Published in final edited form as:

J Hypertens. 2015 June ; 33(6): 1193–1200. doi:10.1097/HJH.0000000000000534.

Association of Major Dietary Patterns and Blood Pressure Longitudinal Change in Bangladesh

Jieying JIANG¹, Mengling LIU¹, Faruque PARVEZ², Binhuan WANG¹, Fen WU¹, Mahbub EUNUS³, Sripal BANGALORE⁴, Alauddin AHMED³, Tariqul ISLAM³, Muhammad RAKIBUZ-ZAMAN³, Rabiul HASAN³, Golam SARWAR³, Diane LEVY⁵, Maria ARGOS⁶, Molly Scannell BRYAN⁶, Joseph GRAZIANO², Richard B. HAYES¹, Habibul AHSAN⁶, and Yu CHEN¹

¹Department of Population Health, New York University School of Medicine, New York, New York, USA

²Department of Environmental Health Sciences, Mailman School of Public Health, Columbia University, New York City, New York, USA

³U-Chicago Research Bangladesh, Ltd., Dhaka, Bangladesh

⁴The Leon H. Charney Division of Cardiology, Department of Medicine, New York University School of Medicine, New York, New York, USA

⁵Department of biostatistics, Mailman School of Public Health, Columbia University, New York City, New York, USA

⁶Departments of Health Studies, Medicine and Human Genetics and Comprehensive Cancer Center, The University of Chicago, Chicago, Illinois, USA

Abstract

Background—Observational studies and clinical trials have shown associations of diet and high blood pressure (BP). However, prospective studies on the association between dietary patterns and longitudinal BP change are lacking, especially in low-income populations.

Method—We evaluated the association of dietary patterns and food groups with longitudinal change of BP in 10,389 participants in the Health Effects of Arsenic Longitudinal Study (HEALS), with a median of 6.7 years of follow-up. Dietary information was obtained through a previously validated food-frequency questionnaire (FFQ). BP was measured at baseline and at each biennial follow-up using the same method.

Result—Each SD increase for the “gourd vegetable” dietary pattern score was related to a slower annual change of 0.08 mmHg, 0.04 mmHg, and 0.05 mmHg in systolic blood pressure (SBP), diastolic blood pressure (DBP) or pulse pressure (PP), respectively. Each SD increase in the “balanced” dietary pattern score was related to a decreasing annual change of 0.06 mmHg (p=0.012) and 0.08 mmHg in SBP and PP (p < 0.001). On the other hand, one SD increase in

Address correspondence to Y. CHEN, New York University School of Medicine, Departments of Environmental Medicine and Medicine, 650 First Avenue, New York, NY 10016 USA. Telephone: (212) 263-4839. Fax: (212) 263-8570. yu.chen@nyumc.org. H. AHSAN, the University of Chicago, Center for Cancer Epidemiology and Prevention, 5841 South Maryland Avenue, Chicago, IL 60637 USA. Telephone: (773) 834-9956. Fax: (773) 834-0139. habib@uchicago.edu.

Conflict of interests: The authors declare they have no actual or potential competing financial interests.

“western” dietary pattern score was related to a greater annual increase of 0.07 mmHg ($p=0.005$) and 0.05 mmHg in SBP and PP ($p=0.013$). Higher intake of fruits and vegetables was associated with a slower rate of change in annual SBP and PP while higher meat intake was related to a more rapid increase in annual PP.

Conclusion—The findings suggest that dietary patterns play a significant role in the rate of BP change over time in a low-income population.

Keywords

Dietary pattern; Blood pressure; Longitudinal analysis

Introduction

Hypertension exerts a staggering worldwide burden on human life quality as well as the health care system. A strong, direct relationship between high blood pressure (BP) and cardiovascular disease (CVD) mortality has already been supported in large, prospective epidemiologic studies [1]. Although great efforts have been made over the United States and in many other countries, the worldwide prevalence estimate for high BP remains high with an estimated 1 billion hypertensive individuals in 2003 [2]. A boom in prevalence of high BP in low-income countries was also observed. For instance, in Bangladesh, prevalence of high BP has been rising from 1.1% to 17.9% from 1976 to 2010 [3]. This increase in high BP prevalence largely contributes to the rising epidemic of CVD in low-income countries [4].

Diet and nutrition have been widely investigated as modifiable risk factors for CVD and high BP [5, 6]. Studies have suggested that some specific foods, food groups and nutrients are related to high BP, particularly foods rich in fat, calories and sugar [4]. As people typically consume foods in combination, an optimal dietary pattern may translate large accumulative and comprehensive beneficial effects into disease prevention or treatment. Although some intervention studies, such as, the Dietary Approach to Stop Hypertension (DASH) [7], which includes mostly African Americans, and the Lyon Diet Heart Study [8] involving European ancestries have shown that certain dietary patterns may be associated with a reduced risk of high BP, it remains important to identify dietary patterns in different populations that may prevent high BP. Several observational studies also indicated relationship between dietary pattern and risk of high BP [9, 10]. Only two longitudinal studies in the Chicago Western Electric Study data reported that certain nutrients and specific food groups (beef-veal-lamb, poultry, vegetables, etc.) were related to 7-8 years BP change in middle-aged men [11, 12]. Longitudinal studies evaluating the relationship of dietary patterns with blood pressure change are lacking. In addition, no prospective studies have been conducted in low-income populations to assess the relationship between dietary patterns and longitudinal BP change. Prospective, longitudinal analyses with multiple BP measurements, in which BP is considered as continuous variable rather than a dichotomized variable based on arbitrary definition of high BP, could better estimate the extent of BP change over time due to diet.

We have identified three major dietary patterns among participants of the Health Effects of Arsenic Longitudinal Study (HEALS) in rural Bangladesh. In the present study, we evaluated the association between diet patterns and longitudinal BP change over 7 years among 10,389 participants in Bangladesh.

Subjects and method

Study population

HEALS is an ongoing prospective cohort study based in Araihaazar, Bangladesh. The principle aim of HEALS is to investigate the health outcomes associated with chronic exposure to arsenic in drinking water. Detailed description of the cohort has been presented elsewhere [13]. Briefly, between October 2000 and May 2002, 11746 men and women were recruited, under the criteria that all were married (to reduce loss to follow-up), between 18 and 75 years old, and had resided in the study area for at least 5 years, leading to a response rate of 97.5%. Baseline interviews were conducted to gather information regarding demographics, life style and environmental exposures. The cohort is being actively followed every two years since baseline following similar procedures. A physical examination that includes a BP measurement and a structured interview were conducted at baseline and follow-up visits. Dietary information was assessed at baseline using a validated food frequency questionnaire (FFQ). BP was measured at baseline (October 2000 and May 2002), the first (September 2002 to May 2004), second (September 2004 to May 2006), and third (June 2007 to March 2009) follow-up. Informed consent was obtained from study participants, and study procedures were approved by the ethics committee of the Bangladesh Medical Research Council and the institutional review boards of Columbia University and the University of Chicago.

For the present study, we included subjects with at least two BP measurements over time. We excluded individuals who died before the first follow-up (n=107), those without systolic blood pressure (SBP) or diastolic blood pressure (DBP) measurements at baseline (n=380), individuals for whom no measurements of SBP or DBP was recorded during the follow-up (n=406), and individuals without baseline dietary information (n=464). The final study population was 10,389. The distributions of demographic and lifestyle factors between the study population and those who were excluded were very similar, except for landownership (Table S1).

Measurement of food intakes and Food pattern derivation

A 39-item FFQ was administered during baseline assessment of all participants in HEALS. Detailed description of this questionnaire and results of its subsequent validation study were presented elsewhere [14]. In brief, two 7 d food diaries (FD) were completed for 189 randomly selected cohort participants during two different seasons of the year. Sufficient correlation was observed (0.30 to 0.76) for common food items, macronutrients and many major micronutrients [14].

Dietary patterns were derived by principle component analysis [15]. The three major patterns identified were named according to the foods that loaded most heavily on the pattern: 1) the "balanced" pattern, which was characterized by rice, some meat, small fish,

fruit, and vegetables; 2) the "western" pattern, which was more heavily weighted on meat, milk, poultry, eggs, bread, large fish, and fruit; and 3) the "gourd and root vegetable" pattern, which consisted largely of squashes and root and leafy vegetables [15]. Association of these diet patterns in relation to blood pressure at baseline [15], as well as risk of skin lesions [16] and cardiovascular mortality [17] has been investigated in the cohort.

Blood pressure measurements

Blood pressure was measured at baseline and each follow-up by trained clinicians using an automatic sphygmomanometer (HEM 712-C; Omron Healthcare GmbH, Hamburg, Germany), which has been validated to have 85 percent of readings falling within 5–10 mmHg of the mercury standard [18]. Measurements were taken with participants in a seated position after 5 minutes of rest, with the cuff around the upper left arm, in accordance with recommended guidelines. Two BP measurements were taken at follow-ups and we used the average of two for the analyses. The reliability of the blood pressure measurement was high, with all intraclass correlation coefficients between 0.92 and 0.94 [19].

Information on the use of anti-hypertensive medication was obtained at baseline and during follow-ups, which were standardized to generic names [20].

Statistical analysis

We first conducted descriptive analyses to compare the distribution of demographic, life style characteristics and dietary variables by different levels of baseline SBP, determined according to BP classifications in Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure [2]: <120 mmHg for normal BP, 120–139 mmHg for prehypertension, and ≥140 mmHg for hypertension status. We used longitudinal mixed effect models with a random slope and an intercept for each subject, to assess the association between baseline dietary patterns or food groups and annual change in blood pressure over time. The main outcomes of the model were SBP, DBP, and pulse pressure (PP), which was calculated as the difference of SBP and DBP. The constructed mixed-effects model is a two-level model, in which the first level describes how BP changes in the population (fixed effect), while the second level of the model depicts how individual blood pressure changes over time (random effect):

$$BP_{ij} = \left[\beta_0 + \beta_1 \text{ (TIME)}_{ij} + \beta_2 \text{ Diet}_{0j} + \beta_{12} \text{ Diet}_{0j} \text{ (TIME)}_{ij} + \beta^T Z_{0j} \right] + \left[\mu_{0j} + \mu_{1j} \text{ (TIME)}_{ij} + r_{ij} \right]$$

, where Diet_{0j} is baseline dietary pattern scores with 1 standard deviation (SD) as a unit, or baseline food group intake with 50g/day as a unit for better interpretation of the effect estimate; TIME is years accurate to days (days/365.25) since baseline at the time of BP measurement; β_2 is the change in mean baseline BP for every unit increase in baseline dietary pattern scores or food group intake; β_{12} is the difference in annual BP change for every unit increase in baseline dietary pattern scores or food group intake (i.e. the estimated effect of dietary pattern scores or food groups intake on annual BP change). Specifically, a positive β_{12} represents a more rapidly rate of annual BP change associated with one unit increase in dietary pattern or food group intake, while a negative β_{12} stands for a slower rate

of annual BP change. α^T is a row vector of regression coefficient estimates for covariates at baseline (T denotes vector transpose); Z_{0j} is a vector of potential confounders; μ_{0j} is the random effect part for intercept; and μ_{1j} (TIME)_{ij} is the random effect part for time. The terms in the first and second brackets are the fixed and random parts of the model, respectively. For potential confounders, we first adjusted sex and age (years) at baseline (model 1), then additionally adjusted for educational attainment (years), smoking status (never, ever), history of diabetes (yes,no), total calories intake and body mass index each year (BMI; kilograms per meter squared) (model 2) since these variables were considered to be associated with both diet intake and BP change. Sensitivity analysis was conducted to control for arsenic exposure in well water. Sensitivity analyses were also conducted to additionally control for land ownership [21], an indicator of socioeconomic status in rural Bangladesh, and table salt use (spoons of table salt), as it is a custom to add salt additionally to meals at the table. We also estimated differences in annual BP change in relation to categorical quartiles of dietary pattern scores or food group intake. In all analyses, BP measurements were treated as missing value for the visit when the use of anti-hypertension treatment was reported and thereafter. There were 122 participants under anti-hypertension medication at baseline, 274 at the first follow-up, 401 at the second follow-up and 642 at the third follow-up, respectively. We also conducted sensitivity analyses excluding all subjects who were ever under treatment at baseline or at any follow-up visits. We carried out stratified analyses to examine potential effect modification factors including sex (male, female), smoking status (never, ever), age (<median, median), baseline BMI (<median, median), baseline SBP (<median, median), and baseline arsenic concentration in well water (<median, median).

Lastly, we examined whether adherence to “balanced” or “gourd vegetable” dietary patterns had lower BP while adherence to “western” dietary patterns had higher BP at the end of follow-up. Linear regression models were used, with dietary pattern variables treated as either continuous or categorical variables, adjusting for the same covariates. Adjusted mean levels of BP by quartiles of dietary pattern variables were estimated using LSMEANS statement in SAS. All statistical analyses were conducted using SAS, version 9.3 (SAS Institute Inc., Cary, NC, USA). All tests were conducted two-sided, and $p < 0.05$ was considered significant.

Results

The final study population was 10,389, with a median follow-up time of 6.7 years, ranging from 0.86 to 8.26 years. Of the study population, 8,674 had all four SBP measurements and 8,667 had all four DBP measurements; 1,107 had three SBP measurements and 1,115 had three DBP measurements; and 608 had two measurements of SBP while 607 had two measurements of DBP in total.

Table 1 showed those with a low baseline SBP were more likely to be women, current smoker, or with a younger age. Participants with a higher baseline SBP were also more likely to be those with higher educational attainment, a higher level of calories intake, a higher baseline BMI, a history of diabetes, or those owned more land (Table 1). Baseline SBP also tended to be positively correlated with BMI, SBP and DBP at first, second and

third follow-up. In addition, those with a higher baseline SBP tended to consume more fish, and more meat, and they were more likely to adhere a "gourd and root vegetable" diet pattern as well as the "western" pattern diet.

For each SD increase in "balanced" dietary pattern score, the slope of SBP with time decreased by 0.06mmHg/year (Table 2, Model 1, 2). For each SD increase in the score of the "gourd vegetables" dietary pattern, the slope of SBP decreased by 0.09mmHg/year (Model 1). These associations remained significant in Model 2 with additional adjustment. A dose response relationship was also observed when score for the "gourd vegetables" dietary pattern was categorized into quartiles; individuals with scores in the higher three quartiles had a flatter slope of SBP change with time compared with those in the bottom quartile ($-0.12\sim-0.30\text{mmHg/year}$). Additional adjustment did not change the association (Model 2). The "western" dietary pattern was positively associated with a greater annual SBP change. Every one SD increase in "western" dietary pattern score was related to an increase in the slope of SBP and time by 0.07mmHg/year (Model 1) and the association remained the same with further adjustment (Model 2), indicating that SBP increased more rapidly over time among individuals who adhered to a western dietary pattern. Every 50g/day increase of fruits and vegetables consumption was associated with 0.11mmHg/year decrease in the slope of SBP change with time (Model 1 and Model 2). Additional control for baseline arsenic concentration in well water, landownership or amount of table salt intake did not make any differences in the results (data not shown).

For each SD increase the "gourd vegetables" dietary pattern score, the slope of DBP decreased by 0.04 mmHg/year (Table 3, Model 1, 2). Other dietary patterns or food group intakes did not greatly impact DBP annual change. For each SD increase in "balanced" dietary pattern score, the slope of PP change with time decreased by 0.08 mm Hg/year (Table 4, Model 1, 2). There was a dose-response relationship between score for "balanced" dietary pattern (categorized into quartile) and PP change; the slope of PP change with time was flatter among individuals with the higher three quartiles of "balanced" diet, compared with those in the lowest intake category ($-0.07\sim-0.27\text{mmHg/year}$, Model 1). The slope of PP change decreased by 0.05 mmHg/year consistently throughout the models for each SD increase in the "gourd vegetables" dietary pattern score. Every one SD increase in "western" dietary pattern score was positively associated with the slope of PP change by 0.05mmHg/year (Model 1, 2). For 50g/day increase in fish intake or fruits and vegetables consumption, the slope of PP change decreased by 0.06mmHg/year or 0.15 mmHg/year, respectively (Model 1, 2). For 50g/day increase in meat intake, PP was estimated to rise more rapidly by 0.01mmHg/year (Model 1). The association was strengthened with further adjustment (Model 2).

In stratified analyses, the decrease in the slope of PP associated with the "balanced" dietary pattern was greater in younger subjects ($<36\text{ yr}$) compared with that in older subjects ($P_{\text{for interaction}}=0.030$, Figure S1, S2 and S3). The decrease in the slope of SBP and PP associated with the "balanced" dietary pattern was also greater in subjects with a lower baseline SBP, compared with those with a higher baseline SBP ($P_{\text{for interaction}}=0.003, 0.047$, respectively). The decrease in the slope of PP associated with "gourd vegetable" dietary pattern was greater in those with higher baseline SBP than those with lower baseline SBP

($P_{\text{for interaction}}=0.032$). On the other hand, the increasing slope in SBP and PP associated with the “western” dietary pattern was greater in those with higher BMI ($>19.2 \text{ kg/m}^2$) ($P_{\text{for interaction}}=0.001, 0.032$, respectively).

Lastly, we assessed the association between dietary patterns and the absolute levels of BP at the third follow-up. Each one SD increase of balanced diet score was associated with 0.61 mmHg lower (95% CI $-0.94, -0.28$, $P<0.001$) in SBP and 0.61 mmHg lower (95% CI $-0.83, -0.39$, $P<0.001$) in PP while each one SD increase of gourd vegetables score was related to 0.35 mmHg lower (95% CI $-0.64, -0.05$, $P=0.020$) in SBP and 0.20 mmHg lower (95% CI $-0.40, -0.01$, $P=0.048$) in DBP. On the other hand, subjects who adhere to “western” dietary pattern had a higher DBP (β 0.27, 95% CI 0.05, 0.49) at the end. A dose-response relationship was indicated between adherence to “balanced” dietary pattern and lower SBP or PP (Figure S4).

Discussion

In a cohort of 10,389 participants in rural Bangladesh, we found that adherence to a more traditional and balanced diet, including gourd and other vegetables and fruits, was related to a slower rate of change in BP, while adherence to a “western” dietary pattern was related to a more rapid annual increase in these measures. Our results are the first to identify dietary patterns associated with longitudinal blood pressure change in a low-income population undergoing demographic transition to a westernized diet [22]. Our findings are also consistent with our earlier finding in the same cohort that “western diet”, which displayed high factor loadings for meat, milk, poultry and eggs, was associated with an increased risk of CVD mortality [17]. The study results are also consistent with findings, largely from developed countries, as recently reviewed [23], diets rich in fruits, vegetables and reduced saturated and total fat (DASH diet) as well as the Mediterranean diet are protective for BP control. Our results indicated that the effects of dietary patterns on BP change observed in a western population can be generalized to low-income countries, where rapid urbanization has resulted in increased consumption of meats and increased incidence of CVD.

We found that diet plays more important role on SBP and PP than on DBP. It is known that elastic wall of the aorta progressively hardens with increasing age, leading to reduced capacity to extend during the systole, as reflected in SBP and PP [24]. It seems possible that diet affects aging-related elasticity of the arterial wall. Our study and work by Wang et al., indicate that the impact of diet rich in fruits on BP may be particularly important at younger ages [25], when there is overall greater arteriole elasticity. On the other hand, we found that the BP raising effects of “western diet” were stronger in subjects with a higher BMI, although the Women’s Health Study (WHS) in a population with greater average BMI, showed no such effect [26]. It will be important in future studies to establish whether diet impacts differentially on population sub-groups, by age, BMI and other factors, in developing versus developed countries.

Strengths of our study include a large, population-based sample size in a non-Western country and a comprehensive, validated FFQ for dietary assessment [14]. Multiple BP measurements taken at the individual level during 7 years follow-up could be another

advantage that enables us to depict BP longitudinal change over time. Additionally, restricted consumption of alcohol due to religious belief in Bangladesh removed a potential confounder. Importantly, the lack of health access in the study population led to a very low rate of individuals with treated high BP and rare use of blood pressure-lowering medications (around 1% at baseline), allowing us to investigate dietary influences on longitudinal BP change in individuals largely free of high BP medicines use. Such analyses may not be feasible in Western populations in which the prevalence of treated high BP is 15-25% [27]. Sensitivity analyses excluding all subjects who were ever under treatment at baseline or at any follow-up visits also indicated similar result. Furthermore, rarely did our participants, who resided in a rural area of Bangladesh, take any dietary supplements in Bangladesh. Therefore, our results could better reflect effects of dietary patterns or food groups on BP longitudinal change, independent of supplement use.

Limitations of the present study should also be acknowledged. Firstly, a single baseline FFQ may not capture diet alterations during the follow-up. However, FFQ was validated against two 7-days food diaries for its validity in measuring long-term intakes of common food items [14]. Future cohort studies should include multiple assessments of food intakes during follow-up. Secondly, although dietary pattern analysis can boast the merit of “assumption free”, the selection of food groups, post-analysis identification of patterns, and selecting method for vector rotation were still somewhat arbitrary [28]. Thirdly, although we used the same methodology for measuring BP since baseline and follow-ups, non-differential systemic error for BP measurements likely reduced our ability to detect diet-BP change relations.

In conclusion, adherence to diet rich in fruits and vegetables was related to a slower rate of change in BP while adherence to diet high in fat was related to a greater annual increase in BP. Although the magnitude of the association appears small, evidence has suggested a continuous dose-response relationship between increasing BP and CVD risk without evidence of threshold [1, 29]. Even a 2 mmHg lower usual SBP would involve about 10% lower stroke mortality and about 7% lower mortality from IHD or other vascular causes in middle age [1]. Our previous study has shown that for one SD increase in Western dietary pattern score, the hazard ratio increased by 13% for circulatory system disease and 17% for heart disease, respectively [17]. Therefore, the differences in the rate of longitudinal change in BP associated with dietary patterns over a long period of time may have a meaningful effect on BP absolute value and thus exert cumulative effect on CVD risk in the long run. Low income countries currently account for 80% of all non-communicable disease including high BP or CVD. The change in diet behavior could partly account for the rise in high BP or CVD [30]. The findings of the study suggest the effects of diet patterns on longitudinal BP change even in a low-income and lean population.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgement

The authors thank the dedicated project staff and field workers in Bangladesh, without whom this work would not have been possible.

Sources of funding: This work is supported by grants R01ES017541, R01CA107431, P42ES010349, P30ES000260, and R01ES017876 from the National Institutes of Health.

Abbreviations

BP	Blood Pressure
DBP	Diastolic Blood Pressure
FFQ	Food Frequency Questionnaire
SBP	Systolic Blood Pressure
BMI	Body Mass Index

References

- Lewington S, Clarke R, Qizilbash N, Peto R, Collins R, Prospective Studies C. Age-specific relevance of usual blood pressure to vascular mortality: a meta-analysis of individual data for one million adults in 61 prospective studies. *Lancet*. 2002; 360(9349):1903–13. [PubMed: 12493255]
- Chobanian AV, Bakris GL, Black HR, Cushman WC, Green LA, Izzo JL, et al. The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure - The JNC 7 Report. *JAMA-J Am Med Assoc*. 2003; 289(19):2560–72.
- Islam AKMM, Majumder AAS. Hypertension in Bangladesh: a review. *Indian heart journal*. 2012; 64(3):319–23. [PubMed: 22664819]
- Ibrahim MM, Damasceno A. Hypertension in developing countries. *Lancet*. 2012; 380(9841):611–9. [PubMed: 22883510]
- Reddy KS, Katan MB. Diet, nutrition and the prevention of hypertension and cardiovascular diseases. *Public Health Nutr*. 2004; 7(1A):167–86. [PubMed: 14972059]
- Toledo E, Carmona-Torre FD, Alonso A, Puchau B, Zulet MA, Martinez JA, et al. Hypothesis-oriented food patterns and incidence of hypertension: 6-year follow-up of the SUN (Seguimiento Universidad de Navarra) prospective cohort. *Public Health Nutr*. 2010; 13(3):338–49. [PubMed: 19656442]
- Appel LJ, Moore TJ, Obarzanek E, Vollmer WM, Svetkey LP, Sacks FM, et al. A clinical trial of the effects of dietary patterns on blood pressure. *N Engl J Med*. 1997; 336(16):1117–24. [PubMed: 9099655]
- Delorgeril M, Renaud S, Mamelle N, Salen P, Martin JL, Monjaud I, et al. Mediterranean alpha-linolenic acid-rich diet in secondary prevention of coronary heart-disease. *Lancet*. 1994; 343(8911):1454–9. [PubMed: 7911176]
- McNaughton SA, Ball K, Mishra GD, Crawford DA. Dietary patterns of adolescents and risk of obesity and hypertension(1-3). *Journal of Nutrition*. 2008; 138(2):364–70. [PubMed: 18203905]
- Schulze MB, Hoffmann K, Kroke A, Boeing H. Risk of hypertension among women in the EPIC-Potsdam Study: Comparison of relative risk estimates for exploratory and hypothesis-oriented dietary patterns. *Am J Epidemiol*. 2003; 158(4):365–73. [PubMed: 12915502]
- Miura K, Greenland P, Stamler J, Liu K, Daviglus ML, Nakagawa H. Relation of vegetable, fruit, and meat intake to 7-year blood pressure change in middle-aged men - The Chicago Western Electric Study. *Am J Epidemiol*. 2004; 159(6):572–80. [PubMed: 15003961]
- Stamler J, Liu K, Ruth KJ, Pryer J, Greenland P. Eight-year blood pressure change in middle-aged men - Relationship to multiple nutrients. *Hypertension*. 2002; 39(5):1000–6. [PubMed: 12019283]

13. Ahsan H, Chen Y, Parvez F, Argos M, Hussain AI, Momotaj H, et al. Health Effects of Arsenic Longitudinal Study (HEALS): Description of a multidisciplinary epidemiologic investigation. *Journal of Exposure Science and Environmental Epidemiology*. 2006; 16(2):191–205. [PubMed: 16160703]
14. Chen Y, Ahsan H, Parvez F, Howe GR. Validity of a food-frequency questionnaire for a large prospective cohort study in Bangladesh. *Br J Nutr*. 2004; 92(5):851–9. [PubMed: 15533275]
15. Chen Y, Factor-Litvak P, Howe GR, Parvez F, Ahsan H. Nutritional influence on risk of high blood pressure in Bangladesh: a population-based cross-sectional study. *Am J Clin Nutr*. 2006; 84(5):1224–32. [PubMed: 17093178]
16. Pierce BL, Argos M, Chen Y, Melkonian S, Parvez F, Islam T, et al. Arsenic Exposure, Dietary Patterns, and Skin Lesion Risk in Bangladesh: A Prospective Study. *Am J Epidemiol*. 2011; 173(3):345–54. [PubMed: 21178101]
17. Chen Y, McClintock TR, Segers S, Parvez F, Islam T, Ahmed A, et al. Prospective investigation of major dietary patterns and risk of cardiovascular mortality in Bangladesh. *Int J Cardiol*. 2013; 164(4):1495–501. [PubMed: 22560940]
18. O'Brien E, Waeber B, Parati G, Staessen J, Myers MG, European Soc Hypertension W. Blood pressure measuring devices: recommendations of the European Society of Hypertension. *Br Med J*. 2001; 322(7285):531–6. [PubMed: 11230071]
19. Chen Y, Factor-Litvak P, Howe GR, Graziano JH, Brandt-Rauf P, Parvez F, et al. Arsenic exposure from drinking water, dietary intakes of B vitamins and folate, and risk of high blood pressure in Bangladesh: A population-based, cross-sectional study. *Am J Epidemiol*. 2007; 165(5): 541–52. [PubMed: 17164464]
20. Scannell M, Argos M, Pierce B, Parvez F, Ahmed A, Ahsan H. Cross-sectional study of the predictors of medication use, hypertension prevalence, and hypertension treatment in Bangladeshi adult. *Am J Epidemiol*. 2013; 177:S38–S.
21. Argos M, Parvez F, Chen Y, Hussain AZ, Momotaj H, Howe GR, et al. Socioeconomic status and risk for arsenic-related skin lesions in Bangladesh. *American journal of public health*. 2007; 97(5): 825–31. [PubMed: 17395836]
22. Thorne-Lyman AL, Valpiani N, Sun K, Semba RD, Klotz CL, Kraemer K, et al. Household Dietary Diversity and Food Expenditures Are Closely Linked in Rural Bangladesh, Increasing the Risk of Malnutrition Due to the Financial Crisis. *Journal of Nutrition*. 2010; 140(1):182S–8S. [PubMed: 19923385]
23. Bazzano LA, Green T, Harrison TN, Reynolds K. Dietary approaches to prevent hypertension. *Current hypertension reports*. 2013; 15(6):694–702. [PubMed: 24091874]
24. Pede S, Lombardo M. [Cardiovascular risk stratification. Systolic, diastolic or pulse pressure?]. *Italian heart journal Supplement : official journal of the Italian Federation of Cardiology*. 2001; 2(4):356–8. [PubMed: 19397006]
25. Wang L, Manson JE, Gaziano JM, Buring JE, Sesso HD. Fruit and Vegetable Intake and the Risk of Hypertension in Middle-Aged and Older Women. *Am J Hypertens*. 2012; 25(2):180–9. [PubMed: 21993367]
26. Wang L, Manson JE, Buring JE, Sesso HD. Meat intake and the risk of hypertension in middle-aged and older women. *Journal of hypertension*. 2008; 26(2):215–22. [PubMed: 18192834]
27. Nwankwo T, Yoon SS, Burt V, Gu Q. Hypertension among adults in the United States: National Health and Nutrition Examination Survey, 2011–2012. *NCHS data brief*. 2013; (133):1–8. [PubMed: 24171916]
28. Hu FB. Dietary pattern analysis: a new direction in nutritional epidemiology. *Current Opinion in Lipidology*. 2002; 13(1):3–9. [PubMed: 11790957]
29. Vasan RS, Larson MG, Leip EP, Evans JC, O'Donnell CJ, Kannel WB, et al. Impact of high-normal blood pressure on the risk of cardiovascular disease. *The New England journal of medicine*. 2001; 345(18):1291–7. [PubMed: 11794147]
30. Khan FS, Lotia-Farrukh I, Khan AJ, Siddiqui ST, Sajun SZ, Malik AA, et al. The Burden of Non-Communicable Disease in Transition Communities in an Asian Megacity: Baseline Findings from a Cohort Study in Karachi, Pakistan. *PLoS One*. 2013; 8(2)

Table 1

Baseline and follow-up characteristics of cohort

Characteristic	Baseline SBP					*P value
	<120	120-139	≥140	No.	Mean (standard deviation)	
	No.	Mean (standard deviation)	No.	Mean (standard deviation)	No.	Mean (standard deviation)
Age (years)/(baseline)	6909	35.8 (9.7)	2763	37.6 (10.1)	717	42.1 (10.9)
Sex: male (%)	2856	41.3	1209	43.8	320	44.6
Current smoker (%)	2037	29.5	740	26.8	260	26.2
Diabetes history (%)	91	1.3	70	2.5	32	4.5
Education years	6905	3.3 (3.7)	2762	3.6 (3.9)	717	3.7 (4.1)
Total calories (kcal)	6909	2285.7 (586.5)	2763	2309.8 (604.6)	717	2292.0 (616.7)
BMI (weight(kg)/height(m ²))						
Baseline	6873	19.3 (2.9)	2742	20.3 (3.3)	713	20.9 (3.6)
Follow up 1	6697	19.4 (3.0)	2671	20.3 (3.4)	696	20.8 (3.9)
Follow up 2	6496	19.7 (3.2)	2593	20.6 (3.6)	662	21.1 (3.9)
Follow up 3	6414	20.0 (3.4)	2549	20.9 (3.7)	633	21.1 (4.0)
SBP (mmHg)						
Follow up 1	6729	108.8 (13.6)	2689	120.8 (16.2)	700	136.0 (23.0)
Follow up 2	6476	113.4 (12.1)	2528	124.8 (15.0)	580	138.2 (21.6)
Follow up 3	6311	108.0 (13.0)	2351	117.4 (16.1)	480	126.8 (20.4)
DBP (mmHg)						
Follow up 1	6729	70.2 (8.8)	2689	76.7 (9.9)	700	83.9 (12.4)
Follow up 2	6476	73.8 (8.9)	2528	80.1 (9.6)	580	86.2 (11.8)
Follow up 3	6311	71.3 (9.2)	2351	76.3 (10.4)	480	80.7 (12.0)
Fish group (77g/day)	6909	51.3 (38.1)	2763	54.2 (38.4)	717	55.8 (40.0)
Meat group (g/day)	6909	17.7 (29.3)	2763	20.3 (33.3)	717	19.8 (34.8)
Vege and fruit group (g/day)	6909	427.1 (216.2)	2763	442.1 (236.9)	717	429.8 (222.5)
Balanced diet (% above median)	3406	49.3	1424	51.5	365	50.9

Characteristic	Baseline SBP							*P value
	<120		120-139		>=140			
	No.	Mean (standard deviation)	No.	Mean (standard deviation)	No.	Mean (standard deviation)		
Gourd and veg diet (% above median)	3395	49.1	1421	51.4	379	52.9	0.028	
Western diet (% above median)	3340	48.3	1467	53.1	387	54.0	0.001	

* Linear regression model was used adjusting for age and sex.

Table 2
Relation between baseline food intake and adjusted annual changes in systolic blood pressure (SBP) over 7 years

Food group	Quartile 1 Change/year (mmHg)	Quartile 2 Change/year (mmHg)	Quartile 3 Change/year (mmHg)	Quartile 4 Change/year (mmHg)	Per unit increase	
					mmHg/year	P value [@]
Balanced diet						
Model 1 [@]	Ref.	-0.09 (-0.23,0.05)	-0.18 (-0.32,-0.04)	-0.22 (-0.35,-0.08)	-0.06	0.011
Model 2 [*]	Ref.	-0.10 (-0.24,0.04)	-0.20 (-0.33,-0.06)	-0.23 (-0.36,-0.09)	-0.06	0.012
Gourd_veg diet						
Model 1 [@]	Ref.	-0.12 (-0.26,0.02)	-0.14 (-0.28,0.01)	-0.30 (-0.44,-0.17)	-0.09	< 0.001
Model 2 [*]	Ref.	-0.10 (-0.24,0.03)	-0.11 (-0.25,0.02)	-0.28 (-0.42,-0.14)	-0.08	< 0.001
Western diet						
Model 1 [@]	Ref.	-0.01 (-0.15,0.13)	0.06 (-0.08,0.20)	0.12 (-0.02,0.26)	0.07	0.008
Model 2 [*]	Ref.	-0.01 (-0.14,0.14)	0.09 (-0.05,0.22)	0.14 (-0.01,0.27)	0.07	0.005
Fish group (50g/day)						
Model 1 [@]	Ref.	-0.01 (-0.14,0.14)	-0.08 (-0.22,0.06)	-0.14 (-0.28,-0.01)	-0.05	0.139
Model 2 [*]	Ref.	0.01 (-0.13,0.14)	-0.09 (-0.23,0.05)	-0.16 (-0.29,-0.02)	-0.06	0.075
Fruit and Vegetable group (50g/day)						
Model 1 [@]	Ref.	0.03 (-0.11,0.17)	-0.11 (-0.25,0.03)	-0.13 (-0.27,0.01)	-0.11	0.028
Model 2 [*]	Ref.	0.05 (-0.09,0.19)	-0.11 (-0.25,0.03)	-0.13 (-0.26,0.01)	-0.11	0.025
Meat group (50g/day)[‡]						
Model 1 [@]	Ref.	0.08 (-0.06,0.22)	-0.04 (-0.17,0.10)	0.11 (-0.02,0.25)	0.01	0.284
Model 2 [*]	Ref.	0.08 (-0.06,0.22)	-0.01 (-0.14,0.12)	0.10 (-0.04,0.23)	0.01	0.269

[@] Unit=1 Standard deviation (SD) for dietary pattern; Unit=50g/day for food groups.

[@] Controlled for baseline age, gender.

^{*} Controlled for model 1 covariates plus smoking status (ever smoker=1, never smoker=0), history of diabetes, education years, total calorie, BMI (each year).

These two models set 0 as reference group, and then divided the rest of data into three groups.

✕

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

Table 3
Relation between baseline food intake and adjusted annual changes in diastolic blood pressure (DBP) over 7 years

Food group	Quartile 1 Change/year (mmHg)	Quartile 2 Change/year (mmHg)	Quartile 3 Change/year (mmHg)	Quartile 4 Change/year (mmHg)	Per unit increase	
					mmHg/year	P value
Balanced diet						
Model 1 [®]	Ref.	-0.02 (-0.11,0.08)	-0.07 (-0.17,0.03)	0.06 (-0.04,0.15)	0.02	0.310
Model 2 [*]	Ref.	-0.03 (-0.12,0.07)	-0.08 (-0.17,0.02)	0.05 (-0.05,0.15)	0.02	0.258
Gourd_veg diet						
Model 1 [®]	Ref.	-0.14 (-0.24,-0.04)	-0.08 (-0.18,0.02)	-0.19 (-0.29,-0.09)	-0.04	0.021
Model 2 [*]	Ref.	-0.12 (-0.22,-0.03)	-0.06 (-0.16,0.03)	-0.17 (-0.27,-0.08)	-0.04	0.042
Western diet						
Model 1 [®]	Ref.	-0.08 (-0.18,0.02)	-0.05 (-0.15,0.05)	-0.01 (-0.11,0.08)	0.02	0.295
Model 2 [*]	Ref.	-0.07 (-0.16,0.03)	-0.03 (-0.13,0.07)	0.01 (-0.13,0.07)	0.02	0.187
Fish group (50g/day)						
Model 1 [®]	Ref.	0.01 (-0.09,0.11)	-0.02 (-0.12,0.08)	0.01 (-0.09,0.11)	0.01	0.804
Model 2 [*]	Ref.	0.02 (-0.08,0.11)	-0.03 (-0.13,0.07)	0.01 (-0.09,0.10)	0.01	0.952
Fruit and Vegetable group (50g/day)						
Model 1 [®]	Ref.	-0.04 (-0.14,0.06)	-0.03 (-0.13,0.06)	0.06 (-0.04,0.15)	0.04	0.261
Model 2 [*]	Ref.	-0.03 (-0.13,0.06)	-0.03 (-0.13,0.06)	0.05 (-0.04,0.15)	0.04	0.283
Meat group (50g/day)[‡]						
Model 1 [®]	Ref.	-0.06 (-0.16,0.03)	-0.10 (-0.19,0.01)	0.04 (-0.06,0.13)	-0.01	0.319
Model 2 [*]	Ref.	-0.07 (-0.17,0.03)	-0.09 (-0.17,0.01)	0.02 (-0.07,0.12)	-0.01	0.273

[®] Unit=1 Standard deviation (SD) for dietary pattern; Unit=50g/day for food groups.

[®] Controlled for baseline age, gender.

^{*} Controlled for model 1 covariates plus smoking status (ever smoker=1, never smoker=0), history of diabetes, education years, total calorie, BMI (each year).

These two models set 0 as reference group, and then divided the rest of data into three groups.

✕

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

Table 4
Relation between baseline food intake and adjusted annual changes in pulse pressure (PP) over 7 years

Food group	Quartile 1 Change/year (mmHg)	Quartile 2 Change/year (mmHg)	Quartile 3 Change/year (mmHg)	Quartile 4 Change/year (mmHg)	@ Per unit increase	
					mmHg/year	P value
Balanced diet						
Model 1 [@]	Ref.	-0.07 (-0.17,0.04)	-0.10 (-0.21,0.01)	-0.27 (-0.38,-0.17)	-0.08	<0.001
Model 2 [*]	Ref.	-0.07 (-0.17,0.03)	-0.11 (-0.21,-0.01)	-0.28 (-0.38,-0.17)	-0.08	<0.001
Gourd_veg diet						
Model 1 [@]	Ref.	0.01 (-0.10,0.11)	-0.06 (-0.16,0.04)	-0.12 (-0.22,-0.02)	-0.05	0.006
Model 2 [*]	Ref.	0.01 (-0.09,0.11)	-0.05 (-0.16,0.05)	-0.12 (-0.22,-0.01)	-0.05	0.009
Western diet						
Model 1 [@]	Ref.	0.06 (-0.04,0.16)	0.11 (0.01,0.21)	0.13 (0.02,0.23)	0.05	0.014
Model 2 [*]	Ref.	0.06 (-0.04,0.16)	0.12 (0.02,0.22)	0.13 (0.03,0.23)	0.05	0.013
Fish group (50g/day)						
Model 1 [@]	Ref.	-0.01 (-0.11,0.09)	-0.05 (-0.15,0.06)	-0.15 (-0.25,-0.05)	-0.06	0.029
Model 2 [*]	Ref.	-0.01 (-0.12,0.09)	-0.05 (-0.16,0.05)	-0.16 (-0.26,-0.06)	-0.06	0.019
Fruit and Vegetable group (50g/day)						
Model 1 [@]	Ref.	0.07 (-0.04,0.17)	-0.07 (-0.17,0.04)	-0.18 (-0.28,-0.08)	-0.15	<0.001
Model 2 [*]	Ref.	0.08 (-0.03,0.18)	-0.07 (-0.17,0.03)	-0.17 (-0.28,-0.07)	-0.15	<0.001
Meat group (50g/day)[‡]						
Model 1 [@]	Ref.	0.13 (0.03,0.24)	0.06 (-0.04,0.16)	0.06 (-0.04,0.16)	0.01	0.031
Model 2 [*]	Ref.	0.14 (0.03,0.24)	0.07 (-0.03,0.17)	0.06 (-0.04,0.16)	0.01	0.019

[@] Unit=1 Standard deviation (SD) for dietary pattern; Unit=50g/day for food groups.

[@] Controlled for baseline age, gender.

^{*} Controlled for model 1 covariates plus smoking status (ever smoker=1, never smoker=0), history of diabetes, education years, total calorie, BMI (each year).

[‡] These two models set 0 as reference group, and then divided the rest of data into three groups.