Adherence to “dietary approaches to stop hypertension” eating plan in relation to gastric cancer

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Abstract

Background: Although adherence to “Dietary Approaches to Stop Hypertension” (DASH) dietary pattern has been linked with reduced risk of several cancers. To our knowledge no studies have examined the association between the DASH dietary pattern and risk of gastric cancer. This study was performed to investigate the association between adherence to the DASH dietary pattern and odds of gastric cancer in Iran.

Methods: This hospital-based case-control study was conducted on 178 histo-pathologically confirmed patients with gastric cancer and 276 sex-matched healthy controls. A validated 146-item Diet History Questionnaire (DHQ) was used to assess participants’ usual dietary intakes. The DASH dietary pattern scores were calculated using the method introduced by Fung. Unconditional logistic regression, in which potential confounders were taken into account, was applied to determine the association of adherence to the DASH dietary pattern and odds of gastric cancer.

Results: Mean age of cases and controls were 60.8 and 53.2 y, respectively. After controlling for age, sex and energy intakes, participants in the highest tertile were 62% less likely to have gastric cancer than those in the lowest tertile (OR 0.38; 95% CI 0.22,0.65; P_trend < 0.004). Further adjustment for other potential confounders, including education, marital status, residential place, alcohol intake and smoking, did not change the association dramatically (OR 0.44; 95% CI 0.25, 0.78; P_trend = 0.005). Even after additional controlling for H-Pylori infection and BMI, greatest adherence to the DASH dietary pattern was associated with a 54% decreased risk of gastric cancer (OR 0.46; 95% CI 0.26, 0.83; P_trend = 0.01).

Conclusions: Adherence to the DASH dietary pattern was associated with lower gastric cancer risk in this case-control study.

Keywords: Gastric cancer, Dietary approach to stop hypertension, Diet, Case-control

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Background
Gastric cancer is one of the most common cancers in the world. Although its incidence is decreasing in most developed countries, it is still known as the forth common cancer in men and the seventh common cancer in women worldwide [1]. In Iran, the estimated Age-Standard Rate (ASR) is 26.1 per 100,000 in men and 11.1 per 100,000 in women [2]. As approximately 80% of patients are diagnosed in advanced stages and do not benefit from therapeutic strategies, primary prevention and screening for early detection are the most effective strategies in gastric cancer control [3].

Prevention strategies need to be designed based on established risk factors. Along with genetics, H. pylori infection, tobacco smoking, alcohol drinking and body fatness; diet has also been shown to play a major role [3–5]. For instance, there is strong evidence that consumption of salt-preserved foods or processed meats is positively associated with the risk [6–10]. A systematic review of 42 studies concluded that higher consumption of red meat was associated with a 67% increase in risk of gastric cancer (OR 1.67 comparing highest to lowest intake; 95%CI 1.36, 2.05). Higher consumption of processed meat was associated with considerable higher risk in this study (OR 1.76 comparing highest to lowest intake; 95%CI 1.51,2.05) [8]. A review of cohort studies indicates that risk of gastric cancer could increase by 12% per 5 g/day increase of salt intake [11]. The latest review by The World Cancer Research Fund and American Institute for Cancer Research reported that there is limited suggestive evidence on the association between fruit intake and risk of stomach cancer. It also asserted that the evidence of associations between other dietary intakes such as vegetables, nuts and dairy and risk of stomach cancer is limited and inconsistence [10]. It has been assumed that inconclusive findings on the diet-disease associations were due to assessment of individual nutrients or foods. Studying dietary patterns would be more reasonable and informative due to considering the interaction among foods and nutrients [12, 13].

Dietary Approaches to Stop Hypertension (DASH) eating pattern was developed and initially recommended for controlling blood pressure [14]. Its protective role in other conditions including obesity [15], diabetes [16], metabolic syndrome [17, 18] and CVD [19] was then demonstrated. This dietary pattern consists of high intake of fruit, vegetables, legumes, nuts, whole grains and low fat dairy, and low intakes of sodium, red and processed meats and sweetened beverages [20]. This dietary pattern is largely similar to the recommendations of American Cancer Society and International Agency for Research on Cancer (IARC) for cancer prevention [21, 22]. Many studies have investigated the association of the DASH dietary pattern components with several cancers [23]. Earlier publications have shown inverse association between adherence to the DASH dietary pattern and risk of colorectal [24] and breast cancers [25], but the association with gastric cancer has not been investigated so far. Moreover, studies on diet-disease associations, including cancer, mostly came from western countries and few data have been reported from the under-studied region of Middle East [26–28]. Dietary cultures and environmental factors affecting the risk of cancer are discrepant in different areas. Traditional diet of Middle Eastern population included large amounts of refined grains and carbohydrates along with high intakes of salt and low intake of animal products [29, 30]. However, nutrition transition in these countries is occurring at an alarming rate and their dietary intakes are changing rapidly [29, 30]. Energy, total fat and animal proteins intakes are increasing in these region and intake of fruits, vegetables and dairy is decreasing at the same time [31–33]. Moreover, their gastrointestinal microbiota is different due to different dietary habit and lifestyle which could effect on association of dietary pattern and cancer risks [34]. Assessment of adherence to the DASH dietary pattern with gastric cancer is particularly relevant for Middle Eastern population due to their specific dietary patterns. This study was, therefore, done to explore the relationship between adherence to the DASH dietary pattern and risk of gastric cancer in Iran.

Methods
Participants
This hospital-based case-control study was conducted in the Cancer Research Center, Imam Khomeini complex, Tehran University of Medical Sciences, Tehran, Iran between May 2010 and June 2012. Histo-pathologically confirmed patients with gastric cancer were recruited in the study. Patients were referred to this hospital from all parts of Iran. The inclusion criteria for case enrollment were diagnosed with gastric cancer within previous 6 months with no medical history of any cancer and age of 40 years or older. Convenience sampling method was used for case enrollment. In total, 276 controls were recruited from the same hospital based on non-random sampling method if they were apparently healthy persons. They were chosen among those who came to visit their relatives in the hospital. The response rate was 95% among cases and 70% among controls.

Ethics
Written informed consent was provided by all participants after face to face description of study protocol and aims. Ethical committee of Cancer Research Center, Tehran University of Medical Sciences reviewed and approved the study protocol.

Assessment of dietary intakes
We used a validated 146-item Diet History Questionnaire (DHQ) to assess participants' dietary intakes. A
detailed description of DHQ, its development and validity has been explained in details elsewhere [35]. Briefly, it included 146 questions related to the past 12-month consumption of foods and Iranian mixed dishes. Trained nutritionists conducted face to face interview to complete the (DHQ). The interviewers asked participants to recall their dietary intakes based on a given portion size in the preceding year. Patients with gastric cancer were requested to recall their intakes before the appearance of cancer symptoms. Participants were able to choose their frequency consumption of different foods and dishes based on Iranian home scales such as spoon, plate, bowl, ladle or splatter. DHQ data were converted to grams/day using the booklet of household measures [36]. Then daily intakes of energy and all micro and macro-nutrients were computed using translated version of McCance and Widdowson’s Food composition table modified for Iranian foods [37–39]. We also asked participants about their supplement use during the previous year.

Previous validation study of DHQ in this population revealed good correlation coefficients between nutrients assessed by DHQ and multiple 24-h recalls completed over a year [35]. Deattenuated spearman correlation coefficients of equal or greater than 0.5 were obtained for energy, carbohydrate, protein, fiber, vitamin A, carotene, niacin, folate, vitamin B12, biotin, vitamin C, sodium, magnesium, iron, zinc, selenium between DHQ and the average of 24-h dietary recalls [40].

Construction of DASH score
The DASH dietary pattern scores were calculated using the method introduced by Fung [41]. DASH diet score were constructed based on nutrients and foods minimized or emphasized in the DASH dietary pattern. It emphasizes high intake of fruit, vegetable, nuts, legumes, low fat dairy products, and whole grains and recommends low intake of sodium, sweetened beverages and red and processed meats [20, 41]. As the Iranian population mainly consumes refined grains [42], therefore, lower intake of grains was considered as a protective factor. Initially, we obtained energy-adjusted amount of components of the DASH dietary pattern using residual method [43]. We classified participants into quintiles according to intakes of each components of the DASH dietary pattern. Quintile cut-off points of these components were obtained based on intakes in control subjects in order to avoid probable bias that might be arise due to the changes in dietary intakes in patients. Then, in terms of fruit, vegetable, nuts, legumes and low fat dairy products participants were given the score of 1 if they placed at quintile 1. This was done for all quintile of these food items such that those in the top quintile of these food items were given the score of 5. We did vice versa for sodium, sweetened beverages and red and processed meats; such that those in the bottom quintile of these food items were given the score of 5 and those in the top quintile were given the score of 1. The overall DASH score for each participant was calculated by summing up all components’ scores. The total score ranged from 8 to 40 [41, 44]. The greater the score presents the great adherence to the DASH dietary pattern.

Assessment of gastric cancer
Diagnosis of gastric cancer was done based on gastroscopic or surgical biopsy reviewed by an experienced pathologist. Patients with histologically confirmed stomach cancer as defined by the second edition of the International Classification of Diseases for Oncology (ICD-O-c16) were enrolled. We only recruited patients who had been diagnosed within the 1 yr prior to the date of interview.

Assessment of covariates
Demographic and general information were collected using a structured questionnaire through a face to face interview conducted by a trained bachelor of health sciences. These included information about gender, marital status, education, residential places and smoking habits. Data on usual weight and height were collected through self-reported method. We did not examine current weight due to the effect of gastric cancer on weight in these patients. Body Mass Index (BMI) was calculated as weight in kilograms divided by height in meters squared. Smoking status was examined through asking participants about their usual behavior on smoking during the last year. They were classified as current smokers and non-smokers. To examine H. pylori infection, we took 10 ml of venous blood samples from all participants at fasting or non-fasting state when they attended the center. Serum samples were evaluated for IgG antibody using ELISA kits. Experienced technicians, who were not aware of the study design and case/control status of donors, performed the serologic assays. The H.pylori antibody test was repeated in a random selection of serums to ascertain validity. The seropositivity was defined as the presence of antibody and seropositivity > 0.87 was considered as positive.

Statistical analysis
Characteristic of patients with gastric cancer and controls were compared using Student’s independent t test for continuous variables and chi-square test for categorical variables. Comparison of these variables across tertiles of DASH diet score was done using chi-square test for categorical and one-way ANOVA for continuous variables. To determine the association of adherence to the DASH dietary pattern and odds of gastric cancer, we
applied unconditional logistic regression models, in which several potential confounding variables were taken into account. In these analyses, first we controlled for age (continuous), sex (male, female) and energy intake (continuous). Then, further adjustments were done for education (categorical), marital status (single, married) and residential place (Tehran, other cities). Alcohol intake (g/day) and smoking status (ever vs. never) were taken into account in an additional model and finally, we controlled for H-pylori infection (positive, negative). To identify independent-of-obesity association between adherence to the DASH dietary pattern and gastric cancer, we also adjusted for BMI (continuous). In all these analyses, the first tertile of DASH diet score was considered as a reference and the odds ratios (ORs) and 95% CIs for gastric cancer were calculated. The trend of odds ratios was examined by considering the median score of the DASH dietary pattern in each tertile as a continuous variable. All statistical analyses were carried out using STATA (STATA, version 14, State Corp., College station, TX).

Results

Study participants were 178 patients with gastric cancer and 276 healthy controls. Table 1 shows the distribution of patients and controls according to selected covariates. Characteristic of participants across tertiles of DASH diet score are also provided in this table. Patients with gastric cancer were older (60.8 vs. 53.2 y, P < 0.001) and more likely to be males (74.2 vs. 63.8%, P = 0.02), married (97.8 vs. 85.9%, P < 0.001) and illiterate (62.4% vs. 26.1%, P < 0.001) than controls. They were less affected with H. pylori (38.2 vs. 56.16%, P < 0.001) and were less likely to be current smokers (54.5% vs. 62.2%, P = 0.01) than controls. When examined across tertiles of DASH diet score, we found that greater adherence to the DASH dietary pattern was not associated with any difference in covariates except for marital status (P = 0.01).

Dietary intakes of participants are shown in Table 2. Compared with controls, patients with gastric cancer had significantly lower intakes of grains (313 vs. 443, P < 0.001), vegetables (242 vs. 378, P < 0.001) and fruits (372 vs. 554, P < 0.001). As expected, greater adherence to the DASH dietary pattern was associated with higher intakes of nuts and legumes (P < 0.001), vegetables (P < 0.001), fruits (P < 0.001) and low fat dairy (P < 0.001). Subjects with greater adherence to the DASH dietary pattern had lower intakes of grains (P = 0.01), sweetened drinks (p = 0.001), and red and processed meats (p = 0.002).

Multivariable adjusted ORs for gastric cancer across tertiles of DASH diet score are provided in Table 3. Before adjusting for covariates, adherence to the DASH dietary pattern was inversely associated with gastric cancer (OR for comparing extreme tertiles: 0.47; 95% CI 0.28–0.77; P trend = 0.004). After controlling for age, sex and energy intakes, greater adherence to the DASH dietary pattern was associated with a substantial reduced odds of gastric cancer; such that participants in the highest tertile were 62% less likely to have gastric cancer than those in the lowest tertile (OR 0.38; 95% CI 0.22, 0.65; P trend < 0.001). Further adjustment for other potential confounders, including education, marital status, residential place, alcohol intake and smoking, did not change the association dramatically (OR 0.44; 95% CI 0.25, 0.78; P trend = 0.005). Even after additional controlling for H-Pylori infection and BMI, greatest adherence to the DASH dietary pattern was associated with a 54% decreased risk of gastric cancer (OR 0.46; 95% CI 0.26, 0.83; P trend = 0.01).

Discussion

In this large hospital-based case control study, we found an inverse association between adherence to the DASH dietary pattern and gastric cancer were older (60.8 vs. 53.2 y, P < 0.001) and more likely to be males (74.2 vs. 63.8%, P = 0.02), married (97.8 vs. 85.9%, P < 0.001) and illiterate (62.4% vs. 26.1%, P < 0.001) than controls. They were less affected with H. pylori (38.2 vs. 56.16%, P < 0.001) and were less likely to be current smokers (54.5% vs. 62.2%, P = 0.01) than controls. When examined across tertiles of DASH diet score, we found that greater adherence to the DASH dietary pattern was not associated with any difference in covariates except for marital status (P = 0.01).

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Table 1. General characteristic of participants across tertiles of DASH score1

| Characteristics       | Groups                          | Tertile of DASH score |
|-----------------------|---------------------------------|-----------------------|
|                       | Cases (n = 178)                 | Controls (n = 276)    |
|                       | Age (years)                     | < 0.001               |
|                       | 60.8 ± 12.0                     | 53.2 ± 11.9           | 54.5 ± 12.9 57.6 ± 12.7 56.6 ± 11.4 0.07 |
| Alcohol intake (g/day)| 6.8 ± 86.4                      | 1.7 ± 11.7            | 1.4 ± 9.9 8.4 ± 92.4 1.11 ± 9.6 0.44 |
| BMI (kg/m2)           | 278 ± 16.4                      | 260 ± 8.2             | 27.6 ± 14.2 26.4 ± 13.3 25.8 ± 4.6 0.44 |
| Gender (Male, %)      | 132(74.2)                       | 176(63.8)             | 108(65.9) 122(71.4) 78(65.6) 0.46 |
| Marital status (Married, %) | 174(97.8)                   | 237(85.9)             | 156(95.1) 157(91.8) 100(84.0) 0.01 |
| Education (illiterate, %) | 111(62.4)                   | 72(26.1)              | 69(42.1) 68(39.8) 46(38.7) 0.53 |
| Residential (Tehran, %) | 93(52.3)                       | 140(50.8)             | 86(52.4) 92(53.8) 55(46.1) 0.42 |
| Smoking (yes %)       | 81(45.5)                        | 85(30.8)              | 62(37.8) 66(38.6) 38(31.9) 0.47 |
| H.pylori (positive, %) | 68(38.2)                        | 155(56.2)             | 82(50.0) 83(48.5) 58(48.7) 0.96 |

1 Reported figures are means±SDs unless indicated
2 Obtained from chi-square test for categorical variables and independent student’s t-test for continuous variables
3 Obtained from chi-square test for categorical and one-way ANOVA for continuous variables
dietary pattern and odds of gastric cancer. To the best of our knowledge, this study is the first examining the association between adherence to the DASH dietary pattern and risk of gastric cancer.

As mentioned before, the DASH dietary pattern was initially suggested to manage hypertension [20]; however, its beneficial effects on other health outcomes including some cancers have also been reported [45–49]. Although no prior information are available about the link between this dietary pattern as a whole and gastric cancer, several studies reported significant associations between components of the DASH dietary pattern and risk of gastric cancer [50]. For instance, high intake of fruits and vegetables, as main components of this dietary pattern, was inversely associated with gastric cancer [51]. However, the comprehensive report on nutrition and cancer prevention by the World Cancer Research Fund and American Institute for Cancer Research revealed that the evidence on the association of fruit and vegetable intake and risk of gastric cancer is not convincing. Based on this report, there is limited evidence to suggest that fruit consumption is protective against gastric cancer. Other dietary components were reported as limited evidence, no conclusion [10].

Several studies have examined the association between other healthy dietary patterns and risk of gastric cancer [26, 52, 53]. In a review by Schwingshackl and Hoffmann, consumption of Mediterranean-type diet was

| Table 2 | Dietary intakes of participants across tertiles of DASH score |
|-----------------------------------------------|
| Nutrient /food group | Groups | Tertiles of DASH diet score |
|-----------------------------------------------|
| | Cases (n = 178) | Controls (n = 276) | P | 1 (n = 176) | 2 (n = 158) | 3 (n = 120) | P |
|-----------------------------------------------|
| Energy (Kcal/d) | 2853 ± 1241 | 2782 ± 1252 | 0.55 | 2678 ± 1154 | 2871 ± 1325 | 2903 ± 1247 | 0.23 |
| Grains (g/d) | 313 ± 272 | 443 ± 218 | < 0.001 | 440 ± 282 | 388 ± 291 | 332 ± 268 | 0.01 |
| Nuts and legumes (g/d) | 37 ± 28 | 43 ± 34 | 0.09 | 34 ± 28 | 39 ± 29 | 51 ± 38 | < 0.001 |
| Vegetables (g/d) | 242 ± 172 | 378 ± 221 | < 0.001 | 249 ± 189 | 310 ± 193 | 448 ± 220 | < 0.001 |
| Fruits (g/d) | 372 ± 278 | 554 ± 392 | < 0.001 | 365 ± 268 | 449 ± 307 | 694 ± 451 | < 0.001 |
| Low fat dairy (g/d) | 588 ± 580 | 582 ± 65 | 0.09 | 275 ± 433 | 651 ± 615 | 914 ± 681 | < 0.001 |
| Red and processed meats (g/d) | 31 ± 29 | 34 ± 36 | 0.27 | 40 ± 39 | 31 ± 29 | 27 ± 28 | 0.002 |
| Sweetened drinks (g/d) | 85 ± 89 | 82 ± 119 | 0.08 | 105 ± 91 | 79 ± 95 | 59 ± 139 | 0.001 |
| Fats (g/d) | 105 ± 58 | 98 ± 61 | 0.23 | 92 ± 49 | 102 ± 61 | 109 ± 69 | 0.06 |
| Proteins (g/d) | 126 ± 51 | 123 ± 47 | 0.49 | 125 ± 51 | 123 ± 49 | 126 ± 46 | 0.83 |
| Carbohydrates (g/d) | 367 ± 181 | 365 ± 177 | 0.90 | 351 ± 166 | 381 ± 200 | 365 ± 159 | 0.32 |
| Potassium (mg/d) | 5682 ± 2478 | 5539 ± 2245 | 0.52 | 5497 ± 2293 | 5620 ± 2413 | 5694 ± 2305 | 0.77 |
| Sodium (mg/d) | 2686 ± 1727 | 2617 ± 1477 | 0.65 | 2818 ± 1742 | 2669 ± 1678 | 2367 ± 1093 | 0.06 |
| Calcium (mg/d) | 2253 ± 1285 | 2218 ± 1193 | 0.77 | 2223 ± 1240 | 2227 ± 1209 | 2249 ± 1251 | 0.98 |
| Folate (mg/d) | 424 ± 178 | 414 ± 164 | 0.53 | 414 ± 164 | 418 ± 175 | 421 ± 169 | 0.93 |

1 using independent student T-test
2 using one-way ANOVA

| Table 3 | Odd Ratios (ORs) and 95% confidence Intervals (CIs) for gastric cancer across tertiles of DASH score |
|-----------------------------------------------|
| OR (95%CI) | Tertile 1 | Tertile 2 | Tertile 3 | P trend |
|-----------------------------------------------|
| Total No. of cases/controls (178/276) | | | | |
| Crude | 1.00 | 0.86(0.56–1.33) | 0.47(0.28–0.77) | 0.004 |
| Model A b | 1.00 | 0.68(0.43–1.09) | 0.38(0.22–0.65) | < 0.001 |
| Model B c | 1.00 | 0.73(0.44–1.19) | 0.43(0.24–0.76) | 0.004 |
| Model C d | 1.00 | 0.73(0.44–1.21) | 0.44(0.25–0.78) | 0.005 |
| Model D e | 1.00 | 0.73(0.44–1.22) | 0.43(0.24–0.77) | 0.005 |
| Model E f | 1.00 | 0.74(0.44–1.25) | 0.46(0.26–0.83) | 0.01 |

a Trend based on median values of each tertile
b Adjusted for age (continuous), sex (male/female) and energy intake (continuous)
c Further adjusted for education (illiterate/literate), marital status (married/single) and residential place (Thran/others)
d Additionally adjusted for alcohol intake (continuous) and smoking status (smoker/nonsmoker)
e Further adjusted for H. pylori infection (positive/negative)
f Additionally controlled for BMI (continuous)
associated with a 27% reduced risk of gastric cancer. There was almost a 2-fold difference in risk of gastric cancer, comparing adherence to a healthy diet rich in fruit and vegetables and a western/unhealthy diet rich in starchy foods, meat and fats [54]. However, some studies did not suggest any significant association. Analyzing data from National Institutes of Health-AARP Diet and Health Study, the investigators found no significant association between adherence to healthy diet, as measured by Healthy Eating Index, or Mediterranean diet and risk of gastric cancer [26]. Therefore, it seems that there are unanswered questions about the association between dash or other dietary patterns and risk of gastric cancer; hence further studies are required to shed light on this issue in the future.

Patients with gastric cancer in this study were less likely to be affected by H-Pylori infection and reflux. This is in opposite to earlier publications [55, 56]. It should be kept in mind that we evaluated H. pylori infection by assessing Ig G antibody which might be cleaned during the gastric atrophy and tumor growth [57]. It is recognized that, H.pylori did not colonize in areas affected by cancer, metaplasia or atrophy and it is lost through development of advanced gastric diseases. This might explain why the patients with gastric cancer had H-pylori seronegative in the current study. Moreover, patients with gastric cancer were more likely to receive anti H.pylori treatments which can further explain this finding [58].

The mechanisms through which adherence to the DASH dietary pattern affect risk of gastric cancer are unknown. Prior investigations have shown the involvement of oxidative stress in the pathophysiology of several cancers [59–61]. The DASH dietary pattern contains high amounts of fruits, vegetables, whole grains, legumes and nuts. These foods are rich sources of dietary fiber, phenolic compounds, folate and carotenes; the beneficial effects of them on oxidative stress has earlier been shown [62, 63]. On the other hand, low consumption of red and processed meats and sweetened drinks might further help explaining the protective association between this dietary pattern and gastric cancer [64]. Red and processed meats contain high amounts of N-Nitroso compounds (NOCs), heterocyclic amines and polycyclic aromatic hydrocarbons [8, 65]. In addition, red meats are rich in iron and saturated fatty acids which have been shown as carcinogenic factors in the literature. Sweetened beverages are high in fructose; greater intake of which is a risk factor for gastric cancer. In addition, the DASH dietary pattern, probably through lower intakes of simple carbohydrates and higher intakes of fiber, is inversely associated with insulin resistance [66], which in turn is positively associated with risk of several cancers including gastric cancer [67]. Insulin and insulin-like growth factor 1 can promote cancer development by activating several signaling pathways associated with an elevated risk of oncogenesis [65].

Strengths and limitations
High rates of participation, the same socioeconomic status of patients and controls, measuring the seropositivity of H. pylori as a risk factor for gastric cancer and the use of a validated FFQ for dietary assessment are strengths of this study. However, several limitations should also be noted. As with all epidemiological studies applying FFQ, misclassification of study participants based on their dietary intakes is unavoidable [68]. We used energy adjusted intakes of food groups to compute adherence to the DASH dietary pattern [43]. This can help reducing the possibility of misclassification. All food groups in the DASH dietary pattern were given an equal weight, while some foods might have greater effects than others in gastric cancer development. Although we controlled for several confounders, the possibility of residual confounding cannot be excluded. Other limitations of this study include a relatively small number of cases which did not allow meaningful analysis by separate histological type or tumor site. Given the case-control design of the study, the inherent limitations of recall and selection bias should also be considered [69].

Conclusion
One the basis of this case-control study, we demonstrated that adherence to the DASH dietary pattern was inversely associated with risk of gastric cancer. This finding supports the current recommendations by several international guidelines to consume high amounts of plant based foods in the usual diet. It is clear that, further studies, in particular of prospective design, are required to confirm these findings. However, as the benefits of this dietary pattern have been firmly confirmed in several health conditions, it would be sensible to advice DASH dietary pattern to enhance public health.

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Authors’ contributions
FT and KZ designed the study, BS and MH supervised data collection and cleaning, FT analyzed the data and wrote the draft under supervision of AE and help of MH. All authors reviewed the final version of manuscript.

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Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.
Ethics approval and consent to participate
This study was conducted according to the guidelines laid down in the Declaration of Helsinki 237 and all procedures involving human subjects/patients were approved by the Tehran University of Medical Sciences. Written informed consent was obtained from all subjects/patients.

Consent for publication
There is no personal information regarding any patients in our article.

Competing interests
There is no potential conflict of interest.

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References
1. 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 Clin. 2018;68(6):394–424.
2. Malekzadeh R, DesaiKhans M, Malekzadeh Z. Gastric cancer in Iran: epidemiology and risk factors. 2009.
3. Rugge M, Fassan M, Graham DY. Epidemiology of gastric cancer. Gastric Cancer: Springer; 2015. p. 23–34.
4. Peleteiro B, Castro C, Morais S, Ferro A, Lunet N. Worldwide burden of gastric cancer attributable to tobacco smoking in 2012 and predictions for 2020. Dig Dis Sci. 2015;60(8):2470–6.
5. de Martel C, Forman D, Plummer M. Gastric cancer: epidemiology and risk factors. Gastroenterol Clin. 2013;42(2):19–40.
6. Wang T, Cai H, Sasazuki S, Tsugane S, Zheng W, Cho R, 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 Cancer. 2017;140(5):951–9.
7. Umetsawa M, Iso H, Fujino Y, Kikuchi S, Tamakoshi A. Salty food preference and intake and risk of gastric cancer: the JACC study. J Epidemiol. 2016;26(2):92–7.
8. Zhao Z, Yin Z, Zhao Q. Red and processed meat consumption and gastric cancer risk: A systematic review and meta-analysis. Oncotarget. 2017;8(18):30563.
9. Boada LD, Henriquez-Hernandez LA, Luzardo O. The impact of red and processed meat consumption on cancer and other health outcomes: epidemiological evidences. Food Chem Toxicol. 2016;92:236–44.
10. Clinton SK, Giovannucci EL, Hursting SD. The World Cancer Research Fund/American Institute for Cancer Research Third Expert Report on Diet, Nutrition, Physical Activity, and Cancer: Impact and Future Directions. J Nutr. 2019.
11. 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 Cancer. 2015;51(18):2802–32.
12. Grosso G, Bella F, Godos J, Siciaca S, Del Rio O, Ray S, et al. Possible role of diet in cancer: Systematic review and multiple meta-analyses of dietary patterns, lifestyle factors, and cancer risk. Nutr Rev. 2017;75(6):405–19.
13. Hu FB. Dietary pattern analysis: a new direction in nutritional epidemiology. Curr Opin Lipidol. 2002;13(1):3–9.
14. Sacks FM, Obarzanek E, Windhauser MM, Svetkey LP, Vollmer WM, McCullough M, et al. Rationale and design of the Dietary Approaches to Stop Hypertension trial (DASH): A multicenter controlled-feeding study of dietary patterns to lower blood pressure. Ann Epidemiol. 1995;5(2):1108–18.
15. Soltani S, Shirani F, Chitsaz MI, Salehi-Abargouei A. The effect of dietary approaches to stop hypertension (DASH) diet on weight and body composition in adults: a systematic review and meta-analysis of randomized controlled clinical trials. Obesity Rev. 2016;17(5):442–54.
16. Janssens F, Kröger J, Schulze MB. Dietary Patterns and Type 2 Diabetes: A Systematic Literature Review and Meta-Analysis of Prospective Studies–3. J Nutr. 2017;147(6):1174–82.
17. Agharizadeh A, Yuzbashian E, Mirimiran P, Hooshmand F, Najafi R, Azizi F. Dietary approaches to stop hypertension (DASH) dietary pattern is associated with reduced incidence of metabolic syndrome in children and adolescents. J Peditiatrics. 2016;174:78–84.
18. Park Y-MM, Steck SE, Fung TT, Zhang J, Hazlett L, Han K, et al. Mediterranean diet, Dietary Approaches to Stop Hypertension (DASH) style diet, and metabolic health in US adults. Nutr. Metab. 2017;13(5):36–10.
19. Servio M, Lara J, Choudhury S, Ashor A, Oggoni C, Mathers JC. Effects of the Dietary Approach to Stop Hypertension (DASH) diet on cardiovascular risk factors: a systematic review and meta-analysis. Br J Nutr. 2015;113(1):1–15.
20. Sacks FM, Moore TJ, Appel LJ, Obarzanek E, Cutler JA, Vollmer WM, et al. A dietary approach to prevent hypertension: a review of the Dietary Approaches to Stop Hypertension (DASH) Study. Clin Cardiol. 1999;22(3):S6–10.
21. Kushi LH, Doyle CC, McCulloh M, Rock CL, Demark-Wahnefried W, Bandera EV, et al. American Cancer Society Guidelines on nutrition and physical activity for cancer prevention: reducing the risk of cancer with healthy food choices and physical activity. CA Cancer J Clin. 2012;62(1):30–67.
22. McGuire S. World cancer report 2014. Geneva, Switzerland: World Health Organization, international agency for research on cancer, WHO Press. 2015. Oxford University Press, 2016.
23. Onvani S, Haightwardost F, Azadbakhht L. Dietary approach to stop hypertension (DASH) diet components may be related to lower prevalence of different kinds of cancer: A review on the related documents. J Res Med Sci. 2015;20(7):707.
24. Jones-McLean E, Hu J, Greene-Finestone L, de Groh M. A DASH dietary pattern and the risk of colorectal cancer in Canadian adults. Health promotion and chronic disease prevention in Canada: research, policy and practice. 2015;35(1):12.
25. Fung TT, Hu FB, Hankinson SE, Willett WC, Holmes MD. Low-carbohydrate diets, dietary approaches to stop hypertension-style diets, and the risk of postmenopausal breast cancer. Am J Epidemiol. 2011;174(6):652–60.
26. Vergnaud A-C, Romaguera D, Peeters PH, Van Gils CH, Chan DS, Romieu I, et al. Adherence to the World Cancer Research Fund/American Institute for Cancer Research guidelines and risk of death in Europe: results from the European Prospective Investigation into Nutrition and Cancer cohort study. Am J Clin Nutr. 2013;97(5):1167–70.
27. Tahz B, Eltorn SE. The role of diet and lifestyle in women with breast cancer: an update review of related research in the Middle East. Biore Open Access. 2018;7(1):73–80.
28. Naja F, Nasreddine L, Awada S, Ahmad RS, Hwalla N. Nutrition in the Prevention of Breast Cancer: A Middle Eastern Perspective. Frontiers Public Health. 2019;7.
29. Hwalla N, Weaver CM, Mekary RA, El Labban S. Public health nutrition in the Middle East: Frontiers Public Health. 2019;7.
30. Keats EC, Rappaport AI, Shah S, Oh C, Jain R, Bhutta ZA. The dietary intake and practices of adolescent girls in low- and middle-income countries: A systematic review of Nutrients. 2018;10(12):1978.
31. Jesili M, Mirimiran P, Golzari M, Rashidihi K, Hossein-Esfahani F, Azizi F. Comparison of trends in dietary pattern in Iran, Middle Eastern and North African countries from 1961 to 2005. Pajoohandeh. 2011;16(1):1–10.
32. Mehoi Sibak A, Nasreddine L, Mokdad AH, Adra N, Tabet M, Hwalla N. Nutrition Transition and Cardiovascular Disease Risk Factors in Middle East and North Africa Countries: Reviewing the Evidence. Ann Nutr Metab. 2010;57(3):193–203.
33. Demini S, Berry EM. Mediterranean Diet: From a Healthy Diet to a Sustainable Dietary Pattern. Frontiers Nutrition. 2015 2015-May-07;2(15).
34. Shankar V, Gouda M, Moncozav J, Gordon A, Reo N, Hussein L, et al. Differences in gut metabolites and microbial composition and functions between Egyptian and US children are consistent with their diets. Msystems. 2017;2(1).
Chikara S, Nagaprashantha LD, Singhal J, Horne D, Awasthi S, Singhal SS. Hecht F, Pessoa CF, Gentile LB, Rosenthal D, Carvalho DP, Fortunato RS. The Helicobacter, Group CC. Gastric cancer and Helicobacter pylori: a combined analysis. Ann Oncol. 2013;24(6):1450–51.

Buckland G, Agudo A, Luján L, Jakszyn P, Bueno-de-Mesquita HB, Palli D, et al. Dietary patterns and gastric cancer risk: a systematic review and meta-analysis. Ann Oncol. 2013;24(6):1450–51.

Toorang F, Sasanfar B, Esmaillzadeh A, Zendehdel K. Adherence to the low carbohydrate diet and the risk of breast Cancer in Iran. Nutr J. 2019;18(1):86.

Dorosti A, Tabatabaei M. Food composition table 2007.

Azar M, Sarkisian E. Food composition table of Iran. Tehran: National Nutrition and Food Research Institute, Shaheed Beheshti University. 1980:65.

Gebhardt S, Lemar L, Haytowitz D, Pehrsson P, Nickle M, Showell B, et al. USDA national nutrient database for standard reference, release 21. United States Department of Agriculture.Agricultural Research Service. 2008.

Toorang F, Sasanfar B, Jahromi SR, Koujan SE, Narmcheshm S, Rafiei A, et al. Validation of Diet History Questionnaire in Assessing Energy and Nutrient Intakes of Iranian Population. Iran J Public Health. 2019;48(6):1074–81.

Fung TT, Chiuve SE, McCullough ML, Rexrode K, Hu FB. Adherence to a DASH-style diet and risk of coronary heart disease and stroke in women. Arch Intern Med. 2008;168(7):713–20.

Bahreinian M, Esmaillzadeh A. Opinion: Quantity And Quality Of Carbohydrate Intake In Iran: A Target For Nutritional Intervention. 2012.

Willett WC, Howe GR, Kushi LH. Adjustment for total energy intake in epidemiologic studies. Am J Clin Nutr. 1997;65(4):1220s–85.

Valipour G, Esmaillzadeh A, Azadbakht L, Afsar H, Hassannazad A, Adibi P. Adherence to the DASH diet in relation to psychological profile of Iranian adults. Eur J Nutr. 2017;56(1):309–20.

Larsson SC, Wallin A, Wolk A. Dietary approaches to stop hypertension diet and incidence of stroke: results from 2 prospective cohorts. Stroke. 2016.

Praud D, Bertuccio P, Bosetti C, Carnevali O, Decarli A, Edefonti V, et al. Inflammatory potential of the diet and risk of gastric cancer in the European Prospective Investigation into Cancer and Nutrition (EPIC) study. The American journal of clinical nutrition. 2018;107(4):607–16.

Zhu H, Yang X, Zhang C, Zhu C, Tao G, Zhao L, et al. Am J Clin Nutr. PloS one. 2013;8(8):e70955.

Correa P. Diet and gastric cancer. Diet, Nutrition and Cancer: A Critical Evaluation: CRC Press; 2018. p. 1–10.

Liese AD, Richards M, Sun X, D’agostino RB, Haffner SM. Adherence to the DASH Diet is inversely associated with incidence of type 2 diabetes: the insulin resistance atherosclerosis study. Diabetes Care. 2009.

Tian T, Zhang L, Ma X, Zhou J, Shen J. Diabetes mellitus and incidence and mortality of gastric cancer: a meta-analysis. Exp Clin Endocrinol Diabetes. 2012;8(12):217–23.

Willett W. Nutritional epidemiology. Oxford University Press; 2012.

Coughlin SS. Recall bias in epidemiologic studies. J Clin Epidemiol. 1990;43(1):87–91.

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