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Diet Quality and Its Association with Type 2 Diabetes and Major Cardiometabolic Risk Factors among Adults in China

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Abstract

Objective—We examined the association between diet quality and diabetes and major cardiometabolic risks among adults in China.

Methods—We developed the China Dietary Guideline Index (CDGI) based on the 2007 Chinese dietary guidelines and tailored the Alternate Healthy Eating Index 2010 (which we call the tAHEI) to assess diet quality. Our analysis linked the dietary intake and covariates measured in 2006 with CM risk factors measured in 2009. We used diet data the longitudinal China Health and Nutrition Survey 2006 collected in 3 consecutive 24-hour recalls from 4,440 adults aged 18 to 65 to calculate both the tAHEI and the CDGI scores. We performed multivariable logistic regressions to analyze the association of each 2006 score with diabetes, abdominal obesity, elevated blood pressure, and lipid-related cardiometabolic risk factors in 2009.

Results—After we adjusted for potential confounders, adults in the top quintile compared with the bottom quintile of the tAHEI scores showed 36% lower odds of high low-density lipoprotein cholesterol (LDL-C) (odds ratio [OR] 0.64; 95% confidence interval [CI] 0.46, 0.90] in men and 33% lower odds (OR 0.67; 95% CI 0.49, 0.91) in women, while the CDGI scores showed 35% lower odds of high LDL-C (OR 0.65; 95% CI 0.46, 0.92) in men only. Further, the CDGI scores indicated 55% lower odds of diabetes in the top versus the bottom quintile (OR 0.45; 95% CI 0.23, 0.87) in men only, whereas a null association was observed for the tAHEI scores for both sexes. Both index scores showed null associations with other cardiometabolic risk factors.

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Contributors

ZW designed and conducted the research and wrote the manuscript. AMS-R, PG-L, JC, LA, BZ, and BP contributed to the interpretation of the data analysis and reviewed the manuscript. ZW and BP had primary responsibility for the final content.

Disclosure Statement

The authors declare no conflicts interest.

Conclusions—Chinese diets that scored high on both the CDGI and the tAHEI showed similarly negative associations with high LDL-C risk, whereas only CDGI score was negatively related to diabetes risk in men.

Keywords

Alternative Healthy Eating Index; diabetes; cardiometabolic risk; Chinese dietary guidelines; Dietary Guideline Index; China

INTRODUCTION

The rising epidemic of obesity and diabetes and associated cardiometabolic (CM) risk factors have been public health concerns worldwide in the past three decades.[1] This is especially pertinent for Asian countries, given that they have faced very rapid socioeconomic and nutrition transitions[2–5] and that Asians tend to have higher CM risks at lower body mass index (BMI) levels[6] and at younger ages relative to Western populations.[7] Studies have shown that approximately 85.0% of Chinese adults aged 40 and older[8] and 33.2% of nonoverweight Chinese adults had high levels of at least one CM risk factor in 2009.[4]

Chinese adults' diets have declined in intake of coarse grains and increased in intake of edible oils and animal-source foods over the past 2 decades.[9] Many studies have suggested that index-based dietary patterns capture the overall complexity of the diet to measure the overall diet quality.[10–14] The Alternative Healthy Eating Index 2010 (AHEI 2010), developed from the best and latest global evidence on relationships between foods and nutrients and diseases, [15] is based on the recommendations of the Harvard Healthy Eating Pyramid (HEP), a popular healthy diet guide that used global scientific evidence on diet-disease relationships.[16–18] The Nurses' Health Study and the Health Professionals Follow-up Study found that adults with higher AHEI 2010 scores had 31% and 33% lower odds of coronary heart disease and diabetes, respectively.[19] The British Whitehall II prospective cohort study found higher odds of reversing metabolic syndrome[20] and reduced risk of mortality[21] associated with higher AHEI 2010 scores. Two recent studies showed a significant association between AHEI 2010 scores and insulin resistance in Chinese adults aged 18–65[22] and hip fracture risk among Chinese adults in Singapore,[23] which validated the health benefits of Chinese diets with high AHEI 2010 scores. China developed the Chinese dietary guidelines (CDG),[24] a food-based national policy, in 2007. However, little is known about the association between adherence to the CDG and CM risk factors in Chinese adults. The present study constructed the China Dietary Guideline Index (CDGI) from the recommendations of the 2007 CDG. We tailored the AHEI 2010 to match the Chinese diet and named our index the tailored Alternative Healthy Eating Index (tAHEI). Our analysis linked the dietary intake and covariates measured in 2006 with CM risk factors measured in 2009. We used data the China Health and Nutrition Survey (CHNS) collected to calculate CDGI and tAHEI scores among Chinese adults aged 18 to 65. Using 3 years of CHNS data, we examined the association between diet quality as assessed by those scores with the risks of type 2 diabetes, prediabetes, abdominal obesity, elevated blood pressure (BP), and lipid-related CM risk factors in 2009.

SUBJECTS AND METHODS

Study Population

We derived all data used in this study from the CHNS, an ongoing longitudinal study. Initiated in 1989, the CHNS focuses on relationships between the social and economic transformation in China and the resulting effects on the health and nutritional status of the Chinese population.[25] The CHNS originally included 8 provinces and used a multistage, random cluster process to select communities for the sample. In each community the survey randomly selected 20 households and surveyed all individuals in each household for all the data in each wave. The sampling procedure has been described in detail elsewhere.[9, 25] The CHNS has completed 9 rounds (1989, 1991, 1993, 1997, 2000, 2004, 2006, 2009, and 2011). It collected fasting blood samples for the first time in 2009.

Our analysis linked the dietary intake and covariates measured in 2006 with the CM risk factors measured in 2009. Of 5,089 eligible subjects aged 18 to 65 who had complete diet data in 2006 and CM risk factor data in 2009, we excluded those with implausible energy intakes (n = 38; for men < 1,000 or > 6,000 kilocalories per day [kcal/d], for women < 800 or > 5,000 kcal/d); pregnant or lactating women (n = 70); those with missing covariates (n = 102); those previously diagnosed by a doctor with diabetes, stroke, or myocardial infarction (n = 88); and those with missing BMI or waist circumference (WC) measurements (n = 351). Our final sample was 4,440 (2,062 males and 2,378 females).

The protocol of the CHNS was approved by the institutional review committees of the University of North Carolina at Chapel Hill and the National Institute of Nutrition and Food Safety, Chinese Center for Disease Control and Prevention. All subjects gave written informed consent for their participation in the protocols.

Dietary Measurement

The CHNS 2006 collected dietary data using 3 consecutive 24-hour recalls for each individual and weighed all foods in the household inventory over the same period. Details of the collection method are described elsewhere.[5, 9] We linked dietary intake data to the China Food Composition Table (FCT).[26] We additionally linked all Chinese foods to the United States Department of Agriculture (USDA) Food and Nutrient Database for Dietary Studies (FNDDS)[27] and the USDA National Nutrient Database for Standard Reference[28] to estimate fatty acid composition, which is unavailable from the China FCT. We used the 3-day average of total energy intake (TEI), nutrients, and foods/food groups to calculate the CDGI and tAHEI scores in the analyses.

Construction of the CDGI—The goal of the CDG is to prevent both undernutrition and chronic diseases.[24] This guide provides 10 qualitative recommendations covering diet, physical activity (PA), alcohol consumption, healthy weight, and food safety. The Chinese Food Guide Pagoda (CFGP) presents 6 energy requirement–specific quantitative recommendations for intake of relevant foods.[24] We referred to the China Nutrition Society dietary intake recommendations[29] to determine age- and sex-specific energy requirements for adults (Supplement Table 1).

To investigate the independent association between diet composition and each CM risk factor, we developed the CDGI based on only diet-related recommendations. The components of the CDGI, the criteria for maximum and minimum scores, and the formula we used to calculate intermediate scores are in Table 1. Briefly, the CDGI consists of 6 adequacy components (coarse grains; total vegetables, including the proportion of dark-colored vegetables, defined as ≥ 500 micrograms (**μg**) of carotene/100 grams [g] of vegetables; fruits; nuts, soybeans, and soybean products; milk and dairy products; and seafood) and 4 moderate components (red meat and poultry, edible oil, salt, and alcohol). Each component is scored on a continuous scale from 0 to 10. Therefore the total CDGI score has a possible range of 0–100, with a higher score indicating better compliance with the dietary guidelines. We used the following equation to calculate the intermediate score of each component:

$$\text{For adequacy components, component score} = \text{maximum score}/(A_{max} - A_{min}) \times (X - A_{min}).$$
$$\text{For moderate components, component score} = \text{maximum score} - [\text{maximum score}/(A_{max} - A_{min}) \times (X - A_{min})].$$

A_{max} is the maximum amount of the component corresponding to recommended intake, A_{min} is the minimum amount of the component corresponding to recommended intake, and X is the amount of each food group consumed by the individual.

Tailoring the Harvard AHEI 2010 to Match Chinese Diet Data

We tailored the Harvard AHEI 2010 to match our diet data in the tAHEI. The detailed methods are in Table 2.(1) To scale several foods measured by serving units, such as vegetables, fruits, nuts, legumes, red/processed meat, and sugar-sweetened beverages (SSBs) and fruit juices, we changed serving units into gram units.(2) We estimated usual intakes of alcohol and SSBs based on several questions about consumption frequency and amount over the past year to reduce the potential underestimation of 24-hour recalls due to episodic consumption.(3) Given that Chinese whole grain intake, defined as the ratio of carbohydrate to fiber ≤ 10:1[30] in the AHEI 2010, was extremely low and lacked variation, we replaced it with a cereal fiber component that M. L. McCullough et al.[31] chose when developing the Harvard AHEI 2002.(4) We scaled only fresh red meat intake to increase the variation, given that Chinese consumption of processed red meat is extremely low (about 3.1% of the total meat intake) and that few adults consumed more processed meat than 64 g.[32](5) Using the past year's food frequency questionnaire (FFQ) regarding alcohol consumption, we changed grams of each type of alcohol (beer, wine, and liquor) into ounces (oz) and calculated the total number of drinks that account for different portion sizes of alcohol subtypes.(6) We omitted the trans fat component, given the lack of information on trans fats in foods in both the China FCT and the USDA FCT. Due to the omission of the trans fat component, the tAHEI scores range from 0 to 100, with a higher score indicating better compliance with the dietary guidelines.

Assessment of CM Risk Factors

For the CHNS 2009 trained, experienced physicians, phlebotomists, or nurses collected overnight fasting blood samples by venipuncture. Plasma and serum samples were frozen and stored at −86°C for later laboratory analysis. All samples were analyzed in a national central lab in Beijing with strict quality control. Fasting glucose was measured with the **glucose oxidase-phenol amino phenazone** method (Randox Laboratories Ltd., UK); hemoglobin A1c (HbA1c) was measured in whole blood with an automated glycohemoglobin analyzer using a high-performance liquid chromatography system (model HLC-723 G7, Tosoh Corporation, Tokyo, Japan); triglycerides (TG) and high-density lipoprotein cholesterol and low-density lipoprotein cholesterol (HDL-C and LDL-C, respectively) were measured using the glycerol-phosphate oxidase method and the polyethylene glycol-modified enzyme method, respectively, by determiner regents (Kyowa Medex Co., Ltd, Tokyo, Japan) on a Hitachi 7600 automated analyzer (Hitachi Inc., Tokyo, Japan).

Following standardized procedure, trained and certified health workers or nurses measured waist circumferences midway between the lowest rib and the iliac crest with a SECA tape measure and used regularly calibrated mercury sphygmomanometers to take 3 BP measurements on the right arm with the participant in a seated position after at least 5 minutes of rest in a quiet room. Participants were advised to avoid cigarette smoking, alcohol, caffeinated beverages, and exercise for at least 30 minutes before the measurement. Systolic blood pressure (SBP) was measured at the first appearance of a pulse sound (Korotkoff phase 1) and diastolic blood pressure (DBP) at the disappearance of the pulse sound (Korotkoff phase 5).

We focused on abdominal obesity, elevated BP, impaired HbA1c, and lipid-related risk factors. We used International Diabetes Federation (IDF) definitions[33] for abdominal obesity for Chinese population (for men ≥ 90 cm, for women ≥ 80 cm), elevated BP in adults (the mean of SBP ≥ 130 millimeters of mercury [mmHg], or the mean of DBP ≥ 85 mmHg, or taking antihypertension medication); for lipid-related risk factors, including elevated triacylglycerol (TAG > 1.7 millimoles per liter [mmol/L]); and for high LDL-C (> 3.4 mmol/L) and low HDL-C (for men < 1.03 mmol/L, for women < 1.29 mmol/L); for metabolism syndrome as abdominal obesity together with at least any two components of elevated BP, elevated blood glucose, elevated TAG and low HDL-C. We choose HbA1c as the indicator of glucose control to capture long-term glycemic exposure in the Chinese population.[34] We defined combined prediabetes and diabetes as HbA1c ≥ 5.6% and diabetes as HbA1c ≥ 6.5%.

Assessment of Covariates

Trained interviewers used standard questionnaires to collect information on annual family income, individual education level, physical activity, smoking status, and community information. We categorized baseline age as 18–34 years (y), 35–49 y, and 50–65 y. We calculated per capita annual family income by dividing annual family income by household size and categorized the results into tertiles. We grouped individual education levels as less than primary school, complete primary school, and higher than primary school.

The community urbanicity index, a complex measure of urbanization, is based on 12 multidimensional components reflecting the heterogeneity in economic, social, demographic, and infrastructural changes at the community level.[35] We categorized the continuous urbanicity index into tertiles. Further, we also considered 3 geographic factors, northern, central, and southern provinces, due to the different dietary intakes previous studies have showed.[36, 37]

PA includes 4 domains: occupational, household chore, leisure time, and transportation activities. These have been shown to be highly predictive of weight gain and incident obesity. [38–41] All activities were reported in average hours per week during the past year. [23] We converted time spent in each activity into metabolic equivalent of task (MET) hours per week based on the Compendium of Physical Activities.[42] The MET hours per week measurement accounts for both the average intensity of each activity and the time spent in each activity. We categorized total MET hours per week into tertiles (light, moderate, and heavy). We also considered smoking status (dichotomized as 1 = current smoker and 0 = former or never smoker), baseline BMI, baseline WC, and TEI as potential confounders.

Statistical Analysis

We performed all analyses separately for men and women based on the statistically significant interaction of each score and gender and the effects on each CM risk factor. We categorized all participants into quintiles of baseline CDGI and tAHEI scores by gender to examine the association of different levels of adherence to each score with each CM risk factor. We presented the median value and its range in each quintile of each score and used Wilcoxon rank sum for a significance test of gender difference. For baseline characteristics of the participants, we used chi-square tests for categorical variables and general linear regression for continuous variables to test differences and trends across quintiles of the CDGI and tAHEI scores. We also calculated a gender-specific Pearson correlation coefficient between the 2 scores and a contingence table of quintiles of the CDGI score by quintiles of the tAHEI score to see how differently they classified the participants.

We constructed a series of multivariable logistic regression models to assess the association of adherence to the CDGI and the tAHEI with each CM risk factor and metabolism syndrome, adjusting for demographic, socioeconomic, and lifestyle factors in the models in turn for checking the change of coefficients considering their potential confounding. We took the clustering at the community level into account in the estimation of variation using the cluster option in regression analyses. We also tested linear trends by assigning median values to quintiles of the CDGI or tAHEI score and modeled this variable as a continuous term.

We conducted all statistical analyses using SAS version 9.2 (SAS Institute Inc., Cary, NC) and Stata version 12.0 (StataCorp., TX). All statistical tests took into account clustering of the data and were two-tailed and considered significant at $P < 0.05$.

RESULTS

Baseline Characteristics

The baseline characteristics of participants across the quintiles of the CDGI and tAHEI scores by gender are summarized in Tables 3 and 4. The baseline median CDGI score of men (38.5; range 5.7, 82.1) was significantly lower than that of women (42.8; range 8.1, 84.9) ($P < 0.0001$), whereas the baseline median tAHEI score of men (49.4; range 13.0, 78.5) was higher than that of women (45.2; range 12.1, 74.2) ($P < 0.0001$). Both median scores are lower than 50 points, reflecting unfavorable adherence in general.

The Pearson correlation between the CDGI and tAHEI scores was 0.48 ($P < 0.0001$) in men and 0.56 ($P < 0.0001$) in women. As categorized into quintiles of the CDGI and the tAHEI scores, about 31.1% of men and 35.2% of women were classified in the same quintiles (data not shown here).

Men and women in higher quintiles of the CDGI scores tended to live in the northern provinces and have lower daily TEIs. In addition, compared with the bottom quintile of CDGI scores, a higher proportion of women in the top quintile had a high income (40.0% vs. 30.7%), had light PA (41.5% vs. 30.7%), and lived in a highly urbanized community (38.3% vs. 31.4%) (Table 3).

In contrast, men and women in higher quintiles of the tAHEI scores tended to live in northern provinces but have higher daily TEIs. In addition, compared with the bottom quintile of tAHEI scores, in the top quintile a higher proportion of men had a high income (42.0% vs. 29.1%) and higher BMIs and WCs, and a higher proportion of women had a high income (41.7% vs. 28.0%), lived in a highly urbanized community (41.3% vs. 29.3%), had light PA (35.4% vs. 30.1%), and had higher BMIs and WCs (Table 4).

Comparison of Nutrient Composition across the Quintiles of CDGI and tAHEI Scores

As Supplement Table 2 shows, most nutrients were significantly associated with both scores except the intakes of cholesterol and vitamin A in men in the CDGI scores and the intakes of vitamin A, vitamin C, vitamin E (women only), and selenium for the tAHEI scores. In men a higher CDGI score was associated with lower TEI and intakes of fat and sodium but with higher intakes of carotene and calcium. A higher tAHEI score was associated with higher TEI and intakes of fat, fiber, protein, vitamin E, potassium, calcium, iron, zinc, and phosphorus.

In women a higher CDGI score was associated with lower TEI and intakes of fat and sodium but with higher intakes of fiber, vitamin C, potassium, calcium, iron, and phosphorus. A higher tAHEI score was associated with higher TEI and intakes of fiber, cholesterol, protein, potassium, calcium, iron, zinc, and phosphorus.

In addition, the gap in sodium intake in the top compared with the bottom quintile was much wider for the CDGI scores than for the tAHEI scores (3,000.0 milligrams [mg] vs. 500.0 mg). On the contrary, we found much wider gaps between the top and the bottom quintiles for the tAHEI scores than for the CDGI scores in the intakes of vitamin E (25.8 mg vs. −0.2 mg), calcium (249.1 mg vs. 129.5 mg), iron (7.0 mg vs. 2.2 mg), zinc (1.9 mg vs. 0.4 mg), and selenium (17.7 mg vs. 5.4 mg) in adult men. We found similar results in adult women.

Associations of the CDGI and tAHEI Scores with Selected CM Risk Factors

Table 5 shows the odds ratios (ORs) of diabetes and major CM risk factors according to quintiles of the CDGI and tAHEI scores in Chinese men. After we adjusted for all potential confounders, men in the top compared with the bottom quintile of the CDGI score showed 55% lower odds of diabetes [OR 0.45, 95% confidence interval [CI] 0.23–0.87], whereas the tAHEI scores were not associated with diabetes risk significantly. The 2 indexes were negatively associated with risk of high LDL-C to a similar extent (CDGI OR 0.65, 95% CI 0.46–0.92, P trend < 0.01; tAHEI OR 0.64; 95% CI: 0.46–0.90; P trend < 0.01).

After we adjusted for all potential confounders, women in the top compared with the bottom quintile of the tAHEI scores showed 33% lower odds of high LDL-C (OR 0.67; 95% CI 0.49–0.91), while women in the top quintile of the CDGI scores showed a 51% higher odds of elevated TAG (OR 1.51, 95% CI 1.08–2.11), although none of linear trend tests were statistically significant. We observed null associations of both scores with risks of diabetes, prediabetes and diabetes, low HDL-C, and elevated BP in women (Table 6).

We also performed regression models of both the CDGI and the tAHEI scores on abdominal obesity and metabolism syndrome, respectively, by gender (Supplement Table 3). We observed that only men in the top compared with the bottom quintile of the CDG scores showed 35% lower odds of abdominal obesity (OR 0.65; 95% CI 0.44–0.97).

DISCUSSION

In this study we developed an a priori–defined diet index based on the recommendations of the 2007 CDG and tailored the AHEI 2010 to better reflect Chinese diets. With these indexes we assessed the quality of Chinese adults' diets and investigated the association between Chinese diet quality and the risk of type 2 diabetes and major CM risk factors. We found that only one-third of the participants fell into the same quintiles in both indexes. The 2 indexes reflected different nutrient profiles to some extent, especially in terms of TEI, fat intake, percentage of energy from fat, and some vitamins and minerals. Moreover, our study indicated that better adherence to the CDGI recommendations was associated with 55% lower odds of diabetes and 35% lower odds of abdominal obesity in Chinese men only. The tAHEI scores were not associated with diabetes risk in either gender. As for lipid-related CM risk factors, a higher CDGI score was related to about one-third lower odds of high LDL-C in men but higher odds of elevated TAG in women. The tAHEI scores show a negative association with high LDL-C risk in men and women. In addition, we observed null associations between both indexes and the prevalence of elevated BP, prediabetes and diabetes together, high HDL-C and metabolism syddrome. The Chinese Diabetes Society has suggested that the Chinese definition of metabolic syndrome includes some components similar to those in the IDF definition, including fasting blood glucose, BP, TG, and HDL-C. However, the Chinese definition used clinical diagnosis cut points higher than the IDF's. Our study used the IDF definition to allow international comparison across studies.[43, 44] The Nurses' Health Study and the Health Professionals Follow-up Study found that a higher AHEI 2010 score was associated with 31% and 33% lower risk of coronary heart disease and diabetes, respectively.[15, 19] However, our results related to the tAHEI in the Chinese population are not consistent with those findings. Several explanations for our null association of the tAHEI with diabetes risk are possible. First, adult men and women had lower median tAHEI scores and narrow gaps across the quintiles, which may fail to detect significant associations due to a lack of variation. Second, the AHEI 2010 was not based on scientific evidence of Asian populations' diet-disease relationships, which may indicate population disparity. S. Jacobs's study of the Hawaiian component of a multiethnic cohort suggested that a higher AHEI 2010 score was related to 13–28% lower risk of type 2 diabetes in white participants aged 45–75 but not in Japanese American and Native Hawaiian participants.[45] Third, our study assessed daily food and nutrient intake using 3 consecutive interviewer-administered 24-hour recalls, which may underestimate episodically consumed foods in usual intake estimates on FFQs. In addition, we assessed the effects in a 3-year follow-up, whereas the Nurses' and the Health Professionals studies diabetes risk in 24-year follow-ups. Finally, the tAHEI developed for our study was not identical to the original AHEI 2010[15] due to several alterations, including the use of a US nutrient database to estimate fatty acid intakes, the omission of a trans fat component, and the use of a dietary fiber component instead of a whole grain component. In addition, we calculated the intake of insoluble fiber rather than total fiber from cereals, given the lack of soluble fiber data in the China FCT. This may underestimate cereal fiber intake and consequently lower its score. The components of the AHEI 2010 may have contributed to a stronger prediction of disease risk.[15, 18] Studies have indicated a positive association between trans fat and risk of diabetes[46, 47] and increased LDL-C[48] and a negative association with risk of decreased HDL-C.[48] R. S. Mozaffarian et al. have suggested that a definition of whole grains with less than a 10:1 ratio of total carbohydrate to fiber is the most healthful, and the AHEI 2010 uses that definition. Several comparative studies have indicated that the AHEI 2010's greater capacity to predict disease risk may be due to its additional dietary information, including an emphasis on increasing intake of whole grains, reducing intake of SSBs, and refining dietary fat quality.[15, 19, 31, 49]

Our study created the CDGI based on the recommendations of the 2007 CDG.[24] The 2007 CDG emphasizes a balanced diet and is based on a general sense of a healthy diet but lacks sufficient evidence on the diet-disease relationship among the Chinese population. Several relevant issues in the CDG need to be considered. First, the CDG should not provide a single recommended intake of combined red meat and poultry given their potentially different impacts on health outcomes.[50–52] Second, coarse grains, defined as including tubers, beans, and other cereals and excluding rice and wheat in the China food group system, are quite different from whole grains in terms of health benefits. With regard to the development of the CDGI, defining the quality of total vegetables (light- or dark-colored) and considering specific age and sex energy requirements in recommended food intakes may be advantageous to assessing overall diet quality and improving predictions of CM risk factors. However, the gender disparity among CDGI scores related to risk of diabetes, elevated TAG and abdominal obesity are not understood well and warrant further study.

The strengths of this study include its examination of the earlier dietary intakes from the CHNS 2006 to estimate their associations with risks of multiple health outcomes in 2009; rigorous measurement of diabetes and lipid-related biomarkers; relatively precise assessment of diet using 24-hour recalls over 3 consecutive days, shown to be effective in other research using the CHNS;[53, 54] and adjustment for a comprehensive range of potential confounders. The prospective nature of our ascertainment for diabetes has the advantage of clear temporality over a cross-sectional design and reduces the possibility of reverse causality. We diagnosed type 2 diabetes and prediabetes using HbA1c, which has the advantage of assessing long-term glycemic exposure over a single measure of glucose and is reliable for diabetes diagnosis in the Chinese population.[34] Further, interviewer-administered 24-hour dietary recalls are a good way to assess adherence to healthy dietary recommendations on a daily basis given their ability to capture extensive and complete information on all foods and beverages consumed.

Our study also has limitations. First, using only 1 time point of biomarker data in the 2009 CHNS makes it impossible to examine prospective associations between diet indexes and incident CM risk factors except elevated BP. Given that blood lipids and BP may vary considerably with short-term modifications in diet, future related randomized controlled trials on diet interventions may enhance the quality of their association. However, our analysis excluded individuals with histories of diabetes, stroke, and myocardial infarction in 2006, which may reduce the possibility of changes in dietary intake resulting from existing disease. Second, the diet data were collected between August and November in each wave of the CHNS, which may not reflect seasonal differences. In addition, 3 consecutive 24-hour dietary recalls may have relatively limited correction for within-subject variation, especially for episodically consumed foods, compared to nonconsecutive 24-hour recalls. However, the average intake over 3 days can offer a relatively valid estimate of usual diet quality, as has been shown in earlier research using the CHNS.[55] Third, our analysis had a small number of incident cases of type 2 diabetes in our 3-year period and consequently limited our ability to detect associations. Another issue concerns the limitations of HbA1c's suitability for detecting prediabetes and diabetes due to testing approaches, standardization, and potential disparities in race, geography, and culture.[56] Moreover, the same total score may result from the sum of quite different component scores, however, the purpose of the predefined indexes is to assess overall diet quality. Further study to identify the relevant individual components contributing to reduced risk may promote an understanding of diet-specific pathways for each CM risk factor.

In summary, this study has shown that a high CDGI score, which assesses adherence to the CDG, was inversely associated with the risk of diabetes and high LDL-C in men only and that a high tAHEI score was beneficially associated with the risk of high LDL-C in both men and women. To the best of our knowledge, this is the first study to investigate simultaneously the associations between adherence to the CDGI and the tAHEI with diabetes and lipid-related CM risk factors in the Chinese population. The association of adherence to tAHEI recommendations with decreased risk of high LDL-C has important health implications, given important role of high LDL-C in the context of rapidly increasing cardiovascular disease in the Chinese population. In 2016 China developed a new version of the CDG that provides diet recommendations based on greater knowledge of diet-disease relationships compared to the 2007 version. Further research on how adherence to the 2007 CDG compared with adherence to the 2016 CDG may differ in their associations with health outcomes among Chinese adults is required.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations used

AHEI	Alternative Healthy Eating Index
BMI	body mass index
BP	blood pressure
CDG	Chinese dietary guidelines
CDGI	China Dietary Guideline Index
CFGP	Chinese Food Guide Pagoda
CHNS	China Health and Nutrition Survey
CI	confidence interval
CM	cardiometabolic
d	day
DBP	diastolic blood pressure
DHA	docosahexenoic acid
EPA	eicosapntemacnioc acid
FCT	food composition table
FFQ	food frequency questionnaire
FNDDS	Food and Nutrient Database for Dietary Studies
g	gram
HbA1c	hemoglobin A1c
HDL-C	high-density lipoprotein cholesterol
HEP	Healthy Eating Pyramid
IDF	International Diabetes Federation

kcal	kilocalories
L	liter
LDL-C	low-density lipoprotein cholesterol
MET	metabolic equivalent of task
mg	milligram
mmHg	millimeters of mercury
mmol/L	millimoles per liter
oz	ounce
OR	odds ratio
PA	physical activity
PUFA	polyunsaturated fatty acid
Q	quintile
SBP	systolic blood pressure
SSB	sugar-sweetened beverage
TAG	triacylglycerol
tAHEI	tailored Alternative Healthy Eating Index
TEI	total energy intake
TG	triglycerides
USDA	United States Department of Agriculture
WC	waist circumference
y	year
μg	microgram

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Table 1

Components of the CDGI and scoring methods according to the CDG and CFGP

Qualitative recommendations of CDG	Quantitative recommendations of CFGP	Components of CDGI	Criteria for minimum score (0)[1]	Criteria for maximum score[1]	Maximum score value
1. Eat a variety of foods, mainly cereals, including a certain amount of coarse grains	Grains/tubers/beans: 250–400 g/d; Coarse grains: 50–100 g/d	Coarse grains (and other cereals excluding rice, wheat, tubers, and beans) (g/d) Total vegetables (g/d)	0 g/d 0 g/d	≥ 75 g/d ≥ (300–500) g/d[4]	10 5
2. Consume plenty of vegetables, fruits, and tubers (at least half of total vegetables dark-colored)	Vegetables: 300–500 g/d Fruits: 200–400 g/d	Ratio of dark-colored vegetables to total vegetables[2] Total fruits (g/d)	0 0 g/d	≥ 1/2 ≥ (200–400) g/d[4]	5 10
3. Consume milk, soybeans, or dairy or soybean products every day	Nuts/soybeans and soybean products: 30–50 g/d Milk/dairy products: 300 g/d	Nuts/soybeans/nuts and soybean products (g/d) Milk/dairy products (g/d)	0 g/d 0 g/d	≥ (30–50) g/d[4] ≥ 300 g/d	10 10
4. Consume appropriate amounts of fish, poultry, eggs, and lean meat	Fish and other seafood: 50–100 g/d Red meat and poultry: 50–75 g/d	Seafood (g/d) Red meat and poultry (g/d)[3]	0 g/d ≥ (50–75) g/d[4]	≥ (50–100) g/d[4] 0 g/d	10 10
5. Reduce cooking oil intake; choose a light diet low in salt	Edible oil: 25–30 g/d Salt: 6 g/d	Edible oil (g/d)[3] Salt (g/d)[3]	≥ 2 (25–30) g/d[4] ≥ 12 g/d	< (25–30) g/d[4] < 6 g/d	10 10
6. If you drink alcoholic beverages, do so in limited amounts		Alcoholic drinks (g/d)[3]	Male ≥ 50 g/d Female ≥ 30g/d	Male < 25 g/d Female < 15 g/d	10
		Total score			100

[1] Participants with intakes between the maximum and the minimum amount were assigned scores based on the formula: for adequacy components, component score = maximum score / (A_{max}-A_{min}) ×(X-A_{min}); for moderate components, component score = maximum score – [maximum score / (A_{max}-A_{min})×(X-A_{min})]. A_{max} is the maximum amount of the component corresponding to the recommended intake. A_{min} is the minimum amount of the component corresponding to the recommended intake. X is the amount consumed by the individual.

[2] Dark-colored vegetables are defined as ≥ 500 μg carotene/100 g of vegetables.

[3] Moderate components in the CDGI. For the components edible oil, salt, and alcoholic drinks, we chose twice the recommended maximum intake as the criteria for 0 to increase the scoring variation.

[4] Age- and sex-specific energy intake recommendations of food groups (see Supplement Table 1).

Table 2

Method of tailoring the Harvard AHEI 2010

Components	Criteria for minimum score (0)[1]	Criteria for maximum score (10)[1]	Comments on tailoring
Vegetables g/d[2]	0	≥ 591	5 servings/d. 1 serving is 0.5 cup of vegetables.
Whole fruits g/d[2]	0	≥ 473	4 servings/d. 1 serving is 0.5 cup of berries.
Cereal fiber g/d[2]	0	15	15 g cereal fiber is the ideal on the basis of epidemiological studies and the distribution in our cohorts.
Nuts and legumes g/d[2]	0	28	1 serving/d is the ideal on the basis of the AHEI recommendations and the current literature. 1 serving is 1 oz of nuts or 1 tablespoon (15 milliliters) of peanut butter.
Long-chain (n-3) fats (EPA + DHA) mg/d[3]	0	250	The cutoff for optimal intake, 250 mg/d, is about 100 g of fish/d.
PUFA, % of energy[3]	≤ 2	≥ 10	The highest score is for individuals with 10% of total energy intake from PUFA. PUFA does not include EPA or DHA intake.*
Red or processed meat g/d[2]	≥ 170 (red meat)	0	An upper limit of 1.5 servings/d. 1 serving is 4 oz of unprocessed meat or 1.5 oz of processed meat.*
Sodium mg/d	Highest decile	Lowest decile	The cutoffs for sodium are based on deciles of distribution in the study population. The AHEI 2010 uses this method due to a lack of brand specificity in the FFQ to accurately estimate absolute intake.
SSBs and fruit juices g/d[2]	≥ 227	0	≥ 1 serving/d is the least optimal. 1 serving is 8 oz. We used the past year's FFQ of SSBs and fruit juices instead of 3 consecutive 24-hour recalls to get a more precise estimate of daily intake for episodically consumed SSBs and fruit juices.
Alcohol, drinks/d[4]			
Women	≥ 2.5	0.5–1.5 (0–< 0.5, score = 2.5)	1 drink is 4 oz of wine, 12 oz of beer, or 1.5 oz of liquor. For both men and women with alcohol intake less than 0.5 oz, including zero, we scored this component 2.5 points.
Men	≥ 3.5	0.5–2.0 (0–< 0.5, score = 2.5)	
Trans fat, % of energy	—	—	We omitted the trans fat component in the tAHEI due to a lack of information on trans fat composition in all foods in both the China FCT and the USDA FCT.
Total score	0	100	

Abbreviations: DHA = docosahexenoic acid, EPA = eicosapntemacnioc acid, PUFA = polyunsaturated fatty acid.

[1] We scored intermediate intakes between the minimum and the maximum according to the formula: for adequacy components, component score = maximum score / (A_{max}-A_{min})) ×(X-A_{min}); for moderate components, component score = maximum score – [maximum score / (A_{max}-A_{min}) × (X-A_{min})] (red or processed meat, sodium, SSBs and fruit juices, and alcohol). A_{max} is the maximum amount of the component corresponding to the recommended intake. A_{min} is the minimum amount of the component corresponding to the recommended intake. X is the amount consumed by the individual.

[2] Serving units were transferred to grams to match the CHNS diet data (1 cup = 236.59 g, 1 oz = 28.35 g).

[3] We additionally linked all China FCT foods to the USDA FNDDS and standard reference nutrient databases to estimate fatty acid composition, which is unavailable in the China FCT.

[4]We transferred grams to drinks for the alcohol component.

Table 3

Baseline characteristics of participants according to sex-specific quintiles of the CDGI scores, CHNS data

Characteristics	Men						P trend[1]	Women						P trend[1]
	Q1	Q2	Q3	Q4	Q5	Total		Q1	Q2	Q3	Q4	Q5	Total	
# of participants	412	413	412	413	412	2,062		475	476	476	476	475	2,378	
Median score[2]	24.2 (5.7, 29.4)	33.2 (29.5, 35.7)	38.5 (35.7, 42.0)	45.2 (42.0, 48.5)	53.9 (48.5, 82.1)	38.5 (5.7, 82.1)		28.8 (8.1, 33.3)	36.8 (33.4, 39.8)	42.8 (39.9, 45.7)	48.8 (45.7, 52.5)	57.4 (52.5, 84.9)	42.8 (8.1, 84.9)	
Age, %														
18–34 y	15.0	17.7	14.3	17.4	14.8	15.9		11.2	12.8	11.1	15.1	11.6	12.4	
35–49 y	39.6	41.6	39.3	38.5	39.1	39.6	0.490	43.6	43.5	44.7	45.8	43.8	44.3	0.560
50–64 y	45.4	40.7	46.4	44.1	46.1	44.5		45.3	43.7	44.1	39.1	44.6	43.4	
Income, %														
Low	32.8	33.2	33.7	37.5	29.4	33.3		33.3	37.4	31.9	36.3	27.6	33.3	
Middle	36.2	32.9	32.0	33.2	32.5	33.4	0.200	36.0	30.5	34.7	33.2	32.4	33.3	0.010
High	31.1	33.9	34.2	29.3	38.1	33.3		30.7	32.1	33.4	30.5	40.0	33.3	
Education, %														
< Primary school	11.9	10.7	10.7	9.0	10.2	10.5		29.7	30.5	30.7	30.0	25.1	29.2	
Primary school	19.4	18.2	18.4	18.9	25.2	20.0	0.200	23.6	21.4	18.9	20.2	21.3	21.1	0.350
> Primary school	68.7	71.2	70.9	72.2	64.6	69.5		46.7	48.1	50.4	49.8	53.7	49.7	
Urbanicity index, %														
Low	28.2	27.4	28.9	41.9	40.8	33.4		28.8	34.0	29.6	38.9	34.5	33.2	
Middle	43.7	37.0	36.2	27.1	22.8	33.4	< 0.001	40.4	35.9	33.8	34.0	24.0	33.6	< 0.001
High	28.2	35.6	35.0	31.0	36.4	33.2		30.7	30.0	36.6	27.1	41.5	33.2	
Geographic region, %														
North	10.0	11.9	17.5	28.8	41.3	21.9		9.5	11.1	19.7	27.3	47.2	23.0	
Central	31.6	36.6	32.3	33.2	31.6	33.0	< 0.001	29.9	35.9	36.3	35.9	30.1	33.6	< 0.001
South	58.5	51.6	50.2	38.0	27.2	45.1		60.6	52.9	43.9	36.8	22.7	43.4	
Physical activity, %														
Light	31.1	36.6	34.0	29.8	35.2	33.3		31.4	31.3	35.7	29.8	38.3	33.3	
Moderate	34.5	32.0	33.0	36.3	31.1	33.4	0.060	32.0	34.7	30.7	37.4	32.0	33.3	< 0.001
Heavy	34.5	31.5	33.0	33.9	33.7	33.3		36.6	34.0	33.6	32.8	29.7	33.3	
Currently smoking, %	60.7	60.3	58.3	56.7	54.1	58.1	0.290	2.3	2.1	2.9	3.6	4.6	3.1	0.160

Characteristics	Men						P trend[1]	Women						P trend[1]
	Q1	Q2	Q3	Q4	Q5	Total		Q1	Q2	Q3	Q4	Q5	Total	
BMI (kg/m^2)[3]	23.1±0.2	23.4±0.2	23.2±0.2	23.2±0.2	23.4±0.1	23.3±0.1	0.400	23.3±0.2	23.5±0.3	23.6±0.2	23.6±0.1	23.6±0.1	23.5±0.1	0.150
WC (cm)[3]	82.9±0.5	83.3±0.5	82.9±0.5	82.6±0.5	83.2±0.4	83.0±0.2	0.920	79.2±0.4	80.0±0.4	80.3±0.5	79.8±0.4	80.3±0.4	79.9±0.2	0.100
TEI (kcal/d)[3]	2,807.0±37.4	2,733.9±40.2	2,576.4±36.3	2,539.5±36.6	2,499.1±37.2	2,631.2±17.0	< 0.010	2,391.8±30.8	2,264.9±31.3	2,207.0±29.6	2,122.9±29.0	2,084.6±29.7	2,214.2±13.6	< 0.010

Abbreviation: Q = quintile.

[1]We used chi-square tests for categorical variables and general linear models for continuous variables to test differences between groups and trends.

[2]Median, range in parentheses.

[3]Mean ± standard error (all such values).

Table 4

Baseline characteristics of participants according to sex-specific quintiles of the tAHEI scores, CHNS data

Characteristics	Men						P trend[1]	Women						P trend[1]
	Q1	Q2	Q3	Q4	Q5	Total		Q1	Q2	Q3	Q4	Q5	Total	
# of participants	412	413	412	413	412	2,062		475	476	476	476	475	2,378	
Median score[2]	36.7 (13.0, 41.0)	44.2 (41.1, 46.8)	49.4 (46.8, 51.7)	54.5 (51.7, 57.7)	62.5 (57.7, 78.5)	49.4 (13.0, 78.5)		34.6 (12.1, 38.0)	40.6 (38.0, 43.1)	45.2 (43.1, 47.6)	50.2 (47.6, 52.8)	57.4 (52.8, 74.2)	45.2 (12.1, 74.2)	
Age, %														
18–34 y	21.8	17.7	14.1	15.0	10.7	15.9		13.7	12.4	12.4	12.6	10.7	12.4	
35–49 y	36.2	37.8	39.6	37.0	47.6	39.6	< 0.001	42.5	43.3	46.2	41.8	47.6	44.3	0.670
50–64 y	42.0	44.6	46.4	47.9	41.7	44.5		43.8	44.3	41.4	45.6	41.7	43.4	
Income, %														
Low	35.7	37.0	32.8	33.9	27.2	33.3		37.3	32.6	37.2	34.0	25.5	33.3	
Middle	35.2	30.8	36.7	33.4	30.8	33.4	< 0.010	34.7	35.1	34.0	30.0	32.8	33.3	< 0.001
High	29.1	32.2	30.6	32.7	42.0	33.3		28.0	32.4	28.8	35.9	41.7	33.3	
Education, %														
< Primary school	10.2	12.8	12.6	8.7	8.0	10.5		32.2	29.2	29.8	31.9	22.7	29.2	
Primary school	19.9	22.3	17.0	21.5	19.4	20.0	0.110	21.9	22.1	20.6	19.5	21.3	21.1	0.040
> Primary school	69.9	64.9	70.4	69.7	72.6	69.5		45.9	48.7	49.6	48.5	56.0	49.7	
Urbanicity index, %														
Low	31.6	36.1	37.6	32.0	29.9	33.4		33.3	38.2	37.0	31.1	26.3	33.2	
Middle	34.5	33.9	34.5	32.7	31.3	33.4	0.050	37.5	30.0	33.8	34.5	32.4	33.6	< 0.001
High	34.0	30.0	27.9	35.4	38.8	33.2		29.3	31.7	29.2	34.5	41.3	33.2	
Geographic region, %														
North	10.7	16.5	20.9	23.2	38.1	21.9		12.6	20.6	21.0	25.2	35.4	23.0	
Central	15.0	32.7	42.0	40.9	34.5	33.0	< 0.001	20.4	29.0	40.8	43.7	34.3	33.6	< 0.001
South	74.3	50.8	37.1	35.8	27.4	45.1		66.9	50.4	38.2	31.1	30.3	43.4	
Physical activity, %														
Light	37.4	32.7	31.3	32.0	33.3	33.3		30.1	31.9	32.1	37.0	35.4	33.3	
Moderate	32.8	32.2	29.6	36.3	35.9	33.4	0.090	30.3	34.7	32.8	33.8	35.2	33.3	0.020
Heavy	29.9	35.1	39.1	31.7	30.8	33.3		39.6	33.4	35.1	29.2	29.5	33.3	
Currently smoking, %	56.3	56.4	60.2	56.4	60.7	58.1	0.500	1.3	4.2	2.9	4.4	2.7	3.1	0.040

Characteristics	Men						P trend[1]	Women						P trend[1]
	Q1	Q2	Q3	Q4	Q5	Total		Q1	Q2	Q3	Q4	Q5	Total	
BMI (kg/m^2)[3]	22.6±0.2	23.3±0.2	23.4±0.2	23.3±0.2	23.6±0.1	23.3±0.1	< 0.001	22.9±0.1	23.4±0.1	23.8±0.2	24.0±0.3	23.6±0.1	23.5±0.1	< 0.001
WC (cm)[3]	80.5±0.5	83.1±0.5	83.1±0.5	83.8±0.5	84.4±0.4	83.0±0.2	< 0.001	78.3±0.4	79.7±0.4	80.9±0.5	80.5±0.5	80.1±0.4	79.9±0.2	< 0.010
TEI (kcal/d)[3]	2,426.8±35.6	2,557.0±35.7	2,624.1±38.4	2,741.3±38.1	2,806.8±39.3	2,631.2±17.0	< 0.001	2,069.2±27.5	2,159.6±28.4	2,180.2±28.3	2,293.0±32.6	2,369.1±33.3	2,214.2±13.6	< 0.001

Abbreviation: Q = quintile.

[1]We used chi-square tests for categorical variables and general linear models for continuous variables to test differences between groups and trends.

[2]Median, range in parentheses.

[3]Mean ± standard error (all such values).

Table 5

OR (95% CI) of prevalence of CM risk factors across the quintiles of the CDGI and tAHEI scores in men, CHNS data

	CDGI scores					P trend[1]	tAHEI scores					P trend[1]
	Q1	Q2	Q3	Q4	Q5		Q1	Q2	Q3	Q4	Q5	
Diabetes												
Cases (%)	33 (8.0)	37 (9.0)	29 (7.0)	27 (6.5)	21 (5.1)		26 (6.3)	24 (5.8)	31 (7.5)	37 (9.0)	29 (7.0)	
Model 1[2]	1.00	1.04 (0.63, 1.72)	0.75 (0.42, 1.33)	0.65 (0.36, 1.17)	0.43 (0.22, 0.81)**	< 0.01	1.00	0.73 (0.42, 1.25)	0.89 (0.53, 1.48)	1.07 (0.59, 1.93)	0.76 (0.41, 1.40)	0.75
Model 2	1.00	1.11 (0.67, 1.86)	0.77 (0.44, 1.38)	0.69 (0.39, 1.24)	0.45 (0.23, 0.86)*	< 0.01	1.00	0.71 (0.41, 1.21)	0.85 (0.51, 1.43)	1.06 (0.59, 1.89)	0.73 (0.39, 1.34)	0.69
Model 3	1.00	1.11 (0.67, 1.87)	0.78 (0.43, 1.41)	0.70 (0.38, 1.27)	0.45 (0.23, 0.87)*	< 0.01	1.00	0.70 (0.41, 1.20)	0.83 (0.49, 1.40)	1.02 (0.57, 1.83)	0.69 (0.37, 1.30)	0.58
Prediabetes and diabetes												
Cases (%)	177 (43.0)	204 (49.4)	189 (45.9)	191 (46.2)	186 (45.1)		156 (37.9)	182 (44.1)	206 (50.0)	203 (49.2)	200 (48.5)	
Model 1[2]	1.00	1.27 (0.97, 1.67)	1.04 (0.79, 1.35)	1.00 (0.74, 1.34)	0.84 (0.61, 1.18)	0.16	1.00	1.08 (0.81, 1.44)	1.26 (0.93, 1.69)	1.22 (0.90, 1.65)	1.11 (0.82, 1.51)	0.41
Model 2	1.00	1.31 (1.00, 1.72)	1.06 (0.81, 1.38)	1.01 (0.76, 1.36)	0.87 (0.63, 1.21)	0.21	1.00	1.06 (0.80, 1.42)	1.23 (0.91, 1.66)	1.19 (0.88, 1.62)	1.08 (0.79, 1.46)	0.52
Model 3	1.00	1.32 (1.00, 1.73)*	1.08 (0.82, 1.41)	1.04 (0.77, 1.40)	0.89 (0.64, 1.24)	0.28	1.00	1.05 (0.78, 1.39)	1.20 (0.89, 1.62)	1.15 (0.84, 1.56)	1.03 (0.75, 1.41)	0.75
Elevated blood pressure												
Cases (%)	192 (46.6)	175 (42.4)	197 (47.8)	176 (42.6)	214 (51.9)		177 (43.0)	189 (45.8)	180 (43.7)	204 (49.4)	204 (49.5)	
Model 1[2]	1.00	0.86 (0.66, 1.12)	0.98 (0.75, 1.28)	0.81 (0.61, 1.06)	1.20 (0.87, 1.67)	0.38	1.00	1.00 (0.75, 1.33)	0.82 (0.60, 1.11)	1.07 (0.79, 1.45)	1.00 (0.72, 1.39)	0.86
Model 2	1.00	0.86 (0.66, 1.12)	0.98 (0.75, 1.29)	0.81 (0.62, 1.07)	1.22 (0.88, 1.70)	0.34	1.00	1.01 (0.76, 1.34)	0.83 (0.61, 1.14)	1.08 (0.80, 1.47)	1.02 (0.73, 1.42)	0.79
Model 3	1.00	0.86 (0.66, 1.12)	0.98 (0.75, 1.29)	0.81 (0.61, 1.07)	1.22 (0.87, 1.70)	0.35	1.00	1.01 (0.76, 1.35)	0.83 (0.61, 1.14)	1.09 (0.80, 1.48)	1.02 (0.73, 1.44)	0.78
Low HDL-C												
Cases (%)	44 (10.7)	40 (9.7)	66 (16.0)	60 (14.5)	54 (13.1)		44 (10.7)	57 (13.8)	51 (12.4)	56 (13.6)	56 (13.6)	
Model 1[2]	1.00	0.84 (0.54, 1.31)	1.51 (0.98, 2.34)	1.31 (0.85, 2.02)	1.10 (0.71, 1.71)	0.29	1.00	1.29 (0.84, 1.99)	1.14 (0.74, 1.77)	1.21 (0.76, 1.94)	1.19 (0.75, 1.88)	0.63
Model 2	1.00	0.87 (0.56, 1.35)	1.56 (1.01, 2.41)*	1.36 (0.88, 2.10)	1.15 (0.74, 1.79)	0.22	1.00	1.30 (0.84, 2.01)	1.15 (0.74, 1.80)	1.23 (0.77, 1.97)	1.19 (0.75, 1.89)	0.61
Model 3	1.00	0.87 (0.56, 1.36)	1.61 (1.05, 2.47)*	1.41 (0.91, 2.18)	1.19 (0.77, 1.84)	0.16	1.00	1.28 (0.83, 1.98)	1.12 (0.72, 1.75)	1.19 (0.75, 1.89)	1.13 (0.71, 1.81)	0.78
High LDL-C												
Cases (%)	139 (33.7)	130 (31.5)	112 (27.2)	102 (24.7)	109 (26.5)		128 (31.1)	121 (29.3)	123 (29.9)	112 (27.1)	108 (26.2)	
Model 1[2]	1.00	0.88 (0.64, 1.20)	0.70 (0.50, 0.97)*	0.63 (0.45, 0.88)**	0.65 (0.47, 0.92)*	< 0.01	1.00	0.85 (0.62, 1.16)	0.83 (0.62, 1.13)	0.71 (0.52, 0.97)*	0.64 (0.46, 0.89)**	< 0.01
Model 2	1.00	0.88 (0.64, 1.21)	0.70 (0.50, 0.97)*	0.63 (0.45, 0.88)**	0.66 (0.47, 0.93)*	< 0.01	1.00	0.86 (0.63, 1.17)	0.85 (0.63, 1.15)	0.71 (0.52, 0.98)*	0.65 (0.46, 0.90)*	< 0.01
Model 3	1.00	0.88 (0.64, 1.21)	0.69 (0.50, 0.96)*	0.62 (0.44, 0.87)**	0.65 (0.46, 0.92)*	< 0.01	1.00	0.85 (0.62, 1.17)	0.84 (0.62, 1.14)	0.71 (0.52, 0.97)*	0.64 (0.46, 0.90)**	< 0.01

	CDGI scores					P trend[1]	tAHEI scores					P trend[1]
	Q1	Q2	Q3	Q4	Q5		Q1	Q2	Q3	Q4	Q5	
Elevated TAG												
Cases (%)	154 (37.4)	145 (35.1)	156 (37.9)	152 (36.8)	152 (36.9)		136 (33.0)	149 (36.1)	162 (39.3)	144 (34.9)	168 (40.8)	
Model 1[2]	1.00	0.86 (0.64, 1.16)	0.99 (0.74, 1.32)	0.98 (0.74, 1.31)	0.93 (0.71, 1.22)	0.91	1.00	1.15 (0.86, 1.54)	1.32 (0.98, 1.80)	1.05 (0.78, 1.42)	1.26 (0.92, 1.72)	0.27
Model 2	1.00	0.89 (0.66, 1.20)	1.02 (0.76, 1.36)	1.02 (0.76, 1.35)	0.97 (0.74, 1.28)	0.87	1.00	1.14 (0.85, 1.53)	1.31 (0.96, 1.77)	1.06 (0.79, 1.43)	1.24 (0.90, 1.70)	0.31
Model 3	1.00	0.89 (0.66, 1.20)	1.04 (0.78, 1.39)	1.05 (0.79, 1.40)	1.01 (0.76, 1.33)	0.66	1.00	1.12 (0.83, 1.51)	1.27 (0.93, 1.73)	1.02 (0.75, 1.38)	1.17 (0.85, 1.62)	0.35

Abbreviation: Q = quintile.

[1] We calculated the P trend by assigning median values to quintiles of the CDGI and tAHEI score and entered this variable as a continuous term in the regression models.

[2] We adjusted multivariable logistic regression models for age (18–34 y, 35–49 y, 50–64 y) individual income (tertile), education (less than primary school, primary school, higher than primary school), urbanicity index (tertile), geographic region (model 1), PA (tertile), smoking status (current smoker, former or never smoker), hypertension history (model 2), and TEI (continuous) (model 3).

[*] $P < 0.05$,

[**] $P < 0.01$.

Table 6

OR (95% CI) of prevalence of CM risk factors across the quintiles of the CDGI and tAHEI scores in women, CHNS data

	CDGI scores					P trend[1]	tAHEI scores					P trend[1]
	Q1	**Q2**	**Q3**	**Q4**	**Q5**		**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	
Diabetes												
Cases (%)	24 (5.1)	29 (6.1)	34 (7.1)	28 (5.9)	20 (4.2)		21 (4.4)	25 (5.3)	31 (6.5)	35 (7.4)	23 (4.8)	
Model 1[2]	1.00	1.15 (0.64, 2.05)	1.26 (0.73, 2.18)	1.11 (0.60, 2.06)	0.61 (0.32, 1.16)	0.13	1.00	1.13 (0.59, 2.17)	1.34 (0.75, 2.38)	1.32 (0.73, 2.37)	0.88 (0.47, 1.67)	0.79
Model 2	1.00	1.21 (0.66, 2.19)	1.28 (0.73, 2.24)	1.17 (0.62, 2.19)	0.62 (0.32, 1.18)	0.14	1.00	1.12 (0.59, 2.15)	1.34 (0.75, 2.39)	1.29 (0.72, 2.32)	0.88 (0.47, 1.67)	0.78
Model 3	1.00	1.22 (0.67, 2.23)	1.35 (0.76, 2.38)	1.26 (0.67, 2.38)	0.68 (0.35, 1.29)	0.27	1.00	1.06 (0.55, 2.04)	1.23 (0.68, 2.20)	1.10 (0.60, 2.01)	0.72 (0.37, 1.39)	0.31
Prediabetes and diabetes												
Cases (%)	187 (39.4)	211 (44.3)	242 (50.8)	220 (46.2)	235 (49.5)		194 (40.8)	203 (42.6)	240 (50.4)	241 (50.6)	217 (45.7)	
Model 1[2]	1.00	1.21 (0.93, 1.59)	1.48 (1.13, 1.94)**	1.21 (0.89, 1.63)	1.17 (0.84, 1.62)	0.43	1.00	0.97 (0.72, 1.31)	1.27 (0.93, 1.72)	1.15 (0.86, 1.54)	1.00 (0.70, 1.44)	0.73
Model 2	1.00	1.22 (0.93, 1.60)	1.49 (1.13, 1.96)**	1.20 (0.89, 1.63)	1.18 (0.85, 1.64)	0.40	1.00	0.96 (0.71, 1.30)	1.26 (0.93, 1.71)	1.14 (0.85, 1.53)	1.00 (0.70, 1.43)	0.75
Model 3	1.00	1.22 (0.93, 1.60)	1.49 (1.13, 1.96)**	1.20 (0.88, 1.64)	1.18 (0.85, 1.65)	0.41	1.00	0.97 (0.72, 1.30)	1.26 (0.93, 1.72)	1.15 (0.85, 1.54)	1.01 (0.70, 1.44)	0.73
Elevated blood pressure												
Cases (%)	162 (34.1)	169 (35.5)	178 (37.4)	188 (39.5)	183 (38.5)		162 (34.1)	157 (33.0)	171 (35.9)	193 (40.5)	197 (41.5)	
Model 1[2]	1.00	1.20 (0.88, 1.63)	1.14 (0.84, 1.56)	1.36 (0.98, 1.90)	1.17 (0.82, 1.69)	0.29	1.00	0.90 (0.66, 1.23)	1.00 (0.74, 1.36)	1.17 (0.86, 1.59)	1.28 (0.94, 1.75)	0.04
Model 2	1.00	1.20 (0.88, 1.63)	1.15 (0.84, 1.57)	1.36 (0.98, 1.89)	1.18 (0.83, 1.68)	0.27	1.00	0.89 (0.65, 1.22)	1.00 (0.73, 1.35)	1.15 (0.85, 1.56)	1.28 (0.94, 1.74)	0.03
Model 3	1.00	1.21 (0.89, 1.64)	1.16 (0.84, 1.58)	1.37 (0.99, 1.91)	1.19 (0.84, 1.70)	0.24	1.00	0.89 (0.65, 1.22)	1.00 (0.74, 1.35)	1.15 (0.85, 1.57)	1.28 (0.93, 1.76)	0.05
Low HDL-C												
Cases (%)		158 (33.3)	162 (34.0)	160 (33.6)	170 (35.7)			156 (32.8)	175 (36.8)	169 (35.5)	164 (34.5)	
Model 1[2]	1.00	1.03 (0.80, 1.33)	0.99 (0.77, 1.27)	1.09 (0.85, 1.41)	1.04 (0.78, 1.37)	0.70	1.00	1.15 (0.89, 1.50)	1.09 (0.83, 1.43)	1.02 (0.77, 1.35)	0.95 (0.71, 1.27)	0.48
Model 2	1.00	1.04 (0.80, 1.33)	0.99 (0.77, 1.28)	1.09 (0.84, 1.40)	1.05 (0.79, 1.38)	0.66	1.00	1.14 (0.88, 1.49)	1.09 (0.83, 1.42)	1.01 (0.77, 1.33)	0.94 (0.71, 1.25)	0.46
Model 3	1.00	1.01 (0.79, 1.30)	0.96 (0.75, 1.24)	1.04 (0.80, 1.34)	1.00 (0.76, 1.32)	0.94	1.00	1.18 (0.91, 1.53)	1.13 (0.86, 1.48)	1.08 (0.82, 1.43)	1.03 (0.77, 1.36)	0.89
High LDL-C												
Cases (%)	152 (32.0)	156 (32.8)	158 (33.2)	137 (28.8)	155 (32.6)		168 (35.4)	136 (28.6)	140 (29.4)	170 (35.7)	144 (30.3)	
Model 1[2]	1.00	1.04 (0.78, 1.40)	1.02 (0.76, 1.36)	0.87 (0.62, 1.22)	0.91 (0.67, 1.23)	0.32	1.00	0.67 (0.50, 0.90)**	0.70 (0.52, 0.94)*	0.89 (0.65, 1.21)	0.68 (0.50, 0.92)*	0.13
Model 2	1.00	1.04 (0.78, 1.40)	1.02 (0.76, 1.37)	0.87 (0.62, 1.21)	0.91 (0.68, 1.23)	0.32	1.00	0.67 (0.50, 0.89)**	0.70 (0.52, 0.93)*	0.87 (0.64, 1.20)	0.67 (0.50, 0.92)*	0.12
Model 3	1.00	1.04 (0.77, 1.40)	1.02 (0.76, 1.37)	0.86 (0.61, 1.22)	0.91 (0.67, 1.24)	0.33	1.00	0.66 (0.49, 0.89)**	0.69 (0.52, 0.93)*	0.87 (0.63, 1.18)	0.67 (0.49, 0.91)**	0.10

	CDGI scores					P trend[1]	tAHEI scores					P trend[1]
	Q1	Q2	Q3	Q4	Q5		Q1	Q2	Q3	Q4	Q5	
Elevated TAG												
Cases (%)	122 (25.7)	151 (31.7)	151 (31.7)	129 (27.1)	158 (33.3)		140 (29.5)	148 (31.1)	141 (29.6)	141 (29.6)	141 (29.7)	
Model 1[2]	1.00	1.39 (1.01, 1.90)*	1.37 (1.01, 1.86)*	1.15 (0.83, 1.59)	1.48 (1.06, 2.07)*	0.09	1.00	1.06 (0.81, 1.39)	1.01 (0.76, 1.34)	0.97 (0.73, 1.30)	0.99 (0.72, 1.35)	0.77
Model 2	1.00	1.43 (1.04, 1.96)*	1.39 (1.02, 1.90)*	1.15 (0.83, 1.60)	1.52 (1.09, 2.13)*	0.08	1.00	1.05 (0.80, 1.36)	1.00 (0.76, 1.32)	0.95 (0.71, 1.27)	0.98 (0.72, 1.33)	0.72
Model 3	1.00	1.42 (1.04, 1.95)*	1.38 (1.01, 1.88)*	1.14 (0.82, 1.59)	1.51 (1.08, 2.11)*	0.09	1.00	1.05 (0.81, 1.37)	1.01 (0.76, 1.33)	0.96 (0.72, 1.29)	1.00 (0.73, 1.36)	0.83

Abbreviation: Q = quintile.

[1] We calculated the P trend by assigning median values to quintiles of the CGFI and tAHEI score and entered this variable as a continuous term in the regression models.

[2] We adjusted multivariable logistic regression models for age (18–34 y, 35–49 y, 50–64 y) individual income (tertile), education (less than primary school, primary school, higher than primary school), urbanicity index (tertile), geographic region (model 1), PA (tertile), smoking status (current smoker, former or never smoker), hypertension history (model 2), and TEI (continuous) (model 3).

* $P < 0.05$,

** $P < 0.01$.