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Original Communication

Association Between a Modified China Healthy Diet Index and the Prevalence of Type 2 Diabetes Mellitus in Community Populations: A Cross-Sectional Study

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Abstract

Background: Although the China Healthy Diet Index (CHDI) was designed to assess diet quality in Chinese populations, its associations with type 2 diabetes mellitus (T2DM), impaired glucose tolerance (IGT), and impaired fasting glucose (IFG) remain understudied. Adaptations may be needed when applying dietary indices to datasets with varying amounts of dietary information. This study examined associations of the modified CHDI score with T2DM, IGT, and IFG among community-dwelling adults aged 40 to 79 years in Guangzhou. **Methods:** Dietary intake was recorded using 3-day 24-hour dietary records, and diet quality was assessed with the modified CHDI. Multivariable logistic regression was used to estimate associations between the modified CHDI and T2DM, IGT, and IFG. Restricted cubic spline models assessed potential nonlinearity, and sensitivity analyses evaluated the robustness of the findings. **Results:** The mean modified CHDI score was 60.69, and 54.34% of participants had scores at or above 60. A higher modified CHDI was associated with lower odds of T2DM; each 5-point increment corresponded to a 4% reduction in odds (odds ratio [OR] = 0.96, p = 0.013). In exploratory grouped analyses, participants with higher modified CHDI scores (≥60) had lower odds of T2DM than those with lower scores (OR = 0.85, p = 0.044). Modified CHDI was not significantly associated with IGT or IFG, and spline analyses showed no evidence of nonlinearity across outcomes. **Conclusions:** Among middle-aged and older Chinese adults, greater adherence to a healthier dietary pattern, as reflected by the modified CHDI score, was associated with a lower prevalence of T2DM. Exploratory grouped analyses suggested an inverse association between higher categories of the modified CHDI score and T2DM prevalence.

Keywords: China Healthy Dietary Index; dietary quality; type 2 diabetes mellitus; impaired glucose tolerance; impaired fasting glucose

1. Introduction

The global burden of diabetes remains considerable. In 2024, an estimated 589 million adults between 20 and 79 years of age were affected by diabetes, alongside approximately 635 million individuals with impaired glucose tolerance (IGT) and 488 million with impaired fasting glucose (IFG) [1]. IGT and IFG are recognized as intermediate dysglycaemic conditions that may precede the development of type 2 diabetes mellitus (T2DM), the predominant form of diabetes worldwide, accounting for over 90% of all cases [1,2]. A recent synthesis of the 2026 American Heart Association statistics indicates that diabetes and metabolic dysfunction are increasingly important upstream contributors to cardiovascular disease (CVD), and that prevention is constrained more by implementation gaps than by the absence of pharmacological options [3]. In Asian populations, the shift toward processed and energy-dense diets may contribute to metabolic dysfunction at lower body mass index and younger ages [4]. In China, where dietary patterns are changing rapidly, identifying diet-quality patterns associated with diabetes is therefore relevant to public health.

Diet quality is increasingly evaluated using composite dietary indices that reflect overall eating patterns rather than isolated foods or nutrients. By assessing adherence to dietary recommendations, these indices capture the combined effects of multiple dietary components and have become widely used in nutritional epidemiology. Several established dietary quality scores, including the Healthy Eating Index (HEI), Alternate Healthy Eating Index (AHEI), Dietary Approaches to Stop Hypertension (DASH), and Alternative Mediterranean Diet Score (aMED), have been widely applied to investigate the relationship between overall dietary patterns and diabetes-related outcomes [5]. A meta-analysis further showed that greater adherence to the HEI, AHEI, and DASH dietary patterns was associated with an approximately 22% lower risk of T2DM [6]. Similar

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evidence has emerged from the National Health and Nutrition Examination Survey (NHANES), in which higher HEI-2015 and aMED scores were linked to a lower prevalence of prediabetes among 20,844 participants [7]. Nevertheless, the inverse association between DASH score and T2DM was reported to be stronger among White participants [8]. A review by Yip et al. [9] further suggested that Asian populations may be more susceptible to IGT, whereas white populations may be more prone to IFG. Chinese patients with T2DM also tend to have more abdominal obesity and earlier beta-cell decline than Western populations [10,11]. Because many existing diet indices were developed from non-Chinese dietary guidelines, they may not fully reflect Chinese dietary patterns or metabolic characteristics.

The China Healthy Diet Index (CHDI) was designed to evaluate dietary quality in accordance with the Dietary Guidelines for Chinese Residents (DGC) and the Chinese Food Pagoda (CFP) [12]. It combines food-group and nutrient components and provides a practical measure of diet quality in Chinese populations [13]. Higher CHDI scores have been linked to lower risks of metabolic syndrome and dyslipidemia [14,15]. Although preliminary evidence suggests an inverse association between CHDI score and hyperglycemia, evidence regarding T2DM, IGT, and IFG remains limited. However, when applying established dietary indices to different populations or epidemiological datasets, modifications may sometimes be necessary to accommodate differences in dietary assessment methods and available dietary information, while maintaining the conceptual framework of the original index. Accordingly, this study is designed to examine data from a community-based cohort in Guangzhou to assess how the association of modified CHDI is related to the prevalence of T2DM, IGT, and IFG.

2. Materials and Methods

2.1 Study Design and Population

Eligible residents aged 40–79 years who had lived in communities surrounding Yuexiu District, Guangzhou, for at least five years were enrolled in 2011 in the REACTION study (Risk Evaluation of Cancers in Chinese Diabetic Individuals: A Longitudinal Study). Details of this cohort have been reported previously [16]. The present analysis was based exclusively on data collected at the local study center of the REACTION study. The study protocol was approved by the Ethics Committee of Sun Yat-sen Memorial Hospital, Sun Yat-sen University, and the Ethics Committee of Ruijin Hospital, Shanghai Jiao Tong University School of Medicine March 10, 2011 (approval No. 14), and all participants provided written informed consent.

Overall, 3845 dietary questionnaires from participants were collected and entered into EpiData 3.1 (EpiData Association, Odense, Denmark). Of the initially screened participants, 55 were excluded because of a history of cancer, stroke, or myocardial infarction. A further 9 participants were removed because their reported energy intake was considered implausible (<800 or >4000 kcal/day for men; <500 or >3500 kcal/day for women), and 23 were excluded because more than 60% of their demographic and measurement variables were missing. After these exclusions, 3758 participants remained for the final analysis (Fig. 1).

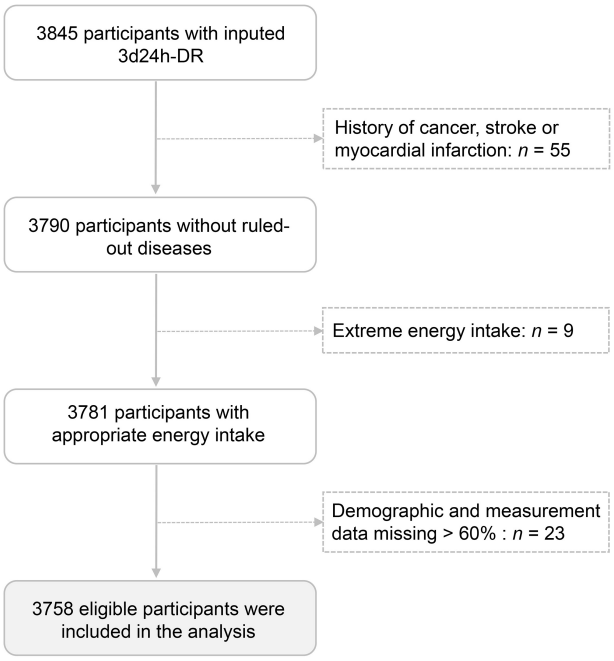


Fig. 1. Flow diagram illustrating participant selection and exclusions. 3d24h-DR, 3-day 24-hour dietary records.

2.2 Assessment of Modified CHDI

Dietary exposure was characterized using 3-day 24-hour dietary records (3d24h-DR), which included two consecutive weekdays and one weekend day. The dietary assessment questionnaire has been detailed in previous publications [17,18]. Its performance was supported by a validation study in Fujian Province, where dietary information obtained from 3d24h-DR was compared with that from a semi-quantitative food frequency questionnaire among 142 adults [19]. Correlations between the two methods ranged from 0.41 to 0.72 for food groups and from 0.40 to 0.70 for nutrients. Moreover, 78.8%–95.1% of participants were assigned to either the same or an adjacent tertile by the two approaches, indicating acceptable agreement in the classification of dietary intake among Chinese adults. Energy and nutrient intakes were subsequently quantified according to the Chinese Food Composition Table (2022 edition).

Based on the DGC (2016 edition) and the CFP, the CHDI includes food-group components (Components 1–10) and nutrient components (Components 11–13). Higher scores indicate greater food-group adequacy and lower in-

take of nutrients or components that should be limited. The scoring criteria for Components 2–12 in the modified CHDI followed the original CHDI report [13]. Because the 3d24h-DR questionnaire did not comprehensively capture alcohol or added sugar intake, and could not calculate the original food variety score, Components 1 and 13 were modified (Table 1). The original CHDI used the average number of food items ingested daily for Component 1 (food variety). In the study, only the distinct foods ingested during a three-day period are available, and repeated consumption between survey days cannot be identified. Based on the DGC (2022 edition), which recommends consuming ≥12 food types per day and ≥25 per week, the maximum score was assigned to ≥25 food types consumed over three days, and the minimum score to ≤12 types. Since alcohol information was incomplete and added sugar intake was not systematically assessed, the original empty calorie component could not be reproduced. Consequently, the percentage of total energy derived from edible oils was used to determine Component 13. The thresholds were adapted so that oil-derived energy ≤10% received the maximum score and ≥26% received the minimum score. Better nutritional quality was indicated by higher scores on the modified CHDI scale, which ran from 0 to 100. Therefore, the index used in this study should be interpreted as a modified CHDI rather than the original CHDI. A diet was deemed qualified if it scored at or above 60, which was regarded as the minimal requirement for acceptable diet quality [13]. The formula was used to determine intermediate values for Components 1–10:

$$\text{Intermediate values} = \frac{(\text{actual intake} - \text{intake of the minimum score})}{(\text{intake of the maximum score} - \text{intake of the minimum score})} \times \text{maximum score}$$

Intermediate values for Components 11–13 were calculated using the formula:

$$\text{Intermediate values} = \frac{(\text{intake of the minimum score} - \text{actual intake})}{(\text{intake of the minimum score} - \text{intake of the maximum score})} \times \text{maximum score}$$

2.3 Study Outcomes

To evaluate fasting plasma glucose (FPG), glycated hemoglobin (HbA1c), and 2-hour plasma glucose (2hPG), blood samples were taken following an overnight fast and two hours following a 75-g oral glucose tolerance test (OGTT). Outcomes were defined according to the IDF Diabetes Atlas [1]. T2DM was defined by any of the following criteria: (I) HbA1c ≥6.5%; (II) FPG ≥7.0 mmol/L; (III) 2hPG ≥11.1 mmol/L; (IV) random plasma glucose ≥11.1 mmol/L with symptoms of hyperglycaemia; or (V) use of medical treatment for diabetes. IGT was defined as FPG <7.0 mmol/L and 7.8 mmol/L ≤ 2hPG < 11.1 mmol/L. IFG was defined as 6.1 mmol/L ≤ FPG < 7.0 mmol/L, with 2hPG <7.8 mmol/L when 2hPG data were available. T2DM included both previously diagnosed and newly detected cases. IGT and IFG were analysed as separate binary outcomes among participants without T2DM; therefore, overlap between IGT and IFG could remain among non-T2DM participants.

2.4 Assessment of Covariates

Demographic characteristics, anthropometric measurements, and laboratory parameters were collected by trained investigators following standardized protocols. The covariates considered in the analyses included age, sex, education level, smoking status, alcohol drinking, tea drinking, activity level, central obesity, and hypertension.

Education level was grouped into three categories: middle school or below, high school or technical secondary school, and university degree or above. Participants were classified as smokers if they reported smoking at least one cigarette per day or seven cigarettes per week for a minimum duration of six months. Alcohol consumption was defined as drinking alcohol at least once weekly for six months or longer. Tea-drinking status included current or former tea drinkers who consumed tea at least once per week. Central obesity was determined according to waist circumference thresholds of ≥90 cm for men and ≥85 cm for women [20]. Hypertension was defined based on systolic blood pressure ≥140 mmHg, diastolic blood pressure ≥90 mmHg, or the current use of antihypertensive medication [21]. Activity level was classified by occupation as light, moderate, or heavy. Cadres, medical and education workers, retired cadres, and unemployed participants were assigned to the light category; military personnel, self-employed participants, business or enterprise workers, governors, housewives, and others were assigned to the moderate category; and workers and farmers were assigned to the heavy category.

2.5 Statistical Analysis

All statistical analyses were conducted using R software (version 4.5.2; R Foundation for Statistical Computing, Vienna, Austria). Statistical significance was determined using a two-sided α level of 0.05. Categorical variables are summarized as numbers with percentages, whereas continuous variables are expressed as mean ± standard deviation ($\bar{x} \pm$ SD). Differences in modified CHDI scores among participants with different diabetes statuses were assessed using one-way analysis of variance (ANOVA), followed by Bonferroni-adjusted pairwise comparisons. Modified CHDI scores were also divided into quartiles (Q1–Q4, in ascending order), and differences across quartiles were evaluated using ANOVA or chi-

Table 1. Modified CHDI components and standards for scoring.

No.	Modified CHDI components	Maximum score	Criteria for maximum score	Criteria for minimum score
1	Food variety[a]	10	≥25 varieties	≤12 varieties
2	Refined grains	5	≥100 g/1000 kcal	No intake
3	Whole grain, dry bean and tuber	5	≥40 g/1000 kcal	No intake
4	Total vegetables	5	≥180 g/1000 kcal	No intake
5	Dark green and orange vegetables	5	≥90 g/1000 kcal	No intake
6	Fruit	10	≥110 g/1000 kcal	No intake
7	Dairy	10	≥100 g/1000 kcal	No intake
8	Soybean	10	≥10 g/1000 kcal	No intake
9	Meat and egg	5	≥50 g/1000 kcal	No intake
10	Fish, shellfish and mollusc	5	≥30 g/1000 kcal	No intake
11	Calories from saturated fatty acids	10	<10%	≥15%
12	Sodium	10	≤1 g/1000 kcal	≥4 g/1000 kcal
13	Empty calories[b]	10	≤10%	≥26%

Abbreviations: CHDI, China Healthy Diet Index.

[a] Food variety was assessed using the total number of unique food items consumed over the 3-day dietary assessment (adapted from the original CHDI).

[b] Empty calories were calculated from edible-oil-derived energy only (adapted from the original CHDI).

square tests, as appropriate. Associations between modified CHDI scores and the prevalence of T2DM, IGT, and IFG were examined using multivariable logistic regression models and restricted cubic spline (RCS) analyses. Four sequential models were constructed. Model 1 included no adjustment variables. Model 2 adjusted for age, sex, and education level. Model 3 additionally incorporated activity level, smoking status, alcohol consumption, and tea-drinking status. Model 4 further adjusted for central obesity. Stratified analyses were conducted to explore whether associations varied across predefined subgroups. To assess potential correlations among individual dietary components, Spearman correlation coefficients were calculated among the 13 components of the modified CHDI. Multicollinearity was further evaluated using variance inflation factors (VIFs) by including all CHDI components simultaneously in a multivariable model.

Missing data were addressed using multiple imputation implemented with the mice package (version 3.18.0; CRAN, https://CRAN.R-project.org/package=mice). Five imputed datasets were generated with 10 iterations per dataset, and convergence was confirmed before analysis. Each regression model was fitted separately within each imputed dataset, and estimates were subsequently pooled according to Rubin's rules. Predictive mean matching was applied for continuous variables, logistic regression for binary variables, and polytomous regression for categorical variables with multiple levels.

Several sensitivity analyses were conducted to evaluate the robustness of the findings. First, the main analyses were repeated among participants with complete data only. Second, logistic regression analyses were repeated after excluding participants with previously diagnosed diabetes. Third, the modified CHDI was recalculated after excluding Components 3 (whole grain, dry bean and tuber) and 9 (meat and egg), Components 1 (food variety) and/or 13 (empty calories), and the fully adjusted models were repeated. Finally, sensitivity analyses were conducted by additionally adjusting for daily energy intake (kcal/day) in the regression models. These analyses were conducted for the primary T2DM analysis and repeated after excluding participants with previously diagnosed diabetes.

This study was reported according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

3. Results

3.1 General Characteristics

Baseline characteristics of the 3758 participants are presented in Table 2. The study population consisted predominantly of women (n = 2776, 73.87%), while men accounted for 982 participants (26.13%). The cumulative average modified CHDI score ranged from 18.37 to 93.51 points, with a mean of 60.69 ± 12.49. Overall, 2042 participants (54.34%) had scores at or above 60, whereas 1716 (45.66%) scored below this value. Participant characteristics were summarized by quartiles of cumulative average modified CHDI. Higher modified CHDI scores were more common among participants who were older, female, more educated, and engaged in lighter activity. Lower modified CHDI scores were more common among smokers and participants with central obesity or hypertension. Significant differences across modified CHDI quartiles were observed for body mass index (BMI), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), FPG, 2hPG, and HbA1c. The overall prevalence of T2DM, IGT, and IFG was 24.35%, 24.37%, and 6.71%, respectively. Compared with participants in the lowest quartile (Q1), those in the

Table 2. General characteristics of participants with quartile of modified CHDI.

Characteristics	Total (n = 3758)	Q1 (n = 941)	Q2 (n = 939)	Q3 (n = 940)	Q4 (n = 938)	p
Modified CHDI score	60.69 ± 12.49	44.15 ± 6.30	57.02 ± 2.61	65.53 ± 2.44	76.12 ± 4.81	<0.001
Age, years	56.29 ± 7.55	56.34 ± 8.45	55.70 ± 7.75	56.02 ± 7.17	57.09 ± 6.63	<0.001
Female, *n* (%)	2776 (73.87)	632 (67.16)	688 (73.27)	723 (76.91)	733 (78.14)	<0.001
Smoker, *n* (%)	595 (15.83)	192 (20.40)	169 (18.00)	133 (14.15)	101 (10.77)	<0.001
Alcohol drinkers, *n* (%)	1006 (26.77)	273 (29.01)	250 (26.62)	244 (25.96)	239 (25.48)	0.316
Tea drinkers, *n* (%)	1815 (48.30)	474 (50.37)	468 (49.84)	455 (48.40)	418 (44.56)	0.051
Central obesity, *n* (%)	1021 (27.17)	305 (32.41)	262 (27.90)	240 (25.53)	214 (22.81)	<0.001
Education level, *n* (%)						<0.001
Middle school or below	1474 (39.22)	436 (46.33)	390 (41.53)	335 (35.64)	313 (33.37)	
High school or technical secondary school	1957 (52.08)	437 (46.44)	475 (50.59)	531 (56.49)	514 (54.80)	
University degree or above	327 (8.70)	68 (7.23)	74 (7.88)	74 (7.87)	111 (11.83)	
Activity level, *n* (%)						<0.001
Light	2856 (76.00)	692 (73.54)	680 (72.42)	717 (76.28)	767 (81.77)	
Moderate	502 (13.36)	141 (14.98)	145 (15.44)	125 (13.30)	91 (9.70)	
Heavy	400 (10.64)	108 (11.48)	114 (12.14)	98 (10.43)	80 (8.53)	
BMI, kg/m^2	23.21 ± 3.13	23.65 ± 3.21	23.17 ± 3.11	23.30 ± 3.28	22.72 ± 2.82	<0.001
TG, mmol/L	1.56 ± 1.20	1.69 ± 1.34	1.53 ± 1.09	1.51 ± 1.20	1.49 ± 1.15	0.001
TC, mmol/L	5.14 ± 1.31	5.14 ± 1.32	5.14 ± 1.27	5.09 ± 1.36	5.20 ± 1.27	0.342
HDL-C, mmol/L	1.31 ± 0.37	1.27 ± 0.36	1.31 ± 0.36	1.31 ± 0.38	1.36 ± 0.37	<0.001
LDL-C, mmol/L	3.09 ± 0.98	3.09 ± 1.00	3.12 ± 0.96	3.05 ± 1.00	3.11 ± 0.94	0.348
FPG, mmol/L	5.70 ± 1.35	5.79 ± 1.45	5.75 ± 1.48	5.67 ± 1.34	5.60 ± 1.08	0.008
2hPG, mmol/L	8.30 ± 3.23	8.56 ± 3.43	8.36 ± 3.48	8.06 ± 2.98	8.22 ± 2.96	0.007
HbA1c, %	6.10 ± 0.90	6.16 ± 0.93	6.13 ± 0.99	6.08 ± 0.94	6.04 ± 0.71	0.013
FINS, μU/mL	8.16 ± 6.91	8.29 ± 5.21	8.44 ± 7.45	8.07 ± 5.86	7.84 ± 8.61	0.267
Hypertension, *n* (%)	808 (21.50)	216 (22.95)	196 (20.87)	200 (21.28)	196 (20.90)	0.653
T2DM, *n* (%)	915 (24.35)	269 (28.59)	219 (23.32)	214 (22.77)	213 (22.71)	0.006
IGT, *n* (%)	916 (24.37)	215 (22.85)	239 (25.45)	225 (23.94)	237 (25.27)	0.516
IFG, *n* (%)	252 (6.71)	69 (7.33)	66 (7.03)	57 (6.06)	60 (6.40)	0.680

Abbreviations: CHDI, China Healthy Diet Index; BMI, body mass index; TG, triglycerides; TC, total cholesterol; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; FPG, fasting plasma glucose; 2hPG, 2-hour plasma glucose following an oral glucose tolerance test; HbA1c, glycated hemoglobin; FINS, fasting insulin; T2DM, type 2 diabetes mellitus; IGT, impaired glucose tolerance; IFG, impaired fasting glucose. Q1, lowest quartile; Q2, second quartile; Q3, third quartile; Q4, highest quartile.

highest quartile (Q4) showed a lower prevalence of T2DM (22.71% vs. 28.59%; p = 0.006). In contrast, the distributions of IGT and IFG did not significantly differ across modified CHDI quartiles (p = 0.516 and 0.680, respectively). Consistently, no statistically significant associations between modified CHDI and IGT or IFG were identified in multivariable models.

Modified CHDI scores were also compared across diabetes status groups (**Supplementary Fig. 1**). Participants without diabetes had the highest mean modified CHDI score (61.08 ± 12.28), followed by those with newly detected diabetes (59.60 ± 13.20) and known diabetes (59.24 ± 12.85; p = 0.003). After Bonferroni correction, the mean score did not differ significantly between participants with previously diagnosed T2DM and those with newly detected T2DM (adjusted p = 1.000), indicating similar modified CHDI levels in these two diabetes groups. Similarly, among participants with previously diagnosed T2DM, modified CHDI scores were comparable between those with known treatment (59.13 ± 12.97) and those with known untreated status (59.67 ± 12.46) (p = 0.762).

3.2 Association Between Modified CHDI Score and T2DM, IGT, and IFG

As shown in Table 3, continuous modified CHDI was inversely associated with T2DM after covariate adjustment (OR = 0.96, 95% CI: 0.93–0.99). In quartile analysis, participants in Q4 had 22% lower odds of T2DM than those in Q1 (OR = 0.78, 95% CI: 0.63–0.97). Modified CHDI was not significantly associated with IGT or IFG in any model.

RCS analyses revealed no significant nonlinear association between modified CHDI and T2DM, IGT, or IFG (Fig. 2, **Supplementary Fig. 2**). For T2DM, the overall association was significant (p for overall = 0.020), and the relationship appeared approximately linear without a significant nonlinear component. When the modified CHDI

Table 3. Association between average modified CHDI score and prevalence of T2DM, IGT, and IFG.

Item	Continuous modified CHDI (per 5 score increment)		Categorical modified CHDI				
	OR (95% CI)	*p*	Q1 OR (95% CI)	Q2 OR (95% CI)	Q3 OR (95% CI)	Q4 OR (95% CI)	*p* for trend
T2DM							
Case/*n*	915/3758		269/941	219/939	214/940	213/938	
Model 1	0.95 (0.92, 0.98)	0.001	1.00 (Ref.)	0.76 (0.62, 0.93)	0.74 (0.60, 0.91)	0.73 (0.60, 0.90)	0.002
Model 2	0.95 (0.92, 0.98)	0.001	1.00 (Ref.)	0.79 (0.64, 0.98)	0.77 (0.62, 0.95)	0.73 (0.59, 0.90)	0.003
Model 3	0.95 (0.92, 0.98)	0.002	1.00 (Ref.)	0.79 (0.64, 0.98)	0.77 (0.62, 0.95)	0.73 (0.59, 0.91)	0.004
Model 4	0.96 (0.93, 0.99)	0.013	1.00 (Ref.)	0.81 (0.65, 1.01)	0.80 (0.65, 1.00)	0.78 (0.63, 0.97)	0.025
IGT							
Case/*n*	916/2843		215/672	239/720	225/726	237/725	
Model 1	1.01 (0.98, 1.04)	0.525	1.00 (Ref.)	1.06 (0.84, 1.32)	0.95 (0.76, 1.20)	1.03 (0.82, 1.29)	0.990
Model 2	1.01 (0.98, 1.04)	0.585	1.00 (Ref.)	1.07 (0.85, 1.34)	0.97 (0.77, 1.21)	1.01 (0.81, 1.27)	0.889
Model 3	1.01 (0.98, 1.04)	0.617	1.00 (Ref.)	1.07 (0.86, 1.35)	0.97 (0.77, 1.21)	1.01 (0.80, 1.27)	0.871
Model 4	1.01 (0.98, 1.05)	0.412	1.00 (Ref.)	1.10 (0.87, 1.38)	0.99 (0.78, 1.24)	1.05 (0.83, 1.32)	0.895
IFG							
Case/*n*	252/2843		69/672	66/720	57/726	60/725	
Model 1	0.95 (0.91, 1.01)	0.077	1.00 (Ref.)	0.88 (0.62, 1.26)	0.74 (0.52, 1.08)	0.79 (0.55, 1.13)	0.129
Model 2	0.96 (0.91, 1.02)	0.181	1.00 (Ref.)	0.91 (0.64, 1.31)	0.79 (0.54, 1.14)	0.84 (0.58, 1.21)	0.253
Model 3	0.96 (0.91, 1.01)	0.140	1.00 (Ref.)	0.92 (0.64, 1.32)	0.78 (0.54, 1.13)	0.83 (0.57, 1.20)	0.219
Model 4	0.96 (0.91, 1.02)	0.169	1.00 (Ref.)	0.93 (0.65, 1.33)	0.79 (0.54, 1.14)	0.84 (0.58, 1.22)	0.256

Abbreviations: CHDI, China Healthy Diet Index; T2DM, type 2 diabetes mellitus; IGT, impaired glucose tolerance; IFG, impaired fasting glucose; OR, odds ratio; CI, confidence interval. Model 1 denotes the crude analysis. Model 2 accounts for age (continuous), sex (male or female), and educational attainment (junior high school or below, high school or technical secondary school, or undergraduate or above). Model 3 additionally incorporates smoking status (yes or no), alcohol drinking (yes or no), tea drinking (yes or no), and physical activity level (light, moderate, or heavy), whereas Model 4 further adjusts for central obesity (yes or no). Participants with T2DM were excluded from analyses involving IGT and IFG. Ref, Reference.

score was below 57, the spline curve suggested lower odds of T2DM as the score increased, whereas the curve was relatively flat around OR = 1 above 57. Given the absence of statistical evidence of nonlinearity, this visual pattern should be interpreted cautiously.

Exploratory grouped analyses used the visually suggested point near 57 from the RCS curve and the predefined minimum standard point of 60 (Table 4). After full adjustment, participants with CHDI ≥57 had lower odds of T2DM than those with CHDI <57 (Model 4: OR = 0.83; 95% CI: 0.71–0.98; $p = 0.027$). A comparable inverse association was observed when the threshold was set at 60, with CHDI scores ≥60 associated with reduced odds of T2DM (Model 4: OR = 0.85; 95% CI: 0.73–1.00; $p = 0.044$). These points were used for exploratory interpretation and were not treated as validated biological thresholds.

Supplementary Fig. 3 presents associations between individual modified CHDI component scores and T2DM. After adjusting for potential confounders, the ORs for every 5-point increase in component scores were as follows: 0.50 for meat and egg (95% CI: 0.30–0.83), 0.79 for dark green and orange vegetables (95% CI: 0.62–1.00), and 0.56 for sodium (95% CI: 0.43–0.73). Conversely, whole grain, dry bean and tuber (OR = 1.29, 95% CI: 1.04–1.61) and empty calories (OR = 1.37, 95% CI: 1.05–1.78) showed unexpected positive associations with T2DM. No associations were observed between the scores of other components and T2DM prevalence. Correlation analyses showed generally weak-to-moderate correlations among the 13 modified CHDI components. Although the strongest correlation was observed between sodium and empty calories ($\rho = 0.74$), Variance inflation factor (VIF) values ranged from 1.03 to 1.55, suggesting no substantial multicollinearity (**Supplementary Fig. 4**).

3.3 Subgroup Analysis and Sensitivity Analysis

Stratified analyses were performed to assess whether the relationship between modified CHDI score (per 5-point increment) and T2DM varied across participant characteristics (Fig. 3). The association appeared to differ according to activity level, with borderline evidence for interaction after pooling estimates from multiply imputed datasets (p for interaction = 0.049). The strongest inverse association was most evident among participants with moderate activity (OR = 0.89; 95% CI: 0.80–0.99) compared with light (OR = 0.97; 95% CI: 0.94–1.00) or heavy activity (OR = 0.94; 95% CI: 0.84–1.05). Associations were otherwise broadly consistent across subgroups, defined by age, sex, education

Table 4. Association analysis between exploratory grouping of modified CHDI and the prevalence of T2DM.

Item	Exploratory dividing point			Minimum standard point		
	<57 OR (95% CI)	≥57 OR (95% CI)	*p*	<60 OR (95% CI)	≥60 OR (95% CI)	*p*
Case/*n*	376/1391	539/2367		452/1716	463/2042	
Model 1	1.00 (Ref.)	0.80 (0.68, 0.93)	0.003	1.00 (Ref.)	0.82 (0.71, 0.95)	0.009
Model 2	1.00 (Ref.)	0.80 (0.68, 0.93)	0.005	1.00 (Ref.)	0.81 (0.70, 0.95)	0.008
Model 3	1.00 (Ref.)	0.80 (0.68, 0.93)	0.005	1.00 (Ref.)	0.82 (0.70, 0.95)	0.010
Model 4	1.00 (Ref.)	0.83 (0.71, 0.98)	0.027	1.00 (Ref.)	0.85 (0.73, 1.00)	0.044

Abbreviations: CHDI, China Healthy Diet Index; T2DM, type 2 diabetes mellitus; OR, odds ratio; CI, confidence interval. Model 1 represents the crude analysis without covariate adjustment. Model 2 accounts for age (continuous), sex (male or female), and educational attainment (junior high school or below, high school or technical secondary school, or undergraduate or above). Model 3 additionally incorporates smoking status (yes or no), alcohol drinking (yes or no), tea drinking (yes or no), and physical activity level (light, moderate, or heavy). Model 4 further includes central obesity (yes or no). Ref., Reference.

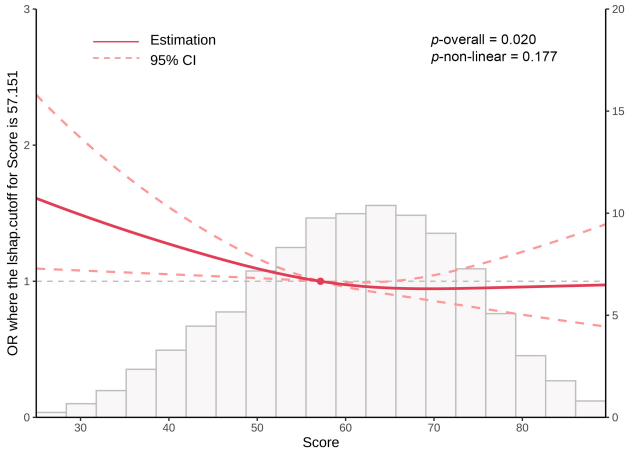


Fig. 2. Restricted cubic spline analysis of the modified China Healthy Diet Index score in relation to type 2 diabetes mellitus prevalence. Estimates were obtained from a model controlling for age (continuous), sex (male or female), educational attainment (junior high school or below, high school or technical secondary school, or undergraduate or above), smoking status (yes or no), alcohol drinking (yes or no), tea drinking (yes or no), physical activity level (light, moderate, or heavy), and central obesity (yes or no). OR, odds ratio.

level, smoking status, alcohol drinking, tea drinking, and central obesity (*p* for interaction = 0.272–0.922).

The robustness of findings after handling missing data was examined through complete-case analyses (*n* = 3588 for T2DM; *n* = 2717 for IGT/IFG; **Supplementary Table 1**). The inverse association between modified CHDI and T2DM remained statistically significant (Model 4: OR = 0.96; 95% CI: 0.93–0.99; *p* = 0.020), and the quartile-based trend remained consistent (*p*-trend = 0.037). No associations with IGT or IFG were observed, consistent with the main analysis.

To assess whether pre-existing diabetes-related dietary changes influenced the observed association, participants with previously diagnosed T2DM were excluded in a sensitivity analysis (**Supplementary Table 2**). The inverse association between the continuous modified CHDI score and newly detected T2DM remained statistically significant across all adjusted models (OR = 0.96; 95% CI: 0.93–1.00; *p* = 0.048). Similarly, higher modified CHDI categories remained associated with lower prevalence of newly detected T2DM, although the linear trend was attenuated after adjustment for central obesity in Model 4.

Additional sensitivity analyses were conducted to determine whether the findings were driven by specific modified components (**Supplementary Table 3**). The inverse association between continuous modified CHDI score and T2DM remained unchanged after excluding Components 1 and 13 (OR = 0.96, 95% CI: 0.92–0.99, *p* = 0.013). Similar estimates were obtained after excluding the two components with unexpected associations with T2DM (whole grain, dry bean and tuber; meat and egg) (OR = 0.96, 95% CI: 0.93–0.99, *p* = 0.007). Leave-one-component-out analyses also produced consistent estimates, with ORs remaining 0.96 regardless of whether Component 1, Component 13, or both were excluded.

In sensitivity analyses with additional adjustment for daily energy intake, the association between modified CHDI and T2DM was slightly attenuated but remained directionally consistent. The OR for T2DM per 5-point increment in modified CHDI was 0.97 (95% CI: 0.93–1.01) in the full sample and 0.97 (95% CI: 0.93–1.01) after excluding participants with previously diagnosed diabetes (**Supplementary Table 4**).

4. Discussion

In this cross-sectional analysis, better dietary quality, as reflected by the modified CHDI, was associated with a lower prevalence of T2DM, whereas no compara-

Variable	Count	OR (95% CI)	p for interaction
Overall	3758	0.96 (0.93, 0.99)*	
Age			0.803
<60	2767	0.96 (0.92, 1.00)*	
≥60	991	0.95 (0.90, 1.01)	
Sex			0.922
Male	982	0.96 (0.91, 1.02)	
Female	2776	0.96 (0.93, 1.00)*	
Education level			0.855
Middle school or below	1474	0.96 (0.91, 1.00)	
High school or technical secondary school	1957	0.96 (0.92, 1.01)	
University degree or above	327	0.97 (0.87, 1.08)	
Smoking status			0.759
No	3163	0.96 (0.93, 0.99)*	
Yes	595	0.96 (0.89, 1.04)	
Alcohol drinking			0.819
No	2752	0.96 (0.93, 1.00)*	
Yes	1006	0.95 (0.90, 1.01)	
Tea drinking			0.653
No	1943	0.95 (0.91, 0.99)*	
Yes	1815	0.97 (0.93, 1.01)	
Activity level			0.049
Light	2856	0.97 (0.94, 1.00)	
Moderate	502	0.89 (0.80, 0.99)*	
Heavy	400	0.94 (0.84, 1.05)	
Central obesity			0.272
No	2737	0.97 (0.93, 1.01)	
Yes	1021	0.94 (0.89, 0.99)*	

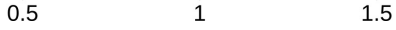


Fig. 3. Associations of modified China Healthy Diet Index component scores with type 2 diabetes mellitus prevalence for each 5-point increase. Subgroup-specific estimates were obtained using the covariate-adjusted Model 4, which included age (continuous), sex (male or female), education level (junior high school or below, high school/technical secondary school, or undergraduate or above), smoking status (yes or no), alcohol drinking (yes or no), tea drinking (yes or no), activity level (light, moderate, or heavy), and central obesity (yes or no). For analyses stratified by a given variable, that variable was removed from the corresponding model. OR, odds ratio; CI, confidence interval. * $p < 0.05$.

ble relationship was identified for IGT or IFG. The odds of T2DM were 4% lower for every 5-point increase in the modified CHDI score, and participants in the highest score quartile had 22% lower odds than those in the lowest quartile. The dose–response relationship appeared approximately linear without evidence of a threshold effect. In exploratory grouped analyses, participants with a modified CHDI score ≥60 had lower odds of T2DM than those scoring <60. These findings support an inverse relationship of dietary quality, reflected by the modified CHDI, and T2DM prevalence.

The CHDI is based on the DGC and is intended to reflect the content of these guidelines while assessing residents' dietary quality. A higher CHDI score indicates greater adherence to the DGC, characterized by higher intake of the first ten indicators and lower consumption of indicators 11 to 13. This index therefore represents the DGC principles of adequate and controlled intake. Earlier studies have validated CHDI for assessing dietary quality in Chinese populations and explored its associations with multiple health outcomes [15,22,23]. To our knowledge, this is the first study to investigate the associations of the CHDI with T2DM, IGT, and IFG simultaneously.

The mean modified CHDI score in this population was 60.69, and 54.34% of participants met the dietary-quality standard, suggesting a generally acceptable level of diet quality in this community. This proportion among middle-aged and older adults (54.34%) was higher than that reported for the broader Chinese adult population (17.7%) [13]. Diet quality is related to education, as individuals with higher educational attainment often have greater access to nutrition-related knowledge and health information [23,24]. In the present study, 60.78% of participants had completed high school, technical secondary school, or higher education. In the published REACTION cohort profile, the prevalence of diabetes in 2011 was 20.89%, and the prevalence of IGT was 24.89% [16]. As a sub-center of that cohort, our sample showed comparable prevalence

rates of T2DM (24.35%) and IGT (24.37%), supporting its relevance to the broader Chinese population.

The inverse relationship between modified CHDI and T2DM was observed after accounting for potential confounding factors. Specifically, a 5-point higher modified CHDI score corresponded to 4% lower odds of T2DM, while individuals in the highest modified CHDI quartile had 22% lower odds than those in the lowest quartile. These findings support an inverse association between modified CHDI-defined diet quality and T2DM prevalence. A meta-analysis involving over 3.2 million individuals reported that higher AHEI, HEI, and DASH scores were associated with a 19% lower T2DM risk [5]. Similarly, findings from the China Health and Nutrition Survey indicated that sustained adherence to a higher Chinese Healthy Eating Index (CHEI) was associated with a lower risk of diabetes, with each 5-point increment corresponding to a 17% reduction in risk [25]. In our study, the attenuation of the quartile trend after excluding known diabetes and adjusting for central obesity may indicate that abdominal adiposity partly lies on the pathway between diet quality and glucose metabolism. Thus, central obesity may act not only as a confounding factor but also as a potential link between dietary quality and T2DM. A healthier diet may be associated with lower abdominal adiposity, which may in turn contribute to better glucose metabolism. However, this possibility cannot be confirmed in the present cross-sectional study.

We did not observe clear associations of modified CHDI with IGT or IFG. This finding differs from some previous reports. In 20,844 US adults participating in NHANES, higher HEI-2015 and aMED scores were associated with a lower prevalence of prediabetes [7]. Likewise, among 100,494 Chinese adults, the single-point insulin sensitivity estimation index (SPISE) was independently and linearly associated with incident IFG, with each one-unit increase corresponding to a 9% lower risk [26]. SPISE may capture downstream metabolic consequences of insulin resistance, whereas CHDI reflects upstream dietary behavior whose effects may require longer follow-up to detect. Several factors may explain the inconsistency with previous studies. Diet-related effects on early dysglycemia may be modest and difficult to detect in a cross-sectional setting. Genetic susceptibility, sedentary behavior, sleep patterns, and other lifestyle factors may also dilute associations between diet quality and IGT or IFG.

Our findings indicated no nonlinear relationship between the modified CHDI and T2DM. Although the restricted cubic spline curve showed a visually steeper decline at lower modified CHDI scores and a plateau-like pattern at higher scores, this pattern does not provide statistical evidence for a meaningful threshold. Previous studies of dietary indices, including the Dietary Inflammatory Index and CHEI, have reported inverse associations with T2DM risk [25,27], but evidence for nonlinear patterns remains limited. Accordingly, the grouped analyses using scores of 57 and 60 were retained as exploratory analyses to improve clinical interpretability rather than to define optimal cut-off points. Participants classified into higher CHDI categories based on these reference points, corresponding to a higher level of adherence to the scoring criteria based on dietary guidelines, showed lower odds of T2DM. However, this value should be regarded as a descriptive reference rather than an established clinical target.

Examination of individual modified CHDI components revealed several associations with T2DM that differed from the overall association observed for the dietary index. In general, dietary patterns characterized by higher consumption of vegetables, whole grains, legumes, and tubers have been associated with a lower risk of T2DM, whereas greater intake of red meat, eggs, and oil has generally been linked to a higher risk [28,29,30,31,32]. In our analysis, higher scores for dark green and orange vegetables (Component 5), meat and egg (Component 9), and sodium (Component 12) corresponded to lower odds of T2DM, with Component 12 showing the strongest inverse association. This result should be interpreted in light of the scoring direction, as a higher CHDI score for sodium represents lower sodium intake. Nevertheless, the finding is compatible with evidence suggesting that excessive sodium consumption may adversely affect glucose metabolism and contribute to insulin resistance and T2DM through pathways involving oxidative stress, endothelial dysfunction, and metabolic disturbances [33,34,35,36,37]. Conversely, higher scores for Component 3 (whole grain, dry bean and tuber) and Component 13 (empty calories) were associated with higher odds of T2DM. Although whole grains and legumes are generally considered beneficial for metabolic health, dietary index components are influenced by the characteristics of the underlying population, food substitution patterns, and residual confounding. In addition, individuals with pre-existing metabolic abnormalities may increase their consumption of foods perceived as healthier after receiving dietary advice, which could contribute to reverse causation. Correlation and VIF analyses showed no evidence of substantial multicollinearity among dietary components, indicating that these findings were unlikely to result from strong correlations between components. Therefore, component-specific associations should be interpreted cautiously and considered within the context of the overall dietary pattern. The modified CHDI is intended to reflect overall dietary quality rather than the effect of any single dietary component. Therefore, the different directions observed for individual components should not be interpreted as inconsistent with the overall association between modified CHDI and T2DM. As suggested by Kant [38], overall diet-quality indices may better reflect the combined effects of multiple dietary factors than individual foods or nutrients.

We observed a borderline interaction between modified CHDI and physical activity. Adequate physical activity can enhance insulin sensitivity and glucose uptake

through muscle mitochondrial function and glucose transporter type 4 (GLUT4) translocation [39,40], which could strengthen the association between healthy diet and glucose metabolism. Evidence from earlier research has indicated that dietary quality and physical activity may jointly influence the risk of diabetes [41]. However, this interaction was modest, and the subgroup analyses were exploratory. Therefore, this finding should be interpreted cautiously.

Several analyses were conducted to evaluate the robustness of the association between modified CHDI and T2DM. The distribution of modified CHDI scores was comparable between participants with previously diagnosed and newly detected T2DM. Among participants with previously diagnosed T2DM, dietary quality scores were also similar between treated and untreated individuals, and mean scores in both groups remained below 60. Furthermore, the inverse association between modified CHDI and T2DM persisted after excluding participants with previously diagnosed diabetes. These results suggest that dietary changes following diabetes diagnosis may not fully account for the observed association, although reverse causation cannot be completely excluded because of the cross-sectional design. Similar estimates were obtained after excluding the modified components (food variety and empty calories) or components showing unexpected associations with T2DM, suggesting that the main findings were not driven by specific components or modifications of the CHDI scoring approach. Daily energy intake was additionally considered in sensitivity analyses because it may confound associations between dietary quality and disease outcomes. Although CHDI components incorporated energy-standardized dietary variables during score construction, additional adjustment for total daily energy intake was performed as a sensitivity analysis. Further adjustment for daily energy intake slightly attenuated the association (OR, 0.96 to 0.97), although the 95% CI crossed 1.00. Thus, the magnitude of the association changed little, but the association was less statistically certain after adjustment for total energy intake and should be interpreted cautiously.

A strength of this study is the use of a comprehensive dietary quality index that integrates food groups and nutrient intake based on Chinese dietary guidelines. In addition, the study included a relatively large community-based sample and standardized diabetes assessment using an oral glucose tolerance test, which enhanced the accuracy of diabetes classification. The consistency of the findings across sensitivity analyses lends further support to the observed inverse relationship between overall diet quality and T2DM.

Limitations

Several limitations should nevertheless be considered. First, the cross-sectional design does not allow temporal or causal relationships to be established, and reverse causation remains possible. Second, dietary intake was assessed using 3d24h-DR, which may not fully represent habitual intake over longer periods. Short-term dietary records cannot capture all within-person variation and may provide limited information on foods consumed infrequently, such as alcohol and added sugars [42,43]. Third, the modified CHDI was adapted because information on alcohol and added sugar intake was unavailable from the dietary assessment dataset. Therefore, comparisons with studies using the original CHDI should be made cautiously. Although external validation was not available in the present study, conservative modifications were applied to Components 1 and 13, and sensitivity analyses excluding these components produced similar results. Finally, residual or unmeasured confounding cannot be ruled out. Longitudinal and intervention-based research is warranted to determine whether these associations are reproducible over time and to further assess the performance and broader applicability of the modified CHDI among Chinese adults.

5. Conclusions

In brief, better dietary quality measured by the modified CHDI was related to lower odds of T2DM, whereas no clear associations were observed for IGT or IFG. The association appeared approximately linear and was broadly consistent across sensitivity analyses and most subgroups. In exploratory grouped analyses, participants with modified CHDI scores of approximately 60 or above had lower odds of T2DM among middle-aged and older adults. Future longitudinal studies and randomized interventions should determine whether these observations can be replicated and help clarify the biological pathways underlying the associations.

Availability of Data and Materials

The datasets used and analyzed in the present study can be obtained from the corresponding authors upon reasonable request.

Author Contributions

CC, MX and LY contributed to conceptualization; YZ conducted the formal analysis; YZ, YL, NL, FH, XLin, DL, SH, XZ, and PL contributed to the investigation; YZ, XLu, YL, and CW developed the methodology; XLu, CW, and CC provided supervision; LY, CW, CC, and MX contributed resources; YZ and XLu were responsible for data curation; XLu, CW, and CC contributed to funding acquisition; YZ prepared the original manuscript draft; and YZ, YL, XLu, CW, CC, and MX contributed to manuscript review and editing. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

The study was carried out in accordance with the guidelines of the Declaration of Helsinki. Data collection and analysis were approved by the Ethics Committee of Sun Yat-sen Memorial Hospital, Sun Yat-sen University, and the Ethics Committee of Ruijin Hospital, Shanghai Jiao Tong University School of Medicine. Both approvals were granted on March 10, 2011, under approval No. 14. Participants in this study all signed an informed consent form.

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Not applicable.

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Conflicts of Interest

The authors declare no conflicts of interest.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.31083/IJVNR54072.

References

[1] International Diabetes Federation. IDF Diabetes Atlas 11th Edition. 2025. Available at: https://diabetesatlas.org (Accessed: 11 October 2025).

[2] Richter B, Hemmingsen B, Metzendorf MI, Takwoingi Y. Development of type 2 diabetes mellitus in people with intermediate hyperglycaemia. The Cochrane Database of Systematic Reviews. 2018; 10: CD012661. https://doi.org/10.1002/14651858.CD012661.pub2

[3] Santulli G. Epidemiology of cardiovascular disease and diabetes in 2026: expanding prevalence, escalating costs, and the limits of contemporary prevention. Cardiovascular Diabetology. Endocrinology Reports. 2026; 12: 15. https://doi.org/10.1186/s40842-026-00283-7

[4] Khanna S, Gan GCH, Sindone AP, Tromp J, Butler J, Foo R, et al. Asia at the Epicenter of the Global Cardiometabolic Shift. JACC. Asia. 2026; 6: 269–283. https://doi.org/10.1016/j.jacasi.2026.01.001

[5] Morze J, Danielewicz A, Hoffmann G, Schwingshackl L. Diet Quality as Assessed by the Healthy Eating Index, Alternate Healthy Eating Index, Dietary Approaches to Stop Hypertension Score, and Health Outcomes: A Second Update of a Systematic Review and Meta-Analysis of Cohort Studies. Journal of the Academy of Nutrition and Dietetics. 2020; 120: 1998–2031.e15. https://doi.org/10.1016/j.jand.2020.08.076

[6] Schwingshackl L, Hoffmann G. Diet quality as assessed by the Healthy Eating Index, the Alternate Healthy Eating Index, the Dietary Approaches to Stop Hypertension score, and health outcomes: a systematic review and meta-analysis of cohort studies. Journal of the Academy of Nutrition and Dietetics. 2015; 115: 780–800.e5. https://doi.org/10.1016/j.jand.2014.12.009

[7] Wu P, Zhang L, Zhao Y, Xu M, Tang Q, Chen GC, et al. Adherence to the 2015-2020 Dietary Guidelines for Americans Compared with the Mediterranean Diet in Relation to Risk of Prediabetes: Results from NHANES 2007-2016. Nutrients. 2023; 15: 3546. https://doi.org/10.3390/nu15163546

[8] Jacobs S, Harmon BE, Boushey CJ, Morimoto Y, Wilkens LR, Le Marchand L, et al. A priori-defined diet quality indexes and risk of type 2 diabetes: the Multiethnic Cohort. Diabetologia. 2015; 58: 98–112. https://doi.org/10.1007/s00125-014-3404-8

[9] Yip WCY, Sequeira IR, Plank LD, Poppitt SD. Prevalence of Pre-Diabetes across Ethnicities: A Review of Impaired Fasting Glucose (IFG) and Impaired Glucose Tolerance (IGT) for Classification of Dysglycaemia. Nutrients. 2017; 9: 1273. https://doi.org/10.3390/nu9111273

[10] Chen X, Duan M, Hou R, Zheng M, Li H, Singh M, et al. Prevalence of Abdominal Obesity in Chinese Middle-Aged and Older Adults with a Normal Body Mass Index and Its Association with Type 2 Diabetes Mellitus: A Nationally Representative Cohort Study from 2011 to 2018. Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy. 2021; 14: 4829–4841. https://doi.org/10.2147/DMSO.S339066

[11] Ke C, Narayan KMV, Chan JCN, Jha P, Shah BR. Pathophysiology, phenotypes and management of type 2 diabetes mellitus in Indian and Chinese populations. Nature Reviews. Endocrinology. 2022; 18: 413–432. https://doi.org/10.1038/s41574-022-00669-4

[12] Wang SS, Lay S, Yu HN, Shen SR. Dietary Guidelines for Chinese Residents (2016): comments and comparisons. Journal of Zhejiang University. Science. B. 2016; 17: 649–656. https://doi.org/10.1631/jzus.B1600341

[13] He YN, Fang YH, Yang XG, Ding GQ. Establishment and application of China healthy diet index. Acta Nutrimenta Sinica. 2017; 39: 436–441. https://doi.org/10.13325/j.cnki.acta.nutr.sin.2017.05.011 (In Chinese)

[14] Zhou Q, Wu XY, Zhong YY. The relationship between the China healthy diet index and blood lipids among middle-aged and elderly residents in communities of Guangzhou city. Chinese Journal of Prevention and Control of Chronic Diseases. 2020; 28: 378–382. https://doi.org/10.16386/j.cjpccd.issn.1004-6194.2020.05.014 (In Chinese)

[15] Zhao Y, Su D, Huang L, Han D, Zhang R. Dietary quality and its relationship with metabolic syndrome in the population aged 45 to 59 in Zhejiang Province in 2022. Wei Sheng Yan Jiu = Journal of Hygiene Research. 2024; 53: 639–645. https://doi.org/10.19813/j.cnki.weishengyanjiu.2024.04.018 (In Chinese)

[16] Bi Y, Lu J, Wang W, Mu Y, Zhao J, Liu C, et al. Cohort profile: risk evaluation of cancers in Chinese diabetic individuals: a longitudinal (REACTION) study. Journal of Diabetes. 2014; 6: 147–157. https://doi.org/10.1111/1753-0407.12108

[17] Zhang B, Wang P, Chen CG, He QQ, Zhuo SY, Chen YM, et al. Validation of an FFQ to estimate the intake of fatty acids using erythrocyte membrane fatty acids and multiple 3d dietary records. Public Health Nutrition. 2010; 13: 1546–1552. https://doi.org/10.1017/S1368980009992849

[18] He F, Chen C, Li F, Qi Y, Lin X, Liang P, et al. An optimal glycemic load range is better for reducing obesity and diabetes risk among middle-aged and elderly adults. Nutrition & Metabolism. 2021; 18: 31. https://doi.org/10.1186/s12986-020-00504-5

[19] Cheng L, Chen Y, Luo Z, Wang Q, Zou F, Lin Y. Evaluation of the Reliability and Validity of a Food Frequency Questionnaire Using Three-Day 24-Hour Dietary Recalls: A Study in Fujian, China. Nutrients. 2025; 17: 2270. https://doi.org/10.3390/nu17142270

[20] Department of Medical Administration, National Health Commission of the People's Republic of China. Guideline for diag-

nosis and treatment of obesity (2024 edition). Chinese Journal of Digestive Surgery. 2024; 23: 1237–1260. https://doi.org/10.3760/cma.j.cn115610-20241017-00455

[21] World Health Organization. Global Report on Hypertension: The Race against a Silent Killer. 2023. Available at: https://www.who.int/publications/i/item/9789240081062 (Accessed: 15 August 2025).

[22] Ji F, Yang Y, Xu L, Cai J, Ni M, Wang Q, et al. Poor diet quality evaluated with the China Healthy Diet Index in Chinese tuberculosis patients. Journal of Human Nutrition and Dietetics: the Official Journal of the British Dietetic Association. 2022; 35: 1192–1201. https://doi.org/10.1111/jhn.12985

[23] Zhang LN, Mo LF, Wei SF, Yang DG. Dietary quality assessed by China healthy diet index and its predictive value of malnutrition risk or malnutrition among the elderly dwelling in community. Modern Preventive Medicine. 2022; 49: 1961–1965.

[24] Azizi Fard N, De Francisci Morales G, Mejova Y, Schifanella R. On the interplay between educational attainment and nutrition: a spatially-aware perspective. EPJ Data Science. 2021; 10: 18. https://doi.org/10.1140/epjds/s13688-021-00273-y

[25] Zhang Z, Liu F, Yin X, Wu B, Li H, Peng F, et al. Chinese Healthy Eating Index (CHEI) and risk of diabetes in Chinese adults: a prospective cohort study. European Journal of Nutrition. 2024; 63: 939–949. https://doi.org/10.1007/s00394-023-03321-7

[26] Yang D, Lin R, Li S, Ye S, Luo Z, Zhang H, et al. Single point insulin sensitivity estimator index and incident impaired fasting glucose in Chinese adults: a retrospective cohort study. Frontiers in Endocrinology. 2026; 17: 1810066. https://doi.org/10.3389/fendo.2026.1810066

[27] Laouali N, Mancini FR, Hajji-Louati M, El Fatouhi D, Balkau B, Boutron-Ruault MC, et al. Dietary inflammatory index and type 2 diabetes risk in a prospective cohort of 70,991 women followed for 20 years: the mediating role of BMI. Diabetologia. 2019; 62: 2222–2232. https://doi.org/10.1007/s00125-019-04972-0

[28] Djoussé L, Gaziano JM, Buring JE, Lee IM. Egg consumption and risk of type 2 diabetes in men and women. Diabetes Care. 2009; 32: 295–300. https://doi.org/10.2337/dc08-1271

[29] Pan A, Sun Q, Bernstein AM, Schulze MB, Manson JE, Willett WC, et al. Red meat consumption and risk of type 2 diabetes: 3 cohorts of US adults and an updated meta-analysis. The American Journal of Clinical Nutrition. 2011; 94: 1088–1096. https://doi.org/10.3945/ajcn.111.018978

[30] Zhuang P, Mao L, Wu F, Wang J, Jiao J, Zhang Y. Cooking Oil Consumption Is Positively Associated with Risk of Type 2 Diabetes in a Chinese Nationwide Cohort Study. The Journal of Nutrition. 2020; 150: 1799–1807. https://doi.org/10.1093/jn/nxaa103

[31] Toi PL, Anothaisintawee T, Chaikledkaew U, Briones JR, Reutrakul S, Thakkinstian A. Preventive Role of Diet Interventions and Dietary Factors in Type 2 Diabetes Mellitus: An Umbrella Review. Nutrients. 2020; 12: 2722. https://doi.org/10.3390/nu12092722

[32] Hu Y, Ding M, Sampson L, Willett WC, Manson JE, Wang M, et al. Intake of whole grain foods and risk of type 2 diabetes: results from three prospective cohort studies. BMJ (Clinical Research Ed.). 2020; 370: m2206. https://doi.org/10.1136/bmj.m2206

[33] Hu G, Jousilahti P, Peltonen M, Lindström J, Tuomilehto J. Urinary sodium and potassium excretion and the risk of type 2 diabetes: a prospective study in Finland. Diabetologia. 2005; 48: 1477–1483. https://doi.org/10.1007/s00125-005-1824-1

[34] Lanaspa MA, Kuwabara M, Andres-Hernando A, Li N, Cicerchi C, Jensen T, et al. High salt intake causes leptin resistance and obesity in mice by stimulating endogenous fructose production and metabolism. Proceedings of the National Academy of Sciences of the United States of America. 2018; 115: 3138–3143. https://doi.org/10.1073/pnas.1713837115

[35] Ekinci EI, Clarke S, Thomas MC, Moran JL, Cheong K, MacIsaac RJ, et al. Dietary salt intake and mortality in patients with type 2 diabetes. Diabetes Care. 2011; 34: 703–709. https://doi.org/10.2337/dc10-1723

[36] Zhao Y, Li Y, Zhuang Z, Song Z, Jia J, Huang T. Frequency of Adding Salt to Foods, Genetic Susceptibility, and Incident Type 2 Diabetes: A Prospective Cohort Study. The Journal of Clinical Endocrinology and Metabolism. 2024; 109: e589–e595. https://doi.org/10.1210/clinem/dgad544

[37] Shen W, Cai L, Wang B, Li J, Sun Y, Chen Y, et al. Associations of a proinflammatory diet, habitual salt intake, and the onset of type 2 diabetes: A prospective cohort study from the UK Biobank. Diabetes, Obesity & Metabolism. 2024; 26: 2119–2127. https://doi.org/10.1111/dom.15517

[38] Kant AK. Indexes of overall diet quality: a review. Journal of the American Dietetic Association. 1996; 96: 785–791. https://doi.org/10.1016/S0002-8223(96)00217-9

[39] Bengone ASM, Nikiema-Ndong R, Nsame D, Edzo EN, Batou AS, Zeba A, et al. Evaluation of physical activity and diet among type 2 diabetics in Libreville. Advances in Biochemistry. 2024; 12: 20–28.

[40] Richter EA, Hargreaves M. Exercise, GLUT4, and skeletal muscle glucose uptake. Physiological Reviews. 2013; 93: 993–1017. https://doi.org/10.1152/physrev.00038.2012

[41] Yu D, Zheng W, Cai H, Xiang YB, Li H, Gao YT, et al. Long-term Diet Quality and Risk of Type 2 Diabetes Among Urban Chinese Adults. Diabetes Care. 2018; 41: 723–730. https://doi.org/10.2337/dc17-1626

[42] van Lee L, Geelen A, van Huysduynen EJCH, de Vries JHM, van't Veer P, Feskens EJM. The Dutch Healthy Diet index (DHD-index): an instrument to measure adherence to the Dutch Guidelines for a Healthy Diet. Nutrition Journal. 2012; 11: 49. https://doi.org/10.1186/1475-2891-11-49

[43] Tooze JA, Midthune D, Dodd KW, Freedman LS, Krebs-Smith SM, Subar AF, et al. A new statistical method for estimating the usual intake of episodically consumed foods with application to their distribution. Journal of the American Dietetic Association. 2006; 106: 1575–1587. https://doi.org/10.1016/j.jada.2006.07.003