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Index-Based Dietary Patterns and Stomach Cancer in a Chinese Population

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Abstract

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Objectives: Dietary factors are of importance in the development of stomach cancer. This study aims to examine index-based dietary patterns associated with stomach cancer in a Chinese population.

Methods: Using data from a population-based case-control study conducted in Jiangsu Province, China, we included a total of 8,432 participants (1,900 stomach cancer cases and 6,532 controls). Dietary data collected by food frequency questionnaire was evaluated by modified Chinese Healthy Eating Index-2016 (mCHEI-2016) and the US Healthy Eating Index-2015 (HEI-2015). Multiple logistic regression analyses were applied to examine the association of mCHEI-2016 and HEI-2015 with stomach cancer while adjusting for potential confounders. The possible interactions between mCHEI-2016 or HEI-2015 and established risk factors were explored.

Results: Among non-proxy interviews, after adjusting for potential confounding factors, a higher score of sodium, reflecting lower intake per day, was inversely associated with stomach cancer (Odds Ratio [OR]= 0.95; 95% CI, 0.91–0.99 for mCHEI-2016; OR= 0.97; 95%CI, 0.94–0.99 for HEI-2015). No clear associations with stomach cancer were identified for total scores of HEI-2015 (OR= 0.98; 95% CI, 0.87–1.10 with a 10-point increase, *p*-trend = 0.98) and mCHEI-2016 (OR= 1.05; 95% CI, 0.94–1.17 with a 10-point increase, *p*-trend =0.22). However, the relation between stomach cancer and the mCHEI-2016 was modified by body mass index, with a possible inverse association in normal weight subjects.

Conclusions: Our findings highlight that reduced intake of dietary sodium would prevent the development of stomach cancer. The data indicate a heterogeneity between normal weight and overweight's dietary factors in relation to stomach cancer.

Keywords

Stomach cancer; Chinese healthy eating index; Healthy eating index; Case-control study

Introduction

Globally, stomach cancer remains the fifth most common cancer and the third most deadly cancer (Bray *et al.,* 2018). In China, stomach cancer is the second most common and the second most deadly cancer with a poor prognosis (Chen *et al.,* 2016; Allemani *et al.,* 2018). Epidemiological studies have suggested that stomach cancer is stemmed from a combination of environmental factors and the accumulation of somatic alterations (Milne *et al.,* 2009). Different environmental factors are involved in the development of stomach cancer, mainly *Helicobacter (H.) pylori* infection (Plummer *et al.,* 2015), plus tobacco smoking (Praud *et al.,* 2018), alcohol consumption (Rota *et al.,* 2017), and dietary factors (Fang *et al.,* 2015).

Fruit and vegetables with rich folates, vitamins, and fiber appear to lower the risk of stomach cancer, while intake of salt is associated with increased risk of stomach cancer (D 'elia *et al.,* 2012; Fang *et al.,* 2015; Wang *et al.,* 2017). Other foods, such as meats, are associated with a high risk of stomach cancer in some populations, but the results are inconsistent (González *et al.,* 2006; Fang *et al.,* 2015). It is difficult to distinguish the individual effect of specific food or nutrients due to the combination of food consumption and the interaction of various food or nutrients in daily life (Hu, 2002). Index-based dietary patterns, calculating scores based on the fact that foods are eaten in combination, may provide insight into the association between dietary factors and stomach cancer.

Index-based dietary patterns have been associated with several cancers, such as breast (Sedaghat *et al.,* 2018), colorectal (Nguyen *et al.,* 2020), esophageal cancer (Li *et al.,* 2013), liver cancer (Ma *et al.,* 2019), and lung cancer (Anic *et al.,* 2016). However, few studies have investigated the association of index-based dietary patterns with stomach cancer, particularly in the Chinese population. Besides, most recent research has focused on the relationships between Mediterranean diet (MED) and stomach cancer (Stojanovic *et al.,* 2017; Castelló *et al.,* 2018; Schulpen *et al.,* 2019). However, because Chinese dietary patterns are different from MED, the finding between MED and stomach cancer cannot be generalized to the Chinese population. For this reason, in the present study, we aimed to examine the potential associations of two newest recommendation-based dietary indexes, the modified Chinese Healthy Eating Index-2016 (mCHEI-2016) and the US Healthy Eating Index-2015 (HEI-2015), with stomach cancer in a large Chinese case-control study conducted in Jiangsu Province, China.

Methods

Study population

We obtained study population from a population-based case-control study, which was conducted from January 2003 to December 2010 in 4 counties in Jiangsu Province, China. Details of the study are available elsewhere (Zhao *et al.,* 2017). In brief, cases were 2,216 newly diagnosed patients with primary stomach cancer. Cases and controls were originally matched based on age (± five years), gender, and residence. However, we pooled all controls together for all four types of cancers (lung, esophageal, stomach, liver cancer) to increase the sample size of the control group. Controls were 8,019 randomly chosen residents with no history of cancer diagnosis and stable medical condition. Both cases and controls were 18 years or older, residents of the respective county for at least five years before diagnosis or interview date. A total of 316 cases and 1,487 controls were excluded due to incomplete food frequency questionnaires (FFQs), total energy intake was less than 500 or more than 5,000 calories per day, and/or complete food items were less than four. We included 1,900 cases and 6,532 controls in this analysis after applying the exclusion criteria. Among them, data from 573 cases and 467 controls were obtained in proxy interviews.

The study was approved by both Jiangsu Center for Disease Control and Prevention (CDC) and UCLA institutional review boards. Written informed consent was obtained from all participants before the epidemiologic data and biological specimen was collected.

Dietary assessment

To capture dietary patterns, we asked participants to report their general dietary history one year before the diagnosis or the interview date based on a 90-item FFQ (Zhu *et al.,* 2019). Each food item's frequency was recorded on a daily, weekly, monthly, and yearly basis. Each food item's frequency was converted daily and multiplied by predefined portion size to get the average daily gram intake of each food item. Then, we obtained energy and nutrient contents per 100 grams of a matched food item or a list of the food item from the China Food Composition (CFC) Tables 2010 (Institute of Nutrition and Food Safety 2010). For two food items that could not be identified with the CFC tables, corresponding energy and nutrient contents per 100 grams were obtained from the Tables of Food Composition in Japan-2015 and the U.S. Department of Agriculture (USDA) National Nutrient Database for Standard Reference, Release 28, 2015. Lastly, the average daily intake of energy or nutrient contents for each participant was calculated by multiplying each food item's daily gram intake by corresponding energy or nutrient contents and summing up all the values.

Dietary recommendation adherence score

The original Chinese Healthy Eating Index (CHEI) was designed to assess the adherence to the 2016 Dietary Guidelines for the Chinese (Yang *et al.,* 2018). Daily food and nutrients intakes were transformed into standard portions (SP) on a density basis (per 1,000 kcal) except for added sugars, cooking oil, and alcohol (Yuan *et al.,* 2017). Given that the amount of cooking oil was not collected in our questionnaire, we modified CHEI by including dietary fat instead of cooking oil. The components include 12 adequacy components with a higher intake indicating a higher score, and five limitation components (Red meat, sodium, added sugars, alcohol, and fat) with a higher intake representing a lower score. There were standards for each component's minimum point as zero and maximum points (5 or 10). Intermediate intakes were scored proportionately between zero and maximum. The total score with all 17 components ranged from 0 to 100, with a higher score indicating better adherence to the dietary guideline.

The United States Healthy Eating Index (HEI)-2015 was designed to align with the 2015–2020 Dietary Guidelines for Americans (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015). The HEI-2015 included nine adequacy components (foods to eat enough) and four limitation components (foods to limit: refined grains, sodium, added sugars, and saturated fats). Each of the components was scored on a density basis out of 1,000 kcal, except for fatty acids, added sugars, and saturated fats. The total score was between 0 (nonadherence) and 100 (optimal adherence). Details of components and scoring of mCHEI-2016 and HEI-2015 were listed in Table 1.

Covariates

All participants provided detailed demographic information, health behaviors, and family history of cancer. Pack-years of tobacco smoking were calculated by multiplying the number of packs of cigarettes smoked per day by the years of smoking. The body weight and height of participants were measured at the interview time following the standard protocol. Body mass index (BMI) was calculated as weight (kg) divided by height squared (m^2). Non-fasting peripheral blood samples (5–8ml) were collected after the time of the interview. Anti-*H. pylori* antibody immunoglobulin G (anti-*H. pylori* Ab IgG) was measured using enzyme-linked immunosorbent assays (ELISA) using kits from Beier Bioengineering (Beijing, China).

Statistical analysis

We first performed t-tests for continuous variables and chi-square tests for categorical variables among proxy and non-proxy interviews, respectively. If the continuous variable distribution in the controls was not normal, the Mann-Whitney test was applied. Considering potential measurement errors of dietary factors among proxy interviews, we did the following analysis among non-proxy interviews. The association between each component's corresponding score in mCHEI-2016 or HEI-2015 and stomach cancer was calculated. Multiple unconditional logistic regression was applied to calculate odds ratios (ORs) and their 95% confidence intervals (CIs), adjusting for potential confounding factors, including age (years), gender (male vs. female), county site, total energy intake (kcal/day) in model 1, and additionally for educational attainment (illiterate, primary, middle, high school or above), income ten years ago (yuan/year), *H. pylori* infection (yes vs. no), family history of stomach cancer (yes vs. no), tobacco smoking (yes or no and pack-years), and BMI (kg/m^2) in model 2. The categorical (quartiles) and continuous (per 10-point increase) analyses were carried out to estimate the associations of total scores in mCHEI-2016 or HEI-2015 with stomach cancer. Analyses were performed stratified by gender, tobacco smoking, *H. pylori* infection, family history of stomach cancer, and BMI. Interaction effects were assessed by including the product of each effect modifier and the score of either of two dietary indexes (per 10-point increase) along with their corresponding individual variables, and potential confounding factors in model 2 to explore the potential effect modification on stomach cancer. Statistical tests were performed using SAS 9.4, and a two-sided p-value < 0.05 was used.

Results

The characteristics of stomach cancer cases and the controls among proxy and non-proxy interviews are presented in Table 2. Compared to the controls, a high proportion of stomach cancer cases were less educated and had lower income. The daily energy intake was higher, and BMI was lower in stomach cancer cases. Pack-years of tobacco smoking, the proportion of family history of stomach cancer, and *H. pylori* infection were higher in the stomach cancer cases than in the controls. The daily intakes of individual food components in mCHEI-2016 for stomach cancer cases and controls and specific ORs among proxy and non-proxy interviews are presented in Supplemental Table 1.

Table 3 summarizes the adjusted ORs for the associations of stomach cancer with each component's score as continuous variables in the mCHEI-2016 and HEI-2015 among non-proxy interviews. A higher sodium score, reflecting lower intake per day, was inversely associated with stomach cancer in both mCHEI-2016 and HEI-2015 (OR=0.95; 95%CI, 0.91–0.99 for mCHEI-2016; OR=0.97; 95%CI, 0.94–0.99 for HEI-2015) in mode 2. In mCHEI-2016, higher scores of tubers and alcohol, reflecting higher intake of tubers but lower intake of alcohol, were negatively associated with stomach cancer in model 1, while higher scores of whole grains and mixed beans and eggs, indicating higher intakes of both, were positively associated with stomach cancer in model 2. Supplemental Table 2 summarizes the associations among proxy interviews and total population.

Table 4 shows the relationships between stomach cancer and the total scores of mCHEI-2016 and HEI-2015. After adjustment for most risk factors, there were null associations for HEI-2015 (*p*-trend = 0.98; OR=0.98; 95% CI, 0.87–1.10 with a 10-point increase) and mCHEI-2016 (*p*-trend =0.22; OR=1.05; 95% CI, 0.94–1.17 with a 10-point increase) in relation to stomach cancer. However, our data (Table 5) suggest that the relationship between stomach cancer and index-based dietary patterns were modified by BMI, with a possible inverse association in normal weight subjects (*p* for interaction= 0.02 for mCHEI-2016).

Discussion

In this large Chinese population-based case-control study, there was no clear association of total scores of mCHEI-2016 and HEI-2015 with stomach cancer, consistent with a study in the United States (Li *et al.,* 2013). Our finding from individual food components points out that better adherence to mCHEI-2016 and HEI-2015 on dietary sodium component was inversely associated with the odds of stomach cancer. It is also worth noting that BMI modified the associations of mCHEI-2016 and stomach cancer.

Few studies have so far investigated the relationship between dietary adherence and stomach cancer, generating inconsistent results. Whereas cohort and case-control studies found that MED adherence was associated with a significant reduction in stomach cancer risk (Jakszyn *et al.,* 2010; Schulpen *et al.,* 2019) or with reduced odds of stomach cancer (Praud *et al.,* 2014; Stojanovic *et al.,* 2017; Castelló *et al.,* 2018), the National Institutes of Health-AARP Diet and Health (NIH-AARP) study found that HEI-2005 and alternate MED scores were not significantly associated with the risk of stomach cancer (Highest vs. lowest quintile: HR= 0.92; 95%CI, 0.67–1.27 for cardia; HR=0.88; 95%CI: 0.65–1.20 for non-cardia) (Li *et al.,* 2013).

A possible reason for our null associations was that mCHEI-2016 and HEI-2015 were not explicitly designed to assess stomach cancer risk. Some components in these dietary indexes may be null or even adversely associated with stomach cancer. Furthermore, HEI-2015 was designed to comply with the 2015–2020 Dietary Guidelines for Americans.

Although different methods and criteria are applied to calculate the specific component scores in the mCHEI-2016 and HEI-2015, they both recommend a lower intake of dietary sodium; this study found an inverse association with stomach cancer. Previous prospective studies have reported that dietary salt intake was monotonically linked with an increased risk of stomach cancer (D ’elia *et al.,* 2012). For sodium, the cutoff points for the maximum and minimum score were 1000mg (1.1g) /1000kcal and 3608mg (2.0g)/1000kcal in mCHEI-2016 (HEI-2015). Nevertheless, we found the means of daily sodium intake were 1746.5 mg/1000kcal among the non-proxy cases and 1558.4 mg/1000kcal among the non-proxy controls (see supplemental Table 1). Given the large number of participants consumed sodium higher than both dietary guidelines, sodium should be consumed within certain restrictions.

Compared with HEI-2015, mCHEI-2016 was more sensitive to identify individual food components associated with stomach cancer in the Chinese population because it contains food items much more closely related to the common Chinese diet. For example, better adherence to mCHEI-2016 on tubers and alcohol showed inverse associations with stomach cancer. However, better adherence on dietary whole grains and mixed beans seems to increase the odds of stomach cancer. One reason for this finding may be the combination of grains and beans into one component, which makes it difficult to estimate the individual association. Better adherence on dietary eggs was also associated with the increased risk of stomach cancer. Of the foods most typical of the Chinese diet, eggs contain high cholesterol. We previously reported a dose-response association between dietary cholesterol and stomach cancer (Zhu *et al.,* 2019), which might explain this relationship.

We found that the relationships between mCHEI-2016 and stomach cancer were modified by BMI, suggesting that adherence to Chinese dietary guidelines was more beneficial for individuals with normal BMI than those with higher BMI. Although this observation is biologically plausible, we should interpret it with caution. The height and weight were measured at the interview time, which might impact the effect modification of BMI because of collider bias. We also found that both the cases and controls with the highest quartile of mCHEI-2016 had the lowest proportion of tobacco smoking, alcohol drinking, and family history of stomach cancer (data not shown). Hence, the observed differences were probably due to a combined effect of various factors.

Our study extends prior knowledge by focusing on a general Chinese population to examine the association of the two newest dietary indexes, mCHEI-2016 and HEI-2015, with stomach cancer. Both dietary indexes were designed as a continuous scoring system, which is easy to perform statistical analyses and interpret results. The comparability of these two dietary indexes' results supports our findings on the relationships between index-based dietary patterns and stomach cancer. The large sample size allows for increasing the statistical power to explore possible interactions between dietary patterns and established risk factors. The study included many potential confounders, such as smoking, alcohol drinking, BMI, *H. pylori* infection, a family history of stomach cancer.

Information bias is inevitable in evaluating self-reported dietary information. Participants were asked at enrollment for their dietary habits that cases had one year before the cancer diagnosis and that controls had one year before the interview, leading to misclassification bias. Recall bias inherent to a case-control study is possible in our study. However, information bias might be limited in unknowing the relationship between diet and stomach cancer during the interview. Furthermore, we applied total energy adjustment to reduce the measurement error in the FFQ. Second, we used the mCHEI instead of the original index due to the lack of cooking oil and excluded data obtained by proxy interviews. When we re-calculated ORs and 95%CIs of total scores in the CHEI (without the score of dietary fat) associated with stomach cancer in sensitivity analyses, the results were similar to our main findings. Compared with non-proxy interviewers, proxy interviewers over-reported most of the food components in mCHEI-2016 compared to the controls, resulting in potential measurement errors. Also, the demographic characteristics were different between the proxy and non-proxy interviewers. Third, we used a complete case analysis that only included participants without missing data on the variables of interest. However, we conducted multiple imputations of the Markov chain Monte Carlo (MCMC) method to impute each covariate's values in sensitivity analyses. Estimated ORs and 95% CIs using multiple imputation methods were consistent with those using the complete case analysis (see Supplemental Table 3). In this study, we were unable to analyze data with subtypes of stomach cancer. Since most stomach cancer is adenocarcinoma of the distal stomach in this Chinese population, our results might not reflect the associations with gastric cardia adenocarcinoma. Lastly, residual confounding is probably existing after adjusting for many covariates in our study.

Conclusion

Our study highlights that reducing dietary intake of sodium appears to be one of the essential methods in preventing stomach cancer. Further research is needed to elucidate the heterogeneity between normal weight and overweight's dietary factors in relation to stomach cancer.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Reference

Allemani C, Matsuda T, Di Carlo V, Harewood R, Matz M, Nikšić M, et al. Global surveillance of trends in cancer survival 2000–14 (CONCORD-3): analysis of individual records for 37513025 patients diagnosed with one of 18 cancers from 322 population-based registries in 71 countries. Lancet (London, England)2018;391:1023–1075.

Anic GM, Park Y, Subar AF, Schap TE, Reedy J. Index-based dietary patterns and risk of lung cancer in the NIH-AARP diet and health study. Eur J Clin Nutr2016;70:123–129. [PubMed: 26264348]

Bray F, Ferlay J, Soerjomataram I, Siegel RL, Torre LA, Jemal A. Global Cancer Statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA Cancer J Clin2018;68:394–424. [PubMed: 30207593]

Buckland G, Agudo A, Luján L, Jakszyn P, Bueno-de-mesquita HB, Palli Det al. Adherence to a Mediterranean diet and risk of gastric adenocarcinoma within the European Prospective Investigation into Cancer and Nutrition (EPIC) cohort study 1 – 3. Am J Clin Nutr2010;91:381–390. [PubMed: 20007304]

Castelló A, Fernández de Larrea N, Martín V, Dávila-Batista V, Boldo E, Guevara M, et al. High adherence to the Western, Prudent, and Mediterranean dietary patterns and risk of gastric adenocarcinoma: MCC-Spain study. Gastric Cancer2018;21:372–382. [PubMed: 29139048]

Chen W, Zheng R, Baade PD, Zhang S, Zeng H, Bray F, et al. Cancer statistics in China, 2015. CA CANCER J CLIN2016;66:115–132. [PubMed: 26808342]

D 'elia L, Rossi G, Ippolito R, Cappuccio FP, Strazzullo P. Habitual salt intake and risk of gastric cancer: A meta-analysis of prospective studies. Clin Nutr2012;31:489–498. [PubMed: 22296873]

Fang X, Wei J, He X, An P, Wang H, Jiang L, et al. Landscape of dietary factors associated with risk of gastric cancer: A systematic review and dose-response meta-analysis of prospective cohort studies. Eur J cancer2015;51:2820–2832. [PubMed: 26589974]

González CA, Jakszyn P, Pera G, Agudo A, Bingham S, Palli D, et al. Meat intake and risk of stomach and esophageal adenocarcinoma within the European Prospective Investigation Into Cancer and Nutrition (EPIC). J Natl Cancer Inst2006;98:345–354. [PubMed: 16507831]

Hu FB. Dietary pattern analysis: A new direction in nutritional epidemiology. Curr Opin Lipidol2002;13:3–9. [PubMed: 11790957]

Li WQ, Park Y, Wu JW, Ren JS, Goldstein AM, Taylor PR, et al. Index-based dietary patterns and risk of esophageal and gastric cancer in a large cohort study. Clin Gastroenterol Hepatol2013;11:1130–1136. [PubMed: 23591281]

Ma Y, Yang W, Simon TG, Smith-Warner SA, Fung TT, Sui J, et al. Dietary patterns and risk of hepatocellular carcinoma among U.S. men and women. Hepatology2019;70:577–586. [PubMed: 30506561]

Milne AN, Carneiro F, O'Morain C, Offerhaus GJ. Nature meets nurture: molecular genetics of gastric cancer. Hum Genet2009;126:615–628. [PubMed: 19657673]

Nguyen S, Li H, Yu D, Gao J, Gao Y, Tran H, et al. Adherence to dietary recommendations and colorectal cancer risk: results from two prospective cohort studies. Int J Epidemiol2020;49:270–280. [PubMed: 31203367]

Petimar J, Smith-Warner SA, Fung TT, Rosner B, Chan AT, Hu FB, et al. Recommendation-based dietary indexes and risk of colorectal cancer in the Nurses' Health Study and Health Professionals Follow-up Study. Am J Clin Nutr2018;108:1092–1103. [PubMed: 30289433]

Plummer M, Franceschi S, Vignat J, Forman D, de Martel C. Global burden of gastric cancer attributable to Helicobacter pylori. Int J Cancer2015;136:487–490. [PubMed: 24889903]

Praud D, Bertuccio P, Bosetti C, Turati F, Ferraroni M, La Vecchia C. Adherence to the Mediterranean diet and gastric cancer risk in Italy. Int J Cancer2014;134:2935–2941. [PubMed: 24259274]

Praud D, Rota M, Pelucchi C, Bertuccio P, Rosso T, Galeone C, et al. Cigarette smoking and gastric cancer in the Stomach Cancer Pooling (StoP) Project. Eur J cancer Prev2018;27:124–133. [PubMed: 27560662]

Rota M, Pelucchi C, Bertuccio P, Matsuo K, Zhang ZF, Ito H, et al. Alcohol consumption and gastric cancer risk — A pooled analysis within the StoP project consortium. Int J Cancer2017;141:1950–1962. [PubMed: 28718913]

Schulpen M, Peeters PH, van den Brandt PA. Mediterranean diet adherence and risk of esophageal and gastric cancer subtypes in the Netherlands Cohort Study. Gastric Cancer2019;22:663–674. [PubMed: 30771119]

Sedaghat F, Heidari Z, Jalali S, Doustmohammadian A, Ehteshami M, Rashidkhani B. Healthy eating index 2010 and breast cancer risk. Nutr Cancer2018;70:860–866. [PubMed: 30273052]

Stojanovic J, Giraldi L, Arzani D, Pastorino R, Biondi A, Persiani R, et al. Adherence to Mediterranean diet and risk of gastric cancer: results of a case-control study in Italy. Eur J Cancer Prev2017;26:491–496. [PubMed: 28542079]

U.S. Department of Health and Human Services and U.S. Department of Agriculture. 2015–2020 Dietary Guidelines for Americans [Internet], 8th edn. 2015.

van den Brandt PA, Schulpen M. Mediterranean diet adherence and risk of postmenopausal breast cancer: results of a cohort study and meta-analysis. Int J Cancer2017;140:2220–2231. [PubMed: 28260236]

Wang T, Cai H, Sasazuki S, Tsugane S, Zheng W, Cho ER, et al. Fruit and vegetable consumption, *Helicobacter pylori* antibodies, and gastric cancer risk: A pooled analysis of prospective studies in China, Japan, and Korea. Int J Cancer2017;140:591–599. [PubMed: 27759938]

Yang Y, Wang X, Leong P, Zhang HM, Yang XG, Kong LZ, et al. New Chinese dietary guidelines: healthy eating patterns and food-based dietary recommendations. Asia Pac J Clin Nutr2018;27:908–913. [PubMed: 30045438]

Yuan YQ, Li F, Dong RH, Chen JS, He GS, Li SG, et al. The development of a Chinese healthy eating index and its application in the general population. Nutrients2017;9:977.

Zhao JK, Wu M, Kim CH, Jin ZY, Zhou JY, Han RQ, et al. Jiangsu Four Cancers Study: a large case–control study of lung, liver, stomach, and esophageal cancers in Jiangsu Province, China. Eur J cancer Prev2017;26:357–364. [PubMed: 27275735]

Zhu YH, Jeong S, Wu M, Jin ZY, Zhou JY, Han RQ, et al. Dietary intake of fatty acids, total cholesterol, and stomach cancer in a Chinese population. Nutrients2019;11:1730.

Table 1.

Score and weighting of modified Chinese Healthy Eating Index-2016 (mCHEI-2016) and US Healthy eating index-2015 (HEI-2015)

	CHEI scores			HEI-2015 scores		
Components	**Weighting**	**Standard for maximum points**	**Standard for 0 points**	**Weighting**	**Standard for maximum points**	**Standard for 0 points**
Total grains	5	≥2.5SP/1000kcal	0			
Whole grains and mixed beans	5	≥0.6SP/1000kcal	0			
Tubers	5	≥0.3SP/1000kcal	0			
Total vegetables	5	≥1.9SP/1000kcal	0	5	≥1.1 cup/1000kcal	0
Dark vegetables	5	≥0.9SP/1000kcal	0			
Total fruits	10	≥1.1SP/1000kcal	0	5	≥0.8 cup/1000kcal	0
Dairy	5	≥0.5SP/1000kcal	0	10	≥1.3 cup/1000kcal	0
Soybeans	5	≥0.4SP/1000kcal	0			
Fish and seafood	5	≥0.6SP/1000kcal	0			
Red meat	5	≤0.4SP/1000kcal	≥3.5SP/1000kcal			
Poultry	5	≥0.3SP/1000kcal	0			
Eggs	5	≥0.5SP/1000kcal	0			
Seeds and nuts	5	≥0.4SP/1000kcal	0			
Sodium	10	≤1000mg/1000kcal	≥3608mg/1000kcal	10	≤1.1 g/ 1000 kcal	≥2.0 g/1000 kcal
Added sugars	5	≤10% of energy	≥20% of energy	10	≤6.5% of energy	≥26% of energy
Alcohol	5	≤25g(men)/15g (women)	≥60g(men)/ 40g (women)			
Fat	10	≤15.6g/1000kcal	≥32.6g/1000kcal	10	(PUFAs + MUFAs)/SFAs ≥2.5	(PUFAs + MUFAs)/SFAs ≤1.2
Whole fruit				5	≥0.4 cup/1000kcal	0
Greens and beans				5	≥0.2 cup/1000kcal	0
Whole grains				10	≥1.5 oz/1000kcal	0
Total protein foods				5	≥2.5 oz/1000kcal	0
Seafood and plant proteins				5	≥0.8 oz/1000kcal	0
Refined grains				10	≤1.8 oz/1000 kcal	≥4.3 oz/1000 kcal
Saturated fats				10	≤8% of energy	≥16% of energy
Total score	100			100		

Notes: SP: Standard Portion; PUFAs: Polyunsaturated Fatty Acids; MUFAs: Monounsaturated Fatty Acids; SFAs: Saturated Fatty Acids.

Table 2.

Demographic characteristics and main risk factors of stomach cancer and population controls stratified by proxy interviews

	Non-proxy, N (%)			Proxy, N (%)			Overall, N (%)		
Characteristics	**Cases (n=1,327)**	**Controls (n=6,056)**	***p*-value**	**Cases (n=573)**	**Controls (n=476)**	***p*-value**	**Cases (n=1,900)**	**Controls (n=6,532)**	***p*-value**
County									
Dafeng	498 (37.5)	2387 (39.4)	<0.001	143 (25.0)	121 (25.4)	<0.001	641 (33.7)	2508 (38.4)	<0.001
Ganyu	328 (24.7)	1755 (29.0)		199 (34.7)	117 (24.6)		527 (27.7)	1872 (28.7)	
Chuzhou	404 (30.4)	1039 (17.2)		50 (8.7)	70 (14.7)		454 (23.9)	1109 (17.0)	
Tongshan	97 (7.3)	875 (14.5)		181 (31.6)	168 (35.3)		278 (14.6)	1043 (16.0)	
Gender									
Male	1010 (76.1)	4382 (72.4)	0.005	391 (68.2)	331 (69.5)	0.65	1401 (73.7)	4713 (72.2)	0.17
Female	317 (23.9)	1674 (27.6)		182 (31.8)	145 (30.5)		499 (26.3)	1819 (27.9)	
Age									
<50	128 (9.7)	648 (10.7)	0.12	57 (10.0)	51 (10.7)	0.24	185 (9.7)	699 (10.7)	0.31
50–59	286 (21.6)	1366 (22.6)		121 (21.1)	84 (17.7)		407 (21.4)	1450 (22.2)	
60–69	478 (36.0)	1977 (32.7)		174 (30.4)	132 (27.7)		652 (34.3)	2109 (32.3)	
≥70	435 (32.8)	2065 (34.1)		221 (38.6)	209 (43.9)		656 (34.5)	2274 (34.8)	
Mean (SD)	63.9 (10.5)	63.8 (11.1)	0.84	64.6 (11.5)	66.2 (12.6)	0.03	64.1 (10.8)	64.0 (11.3)	0.73
Education									
Illiterate	659 (49.8)	2943 (48.7)	0.001	295 (51.6)	272 (57.1)	0.005	954 (50.3)	3215 (49.3)	<0.001
Primary school	460 (34.7)	1902 (31.5)		203 (35.5)	125 (26.3)		663 (35.0)	2027 (31.1)	
Middle school	169 (12.8)	941 (15.6)		55 (9.6)	66 (13.9)		224 (11.8)	1007 (15.5)	
High school or above	36 (2.7)	257 (4.3)		19 (3.3)	13 (2.7)		55 (2.9)	270 (4.1)	
Income 10 years ago (Yuan/year)									
<1000	315 (24.4)	1265 (21.2)	0.003	150 (27.0)	128 (27.7)	0.26	465 (25.2)	1393 (21.7)	<0.001
1000–1499	261 (20.2)	1124 (18.8)		122 (22.0)	94 (20.4)		383 (20.8)	1218 (18.9)	
1500–2499	351 (27.2)	1604 (26.9)		145 (26.1)	103 (22.3)		496 (26.9)	1707 (26.5)	
≥2500	364 (28.2)	1979 (33.1)		138 (24.9)	137 (29.7)		502 (27.2)	2116 (32.9)	
Body mass index (kg/m2)									
<18.5	229 (17.3)	374 (6.2)	<0.001	69 (12.1)	36 (7.7)	<0.001	298 (15.8)	410 (6.3)	<0.001
18.5-<24	898 (68.0)	3681 (61.1)		379 (66.5)	289 (61.8)		1277 (67.5)	3970 (61.1)	

Characteristics	Non-proxy, N (%) Cases (n=1,327)	Non-proxy, N (%) Controls (n=6,056)	*p*-value	Proxy, N (%) Cases (n=573)	Proxy, N (%) Controls (n=476)	*p*-value	Overall, N (%) Cases (n=1,900)	Overall, N (%) Controls (n=6,532)	*p*-value
24-<28	157 (11.9)	1617 (26.8)		98 (17.2)	126 (26.9)		255 (13.5)	1743 (26.8)	
≥28	37 (2.8)	355 (5.9)		24 (4.2)	17 (3.6)		61 (3.2)	372 (5.7)	
Daily energy intake (kcal/day): Mean (SD)	2244.1 (847.0)	2145.6 (808.2)	<0.001	2065.8 (794.8)	1957.7 (798.4)	0.03	2190.3 (835.4)	2131.9 (808.9)	0.007
Tobacco smoking									
Never	469 (35.3)	2859 (47.2)	<0.001	265 (46.3)	277 (58.2)	<0.001	734 (38.6)	3136 (48.0)	<0.001
Ever	858 (64.7)	3197 (52.8)		308 (53.8)	199 (41.8)		1166 (61.4)	3396 (52.0)	
Pack-years of tobacco smoking									
Never	469 (38.8)	2859 (50.8)	<0.001	265 (50.7)	277 (65.3)	<0.001	734 (42.4)	3136 (51.8)	<0.001
1 to 19	155 (12.8)	700 (12.4)		64 (12.2)	46 (10.9)		219 (12.6)	746 (12.3)	
20–39	223 (18.4)	979 (17.4)		80 (15.3)	49 (11.6)		303 (17.5)	1028 (17.0)	
≥40	363 (30.0)	1087 (19.3)		114 (21.8)	52 (12.3)		477 (27.5)	1139 (18.8)	
Alcohol drinking									
Never	610 (46.0)	2941 (48.6)	0.09	293 (51.1)	282 (59.2)	0.009	903 (47.5)	3223 (49.3)	0.16
Ever	717 (54.0)	3115 (51.4)		280 (48.9)	194 (40.8)		997 (52.5)	3309 (50.7)	
Family history of stomach cancer									
No	1179 (88.9)	5708 (94.3)	<0.001	532 (92.8)	462 (97.1)	0.002	1711 (90.1)	6170 (94.5)	<0.001
Yes	148 (11.2)	348 (5.8)		41 (7.2)	14 (2.9)		189 (10.0)	362 (5.5)	
Exercise ten years ago									
No	950 (71.6)	4298 (71.0)	0.65	354 (61.8)	266 (55.9)	0.05	1304 (68.6)	4564 (69.9)	0.3
Yes	377 (28.4)	1758 (29.0)		219 (38.2)	210 (44.1)		596 (31.4)	1968 (30.1)	
H. pylori infection									
No	239 (23.5)	1499 (29.7)	<0.001	93 (24.7)	114 (30.1)	0.1	332 (23.8)	1613 (29.7)	<0.001
Yes	779 (76.5)	3546 (70.3)		283 (75.3)	265 (69.9)		1062 (76.2)	3811 (70.3)	

Based on the chi-square test for category variables and t-test for continuous variables.

Table 3.

Odds ratios for stomach cancer by each component of dietary recommendation adherence scores among non-proxy interview (Cases=1,327, Controls=6,056).

	OR and 95%CI per 1-point increase			
	mCHEI-2016 score		HEI-2015 score	
Components	**Model 1**	**Model 2**	**Model 1**	**Model 2**
Total grains†	1.07 (0.91, 1.26)	0.97 (0.80, 1.19)		
Whole grains and mixed beans†	1.03 (0.96, 1.10)	**1.11 (1.02, 1.22)**		
Tubers†	**0.94 (0.89, 0.99)**	0.98 (0.92, 1.05)		
Total vegetables†	1.05 (1.00, 1.10)	1.06 (1.00, 1.12)	1.03 (0.99, 1.08)	1.05 (0.99, 1.11)
Dark vegetables†	0.99 (0.96, 1.03)	1.00 (0.95, 1.05)		
Total fruits†	0.97 (0.94, 1.00)	1.00 (0.96, 1.05)	0.94 (0.88, 1.01)	1.01 (0.93, 1.10)
Dairy†	1.07 (0.94, 1.23)	1.15 (0.96, 1.38)	1.04 (0.96, 1.13)	1.10 (0.98, 1.23)
Soybeans†	1.02 (0.97, 1.07)	1.00 (0.94, 1.06)		
Fish and seafood†	1.03 (0.99, 1.07)	1.05 (1.00, 1.11)		
Red meat€	0.99 (0.88, 1.11)	0.94 (0.81, 1.10)		
Poultry†	0.94 (0.87, 1.01)	0.97 (0.88, 1.07)		
Eggs†	1.02 (0.98, 1.06)	**1.08 (1.02, 1.13)**		
Seeds and nuts†	1.00 (0.97, 1.03)	0.99 (0.96, 1.04)		
Sodium€	**0.96 (0.93, 0.99)**	**0.95 (0.91, 0.99)**	**0.97 (0.95, 0.99)**	**0.97 (0.94, 0.99)**
Added sugars€	1.12 (0.83, 1.52)	0.92 (0.65, 1.32)	1.04 (0.90, 1.20)	0.95 (0.79, 1.14)
Alcohol€	**0.95 (0.93, 0.98)**	0.99 (0.95, 1.03)		
Fat¥	1.00 (0.99, 1.02)	0.99 (0.97, 1.02)	0.97 (0.94, 1.01)	0.96 (0.92, 1.01)
Whole fruit†			0.96 (0.92, 1.00)	1.01 (0.96, 1.07)
Greens and beans†			0.98 (0.94, 1.03)	1.00 (0.94, 1.06)
Whole grains†			1.01 (0.98, 1.05)	1.00 (0.95, 1.05)
Total protein foods†			1.04 (0.98, 1.10)	1.04 (0.97, 1.11)
Seafood and plant proteins†			1.03 (0.96, 1.10)	1.02 (0.94, 1.11)

	OR and 95%CI per 1-point increase			
	mCHEI-2016 score		HEI-2015 score	
Components	**Model 1**	**Model 2**	**Model 1**	**Model 2**
Refined grains[€]			0.97 (0.91, 1.03)	1.01 (0.93, 1.08)
Saturated fats[€]			0.97 (0.90, 1.04)	0.92 (0.83, 1.02)

Note: mCHEI-2016, modified Chinese Healthy Eating Index; HEI, Healthy Eating Index.

Model 1: Adjusted for age, gender, county, total energy intake.

Model 2: Adjusted for model 1 in addition to tobacco smoking (yes vs. no), pack year of smoking, *H. pylori* infection status, family history of stomach cancer, body mass index (continuous), education level (illiterate, primary, middle, high school or above), and income ten years ago (continuous).

[†]Adequacy components mean a higher intake indicating a higher score.

[€]Limitation components mean a lower intake indicating a higher score.

[¥]Because of different definitions of fat, it was regarded as a limitation component in mCHEI-2016, but an adequate component in HEI-2015.

Table 4.

Odds ratios for stomach cancer by quartiles of dietary recommendation adherence scores among non-proxy interview

	Quartiles of dietary recommendation adherence scores					
	I	**II**	**III**	**IV**	***p*-trend**	**per 10-point increase**
mCHEI-2016 score						
Total population						
Case/Control	379/1514	337/1514	328/1514	283/1514		
Crude	1.00	0.89 (0.76, 1.05)	0.87 (0.73, 1.02)	**0.75 (0.63, 0.89)**	**0.001**	**0.83 (0.77, 0.90)**
Model 1	1.00	1.00 (0.84, 1.18)	1.04 (0.88, 1.24)	0.98 (0.82, 1.18)	0.98	0.96 (0.88, 1.05)
Model 2	1.00	1.05 (0.85, 1.29)	1.03 (0.83, 1.28)	1.18 (0.94, 1.48)	0.22	1.05 (0.94, 1.17)
HEI-2015 score						
Total population						
Case/Control	360/1514	282/1514	397/1514	288/1514		
Crude	1.00	**0.80 (0.68, 0.95)**	1.10 (0.94, 1.29)	**0.78 (0.66, 0.93)**	0.26	0.94 (0.86, 1.02)
Model 1	1.00	**0.77 (0.65, 0.92)**	1.09 (0.92, 1.28)	0.85 (0.71, 1.01)	0.65	0.96 (0.88, 1.05)
Model 2	1.00	**0.72 (0.58, 0.90)**	1.09 (0.89, 1.34)	0.87 (0.69, 1.08)	0.98	0.98 (0.87, 1.10)

Note: mCHEI-2016, modified Chinese Healthy Eating Index; HEI, Healthy Eating Index.

Model 1: Adjusted for age, gender (only for total population), county, total energy intake.

Model 2: Adjusted for model 1 in addition to tobacco smoking (yes vs. no), pack year of smoking, *H. pylori* infection status, family history of stomach cancer, body mass index (continuous), education level (illiterate, primary, middle, high school or above), and income ten years ago (continuous).

Table 5.

Odds ratios for stomach cancer per 10-point increase of dietary recommendation adherence scores in stratified analyses among non-proxy interview (Cases=1,327, Controls=6,056).

	mCHEI-2016 score			HEI-2015		
	Crude	**Model 1**	**Model 2**	**Crude**	**Model 1**	**Model 2**
Gender						
Female	0.95 (0.81, 1.13)	1.04 (0.87, 1.25)	1.10 (0.89, 1.37)	1.07 (0.89, 1.27)	1.05 (0.87, 1.26)	1.06 (0.84, 1.34)
Male	**0.81 (0.73, 0.89)**	0.94 (0.85, 1.04)	1.02 (0.89, 1.16)	**0.90 (0.81, 0.99)**	0.93 (0.84, 1.03)	0.94 (0.82, 1.07)
p for interaction			0.13			0.12
Tobacco smoking						
Non-smoker	**0.86 (0.75, 0.98)**	0.97 (0.84, 1.12)	1.07 (0.90, 1.28)	0.96 (0.84, 1.11)	0.96 (0.83, 1.11)	0.98 (0.82, 1.18)
Smoker	**0.84 (0.76, 0.93)**	0.97 (0.87, 1.09)	1.00 (0.87, 1.15)	**0.90 (0.80, 0.998)**	0.94 (0.84, 1.05)	0.94 (0.82, 1.09)
p for interaction			0.62			0.97
H. pylori infection						
Negative	**0.80 (0.66, 0.97)**	1.04 (0.85, 1.28)	1.14 (0.91, 1.43)	0.89 (0.73, 1.08)	0.95 (0.78, 1.17)	1.04 (0.83, 1.31)
Positive	**0.78 (0.70, 0.87)**	0.96 (0.85, 1.08)	1.02 (0.90, 1.16)	0.90 (0.80, 1.01)	0.93 (0.83, 1.06)	0.96 (0.84, 1.10)
p for interaction			0.57			0.68
Family history of stomach cancer						
No	**0.84 (0.77, 0.91)**	0.95 (0.87, 1.04)	1.03 (0.92, 1.16)	0.94 (0.86, 1.02)	0.96 (0.88, 1.05)	0.98 (0.88, 1.11)
Yes	0.87 (0.65, 1.16)	1.12 (0.82, 1.53)	1.24 (0.85, 1.82)	0.99 (0.73, 1.35)	1.16 (0.84, 1.60)	1.09 (0.74, 1.61)
p for interaction			0.64			0.83
Body max index						
<24 (kg/m^2)	**0.81 (0.74, 0.88)**	0.94 (0.86, 1.04)	0.97 (0.86, 1.10)	0.92 (0.84, 1.01)	0.94 (0.85, 1.04)	0.91 (0.80, 1.04)
≥24 (kg/m^2)	1.00 (0.82, 1.23)	1.09 (0.87, 1.36)	1.29 (0.98, 1.69)	1.06 (0.85, 1.32)	1.06 (0.84, 1.32)	1.19 (0.89, 1.60)
p for interaction			**0.02**			0.09

Note: mCHEI-2016, modified Chinese Healthy Eating Index; HEI, Healthy Eating Index.

Model 1: Adjusted for age, gender, county, total energy intake.

Model 2: Adjusted for model 1 in addition to tobacco smoking (yes vs. no), pack year of smoking, *H. pylori* infection status, family history of stomach cancer, body mass index (continuous), education level, and income ten years ago, except for the corresponding variables used for stratification.