98, 1066−83.
21. Shin JY, Xun PC, Nakamura Y, et al. Egg consumption in relation to risk of cardiovascular disease and diabetes: a systematic review and meta-analysis. Am J Clin Nutr, 2013; 98, 146−59.
22. Zhang B, Zhai FY, Du SF, et al. The China health and nutrition survey, 1989-2011. Obes Rev, 2014; 15, 2−7.
23. Alberti KGMM, Zimmet PZ. Definition, diagnosis and classification of diabetes mellitus and its complications. Part 1: diagnosis and classification of diabetes mellitus. Provisional report of a WHO consultation. Diabet Med, 1998; 15, 539−53.
24. Chinese Diabetes Society. Guideline for the prevention and treatment of type 2 diabetes mellitus in China (2020 edition). Chin J Diabetes, 2021; 13, 315−409. (In Chinese)
25. Nagin DS, Odgers CL. Group-based trajectory modeling in clinical research. Annu Rev Clin Psychol, 2010; 6, 109−38.
26. Nagin DS. Group-based trajectory modeling: an overview. Ann Nutr Metab, 2014; 65, 205−10.
27. van der Nest G, Lima Passos V, Candel MJJM, et al. An overview of mixture modelling for latent evolutions in longitudinal data: modelling approaches, fit statistics and software. Adv Life Course Res, 2020; 43, 100323.
28. Ju LH, Yu DM, Fang HY, et al. Trends and food sources composition of energy, protein and fat in Chinese residents, 1992-2012. J Hyg Res, 2018; 47, 689−94,704. (In Chinese)
29. Zhao LY, Fang YH, He YN, et al. Trends of food consumption

among Chinese population in 1992—2012. J Hyg Res, 2016; 45, 522−6. (In Chinese)
30. Yang WY, Lu JM, Weng JP, et al. Prevalence of diabetes among men and women in China. N Engl J Med, 2010; 362, 1090−101.
31. Wang LM, Gao P, Zhang M, et al. Prevalence and ethnic pattern of diabetes and prediabetes in China in 2013. JAMA, 2017; 317, 2515−23.
32. Nanri A, Mizoue T, Noda M, et al. Rice intake and type 2 diabetes in Japanese men and women: the Japan Public Health Center–based prospective study. Am J Clin Nutr, 2010; 92, 1468−77.
33. Sone H, Ito H, Ohashi Y, et al. Obesity and type 2 diabetes in Japanese patients. Lancet, 2003; 361, 85.
34. Villegas R, Liu SM, Gao YT, et al. Prospective study of dietary carbohydrates, glycemic index, glycemic load, and incidence of type 2 diabetes mellitus in middle-aged Chinese women. Arch Intern Med, 2007; 167, 2310−6.
35. Matsuoka T, Tsuchida A, Yamaji A, et al. Consumption of a meal containing refined barley flour bread is associated with a lower postprandial blood glucose concentration after a second meal compared with one containing refined wheat flour bread in healthy Japanese: a randomized control trial. Nutrition, 2020; 72, 110637.
36. de Punder K, Pruimboom L. The dietary intake of wheat and other cereal grains and their role in inflammation. Nutrients, 2013; 5, 771−87.
37. Zuñiga YLM, Rebello SA, Oi PL, et al. Rice and noodle consumption is associated with insulin resistance and hyperglycaemia in an Asian population. Br J Nutr, 2014; 111, 1118−28.
38. Zhang JG, Wang ZH, Du WW, et al. Differential association of wheat and rice consumption with overweight/obesity in Chinese adults: China health and nutrition survey 1991-2015. Front Nutr, 2022; 9, 808301.
39. Wang PY, Fang JC, Gao ZH, et al. Higher intake of fruits, vegetables or their fiber reduces the risk of type 2 diabetes: a meta-analysis. J Diabetes Invest, 2016; 7, 56−69.
40. Wallace TC, Bailey RL, Blumberg JB, et al. Fruits, vegetables, and health: a comprehensive narrative, umbrella review of the science and recommendations for enhanced public policy to improve intake. Crit Rev Food Sci Nutr, 2020; 60, 2174−211.
41. Cooper AJ, Sharp SJ, Lentjes MAH, et al. A prospective study of the association between quantity and variety of fruit and vegetable intake and incident type 2 diabetes. Diabetes Care, 2012; 35, 1293−300.
42. Blumfield M, Mayr H, De Vlieger N, et al. Should we 'eat a rainbow'? An umbrella review of the health effects of colorful bioactive pigments in fruits and vegetables. Molecules, 2022; 27, 4061.
43. Zurbau A, Au -Yeung F, Blanco Mejia S, et al. Relation of different fruit and vegetable sources with incident cardiovascular outcomes: a systematic review and meta-analysis of prospective cohort studies. J Am Heart Assoc, 2020; 9. **(查阅网上资料, 未找到页码信息, 请确认补充)**
44. Hamer M, Chida Y. Intake of fruit, vegetables, and antioxidants and risk of type 2 diabetes: systematic review and meta-analysis. J Hypertens, 2007; 25, 2361−9.
45. Cooper AJ, Sharp SJ, Lentjes MAH, et al. A prospective study of the association between quantity and variety of fruit and vegetable intake and incident type 2 diabetes. Diabetes Care, 2012; 35, 1293-300. **(查阅网上资料, 本条文献与第 41 条文献重复, 请核对)**
46. Giugliano D, Ceriello A, Esposito K. The effects of diet on inflammation: emphasis on the metabolic syndrome. J Am Coll Cardiol, 2006; 48, 677−85.
47. Hotamisligil GS. Inflammation and metabolic disorders. Nature, 2006; 444, 860−7.
48. Li J, Lee DH, Hu J, et al. Dietary inflammatory potential and risk of cardiovascular disease among men and women in the U. S. J Am Coll Cardiol, 2020; 76, 2181−93.
49. Gao X, Bermudez OI, Tucker KL. Plasma C-reactive protein and homocysteine concentrations are related to frequent fruit and vegetable intake in Hispanic and non-Hispanic white elders. J Nutr, 2004; 134, 913−8.
50. Minihane AM, Vinoy S, Russell WR, et al. Low-grade inflammation, diet composition and health: current research evidence and its translation. Br J Nutr, 2015; 114, 999−1012.